EHT PERDO

International Conference

Environmental Pollutants and Toxicants Affecting Health:

Collaborative Efforts for Improving Quality of Life

Organized by

Center of Excellence on Environmental Health and Toxicology (CoE EHT)
(Program: Hub of Talents in Environmental Health
with Support of the National Research Council of Thailand)

Collaborating Institutions

Hub of Talents on Air pollution and Climate, Thailand
Health and Environmental Sciences Institute, U.S.A.

PROGRAM - ABSTRACTS

June 19-21, 2024

Convention Center, Chulabhorn Research Institute, Bangkok, Thailand

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ORGANIZING COMMITTEE

***Khunying* Mathuros Ruchirawat**	**Chairperson**
Jutamaad Satayavivad	**Vice Chairperson**

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Kanistha Thanindratarn

INVITED SPEAKERS / CHAIRPERSONS

Rozaini B. Abdullah	Malaysia
William W. Au	U.S.A.
Choowong Auesukaree	Thailand
Herman Autrup	Denmark
Furong Deng	China
Michelle R. Embry	U.S.A.
John M. Essigmann	U.S.A.
Bengt Fadeel	Sweden
Henry Falk	U.S.A.
Prayoon Fongsatitkul	Thailand
Jenna Frey	U.S.A.
Masami Furuuchi	Japan
Budi Haryanto	Indonesia
Denis L. Henshaw	U.K.
Xia Huo	China
Thongchai Kanabkaew	Thailand
Yongjua Laosiritaworn	Thailand
Siew Yan Lew	Malaysia
Ekachai Lojanaphiwat	Thailand
Panida Navasumrit	Thailand
Thitirat Ngaotepprutaram	Thailand
Phan Quynh Nhu	Vietnam
Puey Ounjai	Thailand
Syril D. Pettit	U.S.A.
Prayad Pokethitiyook	Thailand
Mathuros Ruchirawat	Thailand
Jeeranuch Sakkamduang	Thailand
Jutamaad Satayavivad	Thailand
Daam Settachan	Thailand
Gyanendra Singh	India
Vong Sok	Cambodia
William A. Suk	U.S.A.
Vanisa Surapipith	Thailand
Tawit Suriyo	Thailand
Phum Tachachartvanich	Thailand
Kessinee Unapumnuk	Thailand
Martin van den Berg	The Netherlands
Tieyu Wang	China
Supat Wangwongwatana	Thailand
Piyajit Watcharasit	Thailand

GENERAL INFORMATION

Venue: The Chulabhorn Research Institute (CRI) Convention Center, Lak Si, Bangkok, Thailand

Registration:

Location: The Registration Counter is located on the ground floor of the convention center.

Hours: Wednesday, June 19th, 2024 from **08:00** to **17:00**.
Thursday, June 20th, 2024 from **08:30** to **17:00**.

Secretariat Office:

Location: The Secretariat Office is located adjacent to the Convention Hall on the second floor of the convention center.

Hours: Wednesday, June 19th, 2024 to Friday, June 21st, 2024 from **08:30** to **17:00**.

Audio-Visual Center:

Location: The Audio-Visual Center is located between the Secretariat Office and the Convention Hall on the second floor.

Hours: Wednesday, June 19th, 2024 to Friday, June 21st, 2024 from **08:30** to **17:00**.

Poster Session:

Location: The Poster Presentation area is located on the second floor lobby of the convention center.

Hours: Posters should be set up for display in the morning of Wednesday, June 19th, 2024.

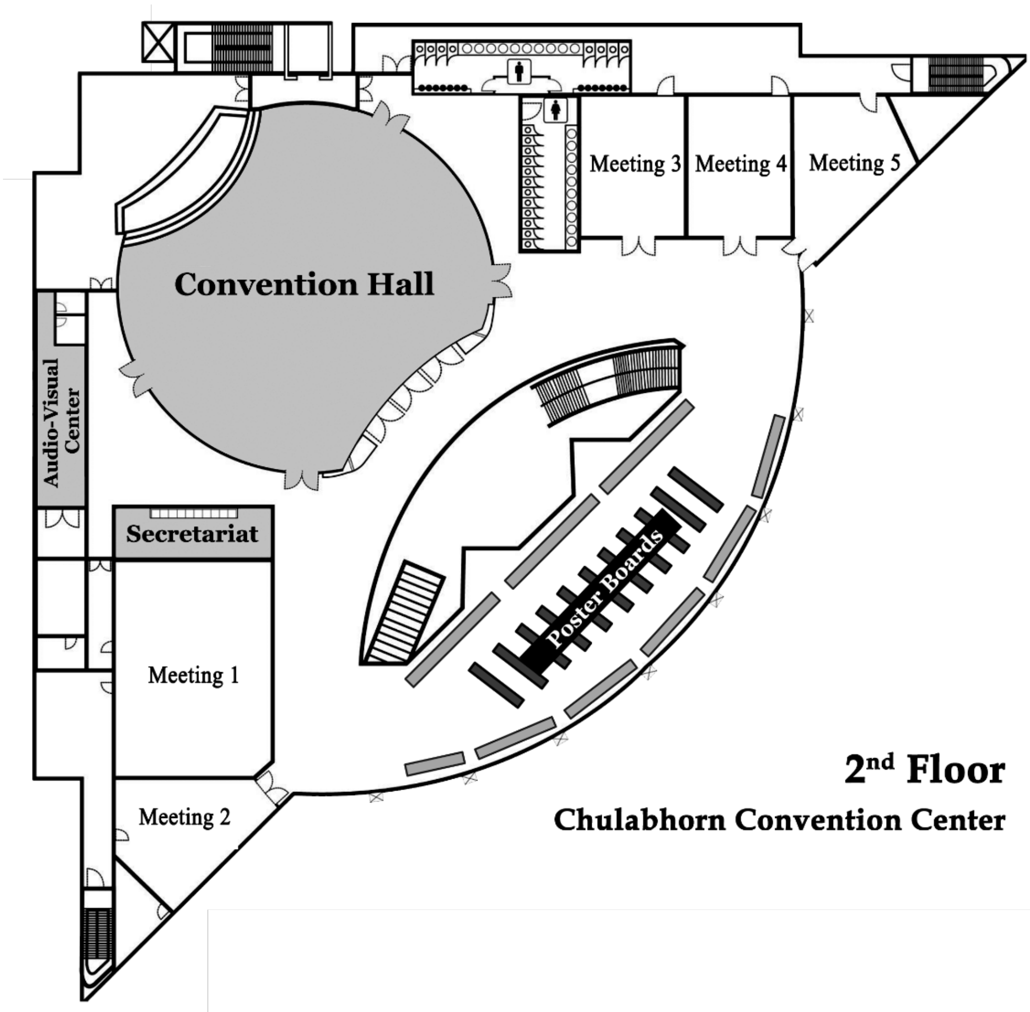
Presenters should be in attendance during the lunch break on:
- Wednesday, June 19th, 2024 from **13:30** to **14:00**.
- Thursday, June 20th, 2024 from **13:00** to **13:30**.

The display must be removed by **16:00** on Friday, June 21st, 2024.

Special Environmental Health Day Exhibition: The Thai Department of Health, Ministry of Public Health have set up a special exhibition as a tribute to Professor Dr. Her Royal Highness Princess Chulabhorn Mahidol for her leadership and dedication to the field of environmental health.

Location: The Exhibition is located on the second floor lobby of the convention center.

THE CONVENTION CENTER FLOOR PLAN



SCIENTIFIC PROGRAM OVERVIEW

Time	Wednesday, June 19th, 2024
08:00	*Registration*
09:00	**OPENING SESSION**
09:15	**PL1:** Climate Change and Impact on Toxic Pollutants and Human Health ***Henry Falk*** *(U.S.A.)*
10:00	**PL2:** Electromagnetic Fields and Health: The Fetus, Child and Young Adult – Advances in Mechanistic Understanding ***Denis L. Henshaw*** *(U.K.)*
10:45	**PL3:** Novel Toxicological Effects and Personalized Health Hazard in Workers Exposed to Benzene ***Willian W. Au*** *(U.S.A.)*
11:30	**PL4:** High-resolution Mutational Fingerprints Identify Past Exposures to Environmental Carcinogens ***John M. Essigmann*** *(U.S.A.)*
12:15	*Lunch and Poster Session*
13:45	**S1: Environmental Health Issues of Concern in Developing Countries** 1. Botswana 2. Ethiopia 3. India 4. Indonesia 5. Malaysia 6. Myanmar 7. Nepal 8. Pakistan 9. Sri Lanka 10. Thailand 11. Cambodia 12. Lao PDR

Time	Thursday, June 20th, 2024	
09:00	**PL5:** Ambient Air Pollution and Adverse Health Effects ***Herman Autrup*** *(Denmark)*	
09:45	**PL6:** No Small Matter: The Potential Hazards of Engineered Nanomaterials for Human Health ***Bengt Fadeel*** *(Sweden)*	
10:30	**PL7:** Bioaccumulation at the Intersection Between Ecological and Human Health ***Michelle R. Embry*** *(U.S.A.)*	
11.15	**PL8:** The Last Mile Challenge (and Opportunity) in Environmental Health Sciences ***Syril D. Pettit*** *(U.S.A.)*	
12:00	*Lunch and Poster Session*	
13:30	*Convention Hall* **E-waste Workshop: Collaborative Efforts for Improving Quality of Life** • *William W. Au (U.S.A.)* • *Xia Huo (China)* • *Henry Falk (U.S.A.)* **Platform Presentation**	*Meeting 1 Room* **S2: Air Pollution: Solution for the Transboundary Haze Issue in the Mekong Subregion** *by Hub of Talents on Air pollution and Climate, NRCT, Thailand*

Time	Friday, June 21st, 2024	
09:00	**PL9:** Carcinogenic Effects of Genotoxic Chemicals in Early Life Stage ***Martin van den Berg*** *(The Netherlands)*	
09:45	*Convention Hall* **S3: Environmental Pollutants Affecting Health** • *Furong Deng (China)* • *Gyanendra Singh (India)* • *Piyajit Watcharasit (Thailand)* • *Phum Tachachartvanich (Thailand)* • *Choowong Auesukaree (Thailand)*	*Meeting 1 Room* **S4: Connecting Health: Exploring Ecological and Human Health Through Contamination in the Food Chain** • *Michelle R. Embry (U.S.A.)* • *Prayad Pokethitiyook (Thailand)* • *Tawit Suriyo (Thailand)* • *Tieyu Wang (China)* • *Martin van den Berg (The Netherlands)*
12:00	*Lunch*	
13:00	**S5: Exposure During Early Life Stage and Its Consequences** • *Xia Huo (China)* • *Panida Navasumrit (Thailand)* • *Thitirat Ngaoteppurtaram (Thailand)* • *Jenna Frey (U.S.A.)* • *William A. Suk (U.S.A.)*	
15:30	**S6: Collaborative Network in Environmental Health**	
17:00	**CLOSING SESSION**	

SCIENTIFIC PROGRAM

Wednesday, June 19th, 2024

08:00 – 09:00 REGISTRATION

Convention Hall

09:00 **OPENING SESSION:**

- Welcome Remarks
  by **Professor Dr. *Khunying* Mathuros Ruchirawat,**
  Director of the Center of Excellence on Environmental Health and Toxicology (CoE EHT)
- Opening Address (VDO presentation)
  by **Professor Dr. Soottiporn Chittmittrapap,**
  Chair of the Advisory Working Group for Development of Hub of Talents and Hub of Knowledge

PLENARY LECTURES:

Abstract No.

09:15 **Plenary Lecture 1:** Climate Change and Impact on Toxic Pollutants and Human Health **PL-1**
Henry Falk *(Emory University, U.S.A.)*

10:00 **Plenary Lecture 2:** Electromagnetic Fields and Health: The Fetus, Child and Young Adult – Advances in Mechanistic Understanding **PL-2**
Denis L. Henshaw *(University of Bristol, U.K.)*

10:45 **Plenary Lecture 3:** Novel Toxicological Effects and Personalized Health Hazard in Workers Exposed to Benzene **PL-3**
Willian W. Au *(University of Texas Medical Branch, U.S.A.)*

11:30 **Plenary Lecture 4:** High-resolution Mutational Fingerprints Identify Past Exposures to Environmental Carcinogens **PL-4**
John M. Essigmann *(Massachusetts Institute of Technology, U.S.A.)*

12:15 Lunch and Poster Session

Poster Session:

Location: The Poster Presentation area is located on the second floor lobby of the convention center.

Hours: Presenters should be in attendance from **13:00 to 13:30.**

SCIENTIFIC PROGRAM

Wednesday, June 19th, 2024 **Convention Hall**

SESSION 1: Environmental Health Issues of Concern in Developing Countries

Chairpersons: Herman Autrup (Denmark) **and** Prayoon Fongsatitkul (Thailand)

		Abstract No.
13:30	• The Status of Water, Sanitation and Hygiene in Botswana ***Tshephang Tumoyagae*** *(University of Botswana, Botswana)*	**S1-1**
13:45	• State of Environmental Health and Pollution in Ethiopia ***Wasihun Alemu Kiro*** *(Environmental Protection Authority, Ethiopia)*	**S1-2**
14:00	• Environmental Health Issues in India: Concerns, Challenges and Their Mitigation ***Beerappa Ravichandran*** *(ICMR-Regional Occupational Health Centre, India)*	**S1-3**
14:15	• Environmental Health Status in Indonesia ***Budi Haryanto*** *(University of Indonesia, Indonesia)*	**S1-4**
14:30	• Addressing Environmental Health and Toxicology Challenges in Malaysia: Towards Sustainable Solutions ***Rozaini Binti Abdullah*** *(Universiti Putra Malaysia, Malaysia)*	**S1-5**
14:45	• Public and Environment Health in Myanmar ***Kay Thwe Hnin*** *(Nursing and Midwifery Training School, Myanmar)*	**S1-6**
15:00	• Environmental Health Issues in Nepal: An Overview ***Ajay Kumar Rajbhandari Shrestha*** *(Patan Academy of Health Sciences, Nepal)*	**S1-7**
15:15	• Health Impacts of Environmental Issues in Pakistan: Challenges and Solutions ***Rashid Iqbal*** *(National Skills University, Pakistan)*	**S1-8**
15:30	• Environmental Health Issues in Sri Lanka ***Kankanam Kasunhari Pathirage*** *(Ministry of Environment, Sri Lanka)*	**S1-9**
15:45	• Environmental Health Issues in Thailand ***Yongjua Laosiritaworn*** *(Ministry of Public Health, Thailand)*	**S1-10**
16:00	• Preliminary Assessment of Personal Exposure to Ultrafine Particles Across Multiple Microenvironments in Phnom Penh ***Masami Furuuchi*** *(Kanazawa University, Japan)*	**S1-11**
16:15	• Pesticides and Arsenic on Concerning Environmental Health Issues in Laos ***Bounphak Lobriayao*** *(National University of Laos, Lao PDR)*	**S1-12**

SCIENTIFIC PROGRAM

Thursday, June 20th, 2024

Convention Hall

PLENARY LECTURES:

		Abstract No.
09:00	**Plenary Lecture 5:** Ambient Air Pollution and Adverse Health Effects ***Herman Autrup*** *(University of Aarhus, Denmark)*	**PL-5**
09.45	**Plenary Lecture 6:** No Small Matter: The Potential Hazards of Engineered Nanomaterials for Human Health ***Bengt Fadeel*** *(Karolinska Institute, Sweden)*	**PL-6**
10.30	**Plenary Lecture 7:** Bioaccumulation at the Intersection Between Ecological and Human Health ***Michelle R. Embry*** *(Health and Environmental Sciences Institute, U.S.A.)*	**PL-7**
11:15	**Plenary Lecture 8:** The Last Mile Challenge (and Opportunity) in Environmental Health Sciences ***Syril D. Pettit*** *(Health and Environmental Sciences Institute, U.S.A.)*	**PL-8**
12:00	*Lunch and Poster Session*	

Poster Session:

Location: The Poster Presentation area is located on the second floor lobby of the convention center.

Hours: Presenters should be in attendance from **13:00 to 13:30.**

The display must be removed by 16:00 on Friday, June 21st, 2024.

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Thursday, June 20th, 2024 | *Convention Hall*

E-waste Workshop: Collaborative Efforts for Improving Quality of Life

Chairperson: William W. Au (U.S.A.)

		Abstract No.
13:00	▪ Global Distribution and Human Exposure Problems to E-waste ***William W. Au*** *(University of Texas Medical Branch, U.S.A.)*	**W-1**
13:30	• 6PPDQ, PBDEs, PCBs, and Metal(loid)s in Indoor Dust from an E-waste Recycling Area and the Health Risk on Children ***Xia Huo*** *(Jinan University, China)*	**W-2**
14:00	• International, Regional, and Local Collaborations to Minimize the eWaste Problem ***Henry Falk*** *(Emory University, U.S.A.)*	**W-3**

Platform Presentations:

Chairpersons: Jutamaad Satayavivad (Thailand) **and** Phum Tachachartvanich (Thailand)

		Abstract No.
15:00	• Dichloromethane Increases Mutagenic DNA Damage and Cell Transformation Ability in Cholangiocytes: A Potential Environmental Risk Factor for Cholangiocarcinoma Development ***Angkhameen Buranarom*** *(Chulabhorn Research Institute, Thailand)*	**O-1**
15:15	• *In Utero* Arsenic Exposure Increases DNA Damage and Gene Expression Changes in Umbilical Cord Mesenchymal Stem Cells (UC-MSCs) from Newborns as well as in UC-MSC Differentiated Hepatocytes ***Siriwan Kantisin*** *(Mae Fah Luang University, Thailand)*	**O-2**
15:30	• Insight into Ambient Ultrafine Particles ($PM_{0.1}$) in Upper Southeast Asia; Local and Transboundary Effects ***Worradorn Phairuang*** *(Kanazawa University, Japan)*	**O-3**
15:45	• Diesel Exhaust Nanoparticle Exposure Induces Small Extracellular Vesicle Secretion in Umbilical Cord-Derived Mesenchymal Stem Cells ***Mayer Calma*** *(Chulabhorn Graduate Institute, Thailand)*	**O-4**
16:00	• Evaluation of Environmental Pollution Using Heavy Metals and Microplastics in Bee Propolis ***Evada Chotiaroonrat*** *(Burapha University, Thailand)*	**O-5**
16:15	• Understanding Molecular Basis of Chemical Toxicology through Structural and Computational Approaches ***Puey Ounjai*** *(Mahidol University, Thailand)*	**O-6**

SCIENTIFIC PROGRAM

Thursday, June 20th, 2024 | *Meeting 1 Room*

SESSION 2: ***Air Pollution: Solution for the Transboundary Haze Issue in the Mekong Subregion*** *[Hybrid (on-site + online)/Presentations]*

Organized by Hub of Talents on Air Pollution and Climate (HTAPC), National Research Council of Thailand (NRCT), and Faculty of Public Health, Thammasat University

13:30 **OPENING SESSION**

- Introduction: ***Dr. Vanisa Surapipith*** *(Deputy-Director of HTAPC, Thailand)*
- Opening Remarks and Overview of ASEAN Transboundary Haze Pollution Situation: ***Dr. Supat Wangwongwatana*** *(Director of HTAPC, NRCT)*

13:45 **Session 2-1:** The session provides an overview of transregional air pollution issues in Southeast Asia, and case studies, starting from the development on air quality assessment for Thai health protection, led by CRI, then the health impacts of air pollution, particularly $PM_{2.5}$, in Vietnam. These will set the scene towards the significance of the Air Pollution Issue for solutions to be sought in the next session.

Moderator: Assoc. Prof. Dr. Thongchai Kanabkaew
(Faculty of Public Health, Thammasat University-Rangsit Campus)

Abstract No.

- ASEAN Haze Free Roadmap 2023-2030 and Its Monitoring & Evaluation **S2-1**
  Dr. Vong Sok *(Head of Environment Division, ASEAN Secretariat)*
- Using Air Quality Assessment for Health Protection in Thailand **S2-2**
  Dr. Daam Settachan *(Chulabhorn Research Institute, Thailand)*
- Major Air Pollution Issues and Health Impacts in Vietnam **S2-3**
  Mrs. Phan Quynh Nhu *(Vietnam Clean Air Partnership (VCAP), Vietnam)*

15:30 **Session 2-2:** The session highlights the work of Pollution Control Department and Thailand Environment Institute (TEI) joint efforts to drive the Clear Sky Strategies and its Joint Plan of Actions being taken among three countries in Mekong Subregion, namely Laos PDR, Myanmar, and Thailand. International cooperation on the integrated approaches for air quality management and climate change mitigation in Southeast Asia will be presented.

Moderator: Dr. Jeeranuch Sakkamduang (Thailand Environment Institute)

- Clear Sky Strategies and Its Joint Plan of Actions **S2-4**
  Dr. Wijarn Simachaya *(Thailand Environment Institute, Thailand)*
- Integrated Approaches for Air Quality Management & Climate Change in Southeast Asia – Preparation of a Regional Approach for Southeast Asia **S2-5**
  Mr. Ekachai Lojanaphiwat *(German International Cooperation (GIZ))*
- Experience and Lessons Learnt in Addressing Fires and Haze in ASEAN **S2-6**
  Ms. Siew Yan Lew *(Global Environment Center, Malaysia) [Online]*

16:45 **CLOSING SESSION**

- Summary and Conclusion: ***Dr. Vanisa Surapipith*** *(Deputy-Director of HTAPC, NRCT)*
- Closing Remarks: ***Dr. Supat Wangwongwatana*** *(Director of HTAPC, NRCT)*

SCIENTIFIC PROGRAM

Friday, June 21st, 2024

Convention Hall

PLENARY LECTURE:

Abstract No.

09:00	**Plenary Lecture 9:** Carcinogenic Effects of Genotoxic Chemicals in Early Life Stage ***Martin van den Berg*** *(Utrecht University, The Netherlands)*	**PL-9**

SESSION 3: Environmental Pollutants Affecting Health

Chairpersons: Herman Autrup (Denmark) **and** Daam Settachan (Thailand)

Abstract No.

09:45	▪ Heath Benefits of Air Pollution Interventions at Population and Individual Levels in China ***Furong Deng*** *(Peking University, China)*	**S3-1**
10:15	• Arsenic Contamination: A Current Scenario in India ***Gyanendra Singh*** *(ICMR-National Institute of Occupational Health, India)*	**S3-2**
10:45	▪ Arsenic Impaired Neuronal Insulin Signaling: A Possible Implication to Neurodegeneration ***Piyajit Watcharasit*** *(Chulabhorn Research Institute, Thailand)*	**S3-3**
11:15	• Perinatal Triphenyl Phosphate Exposure Induces Metabolic Dysfunctions Through the EGFR/ERK/AKT Signaling Pathway: Mechanistic *In Vitro* and *In Vivo* Studies ***Phum Tachachartvanich*** *(Chulabhorn Research Institute, Thailand)*	**S3-4**
11:45	• Cellular Mechanisms Involved in Protecting Alachlor-induced Proteotoxic Stress ***Choowong Auesukaree*** *(Mahidol University, Thailand)*	**S3-5**

12:15	Lunch

Friday, June 21st, 2024 **Meeting 1 Room**

SESSION 4: Connecting Health: Exploring Ecological and Human Health Through Contamination in the Food Chain

Chairpersons: Michelle R. Embry (U.S.A.) **and** Prayad Pokethitiyook (Thailand)

Time	Presentation	*Abstract No.*
09:45	• Introduction ***Michelle R. Embry*** *(Health and Environmental Sciences Institute, U.S.A.)*	
09:55	• Xenobiotic Compounds and Metals Contamination in the Environment ***Prayad Pokethitiyook*** *(Mahidol University, Thailand)*	**S4-1**
10:25	• Per- and Polyfluorinated Substances (PFAS) Contamination in Environment, Seafood, and Human Exposure in Thailand ***Tawit Suriyo*** *(Chulabhorn Research Institute, Thailand)*	**S4-2**
10:55	• Environmental Processes and Health Implication of Emerging Pollutants in Coastal Region ***Tieyu Wang*** *(Shantou University, China)*	**S4-3**
11:25	• The Risk-Benefit Situation of Dioxin-like Compounds in Human Milk for the Breastfed Infant ***Martin van den Berg*** *(Utrecht University, The Netherlands)*	**S4-4**
11:55	*Lunch*	

SCIENTIFIC PROGRAM

Friday, June 21st, 2024 **Convention Hall**

SESSION 5: Exposure During Early Life Stage and Its Consequences

Chairpersons: Martin van den Berg (The Netherlands) **and** Panida Navasumrit (Thailand)

		Abstract No.
13:00	• Exposure to Environmental Toxicants and Immune Dysfunction in Children ***Xia Huo*** *(Jinan University, China)*	**S5-1**
13:30	• Exposure to Toxic Substances and Increased Various Types of DNA Damage in Young Children Living in the Vicinity of Electronic Waste Informal Recycling Site ***Panida Navasumrit*** *(Chulabhorn Research Institute, Thailand)*	**S5-2**
14:00	• The Impact of Developmental Exposure to Arsenic on the Expression of Genes Related to Metabolic Diseases: Evidences from Differentiated Adipocyte Model and Human Studies ***Thitirat Ngaotepprutaram*** *(Chulabhorn Research Institute, Thailand)*	**S5-3**
14:30	• Protecting Our Most Vulnerable Populations from Toxics in Drinking Water ***Jena Frey*** *(University of North Carolina at Chapel Hill, U.S.A.)*	**S5-4**
15:00	• Solution-Oriented Fundamental Transdisciplinary Research for Improving Children's Health and the Environment: A Global Environmental Health Network ***William A. Suk*** *(University of North Carolina in Chapel Hill, U.S.A.)*	**S5-5**

SESSION 6: Collaborative Network in Environmental Health

15:30 **Moderators: William A. Suk** (U.S.A.) and **Mathuros Ruchirawat** (Thailand)

Panelists:- **Syril Pettit** *(Health and Environmental Sciences Institute, U.S.A.)*
- **William A. Suk** *(University of North Carolina in Chapel Hill, U.S.A.)*
- **Supat Wangwongwatana** *(Hub of Talents on Air Pollution and Climate, Thailand)*

Regional perspectives and discussion:
- **Rozaini Binti Abdullah** *(Universiti Putra Malaysia, Malaysia)*
- **William W. Au** *(University of Texas Medical Branch, U.S.A.)*
- **Budi Haryanto** *(University of Indonesia, Indonesia)*
- **Xia Huo** *(Jinan University, China)*
- **Daam Settachan** *(Chulabhorn Research Institute, Thailand)*

17:00 - **Closing Address** by **Professor Dr. *Khunying* Mathuros Ruchirawat,** Director of the Center of Excellence on Environmental Health and Toxicology (CoE EHT)

Plenary Lectures

Climate Change and Impact on Toxic Pollutants and Human Health

Henry Falk

Rollins School of Public Health, Emory University, Atlanta, Georgia, U.S.A.

E-mail: hxfalk@gmail.com

Climate change poses the greatest challenge to the global environment and health, both in terms of potential catastrophic impact and in effectively responding to this pervasive threat. Conceptually, climate change represents an expanded view of environmental pollution. The release of greenhouse gases to the atmosphere and their mode of action differs in significant ways from many traditional environmental pollutants and toxicants. And the effects of climate change on both the environment and health will be extraordinarily diverse.

The Intergovernmental Panel on Climate Change has conclusively affirmed that global warming is already occurring and that manmade inputs to climate change are the key driver in this process. They have also modelled how this warming process will affect many aspects of the environment such as extreme weather events; for example, both heat wave frequency and intensity are predicted to increase dramatically as the globe warms.

But we are no longer just predicting the effects of climate change. We are already experiencing in many ways the impact of the initial phases of global warming. Rapidly intensifying hurricanes, heat waves in unexpected places, calamitous wildfires, disappearing glaciers, threatened coastlines, infectious diseases spreading beyond traditional boundaries, etc., have led to greater public awareness and acceptance of the reality of climate change. We have reached the point where World Weather Attribution and other scientific groups regularly report on the likelihood that climate change was responsible in whole or in part for the unusual environmental impacts that we currently experience.

There are potentially so many diverse effects of climate change that it helps to group them in an organized way; each type of effect below comes with its own distinctive set of environmental and health impacts:

1- Direct Effects from extreme climate and weather patterns:

- a. Heat, both short term heat waves and long-term extreme heat
- b. Wildfires, both direct impacts of fire and resulting air pollution
- c. Floods and Storms (acute impact), and Sea Level Rise (long-term)
- d. Drought

2- Indirect Effects mediated through changes in the environment:

- e. Changing patterns of disease vectors and infectious diseases
- f. Changing patterns of vegetation affecting pollen and asthma/allergies
- g. Changing atmospheric patterns leading to increases in air pollutants
- h. Changing exposure to toxic pollutants and hazardous conditions, affecting both environmental and occupational health
- i. Changing agricultural and oceanic patterns leading to major impacts on food, livestock, and fisheries, and resulting effects on food security and nutrition

3- Complex effects resulting from broad societal impacts and overlapping with above:
   j. Large-scale population migration
   k. Civil disturbances, conflict, and war
   l. Major economic impacts, including increasing poverty in heavily affected areas

4- Cross-cutting issues:
   m. Mental health impacts from any combination of all the above
   n. Vulnerable populations at increased risk for any or multiple of the above
      i. Individuals with disabilities and/or chronic diseases
      ii. Socioeconomically deprived or impoverished groups, including widespread slum dwellers
      iii. Marginalized communities, e.g., from environmental degradation or racism
      iv. Vulnerable age groups, such as children, elderly, and pregnant women
      v. Occupational groups exposed to major heat stress
      vi. Indigenous populations, such as Native Americans in the US
      vii. Geographically exposed populations, such as those in coastal areas facing rising seas, or in inland areas facing drought and extreme heat
      viii. Communities already heavily impacted by environmental pollution and toxicants, and at greater risk from additional exposures
      ix. Note: All the above comprise a major portion of the earth's population

In a single presentation it is neither possible nor meaningful to systematically review all the above potential impacts of climate change and their related health effects as well as the cross-cutting issues. This presentation will highlight the following:

1. The US experience- Recent years have seen an increasing number of costly and damaging hurricanes and wildfires with apparent links to climate change. Hurricane Katrina led to the flooding and near-total evacuation of a modern city with many lessons learned; it also is a clear example of the impact on a very vulnerable population of children. There are also many concerns about sea level rise and the long-term protection of coastal cities such as Miami, New York, and Boston. While a long-standing severe drought in the US West has been at least partially ended this year, there remain major concerns about the long-term availability of adequate water supplies particularly in the arid West.

Heat waves have been dramatic and have even occurred in the most unexpected places such as in the Pacific Northwest adjacent to Canada; the elderly are particularly vulnerable. Recent newspaper accounts suggest that the current administration is considering major new regulations to protect heat-stressed workers in vulnerable occupations; migrant laborers are a very vulnerable group. In general, the Biden administration has been very forceful in adopting legislation and regulatory initiatives related to climate change, but recent history shows the challenges of maintaining those efforts over the long-term as succeeding administrations often attempt to change or even fully reverse prior initiatives.

2. Global highlights- This presentation will look at some of the most critical impacts of climate change in different geographic regions, e.g. which areas are most vulnerable to extreme heat, environmental pollution, air pollution, infectious diseases, sea level rise, or food insecurity, etc. because of climate change. It will also highlight the potential magnitude of some of the complex effects of climate change, such as migration and economic impact. It will also highlight some of the challenges of evaluating cross-cutting issues, such as the mental health impact of global crises and disasters.

3. Major issues in South and Southeast Asia-

a-Sea level rise and saltwater intrusion are critical issues for the large river deltas as e.g. in the Mekong Delta in Vietnam or in Bangladesh. Sea level rise combined with land subsidence is a critical factor in repeated flooding in cities such as Jakarta (and Bangkok); Indonesia is already implementing a decision to relocate its capital.

b-Extreme heat has impacted this region earlier in the spring than expected for the past several years; extreme heat has multiple potential health effects, such as cardiovascular disease, particularly in the elderly and in those working in conditions of heat stress.

c-Most of the cities with the greatest levels of air pollution are in South Asia and nearby countries; climate change has the potential to greatly exacerbate the impacts of air pollutants.

d-A variety of infectious diseases (e.g., vector borne, food- and water-borne, others) pose greater risks in this region as a result of climate change.

e-Asia is the largest producer of chemicals globally. The ability to address environmental pollutants and toxicants is very critical. Many climate factors such as extreme weather patterns but also complex factors such as economic impacts and migration patterns may have critical effects on environmental pollution and on environmental and occupational health. New or alternative energy sources in the drive to net-zero emissions can also have a very significant impact on environmental pollution in the region.

f-Food security is another important issue in this region, especially the impact of climate change on rice production.

Electromagnetic Fields and Health: The Fetus, Child and Young Adult – Advances in Mechanistic Understanding

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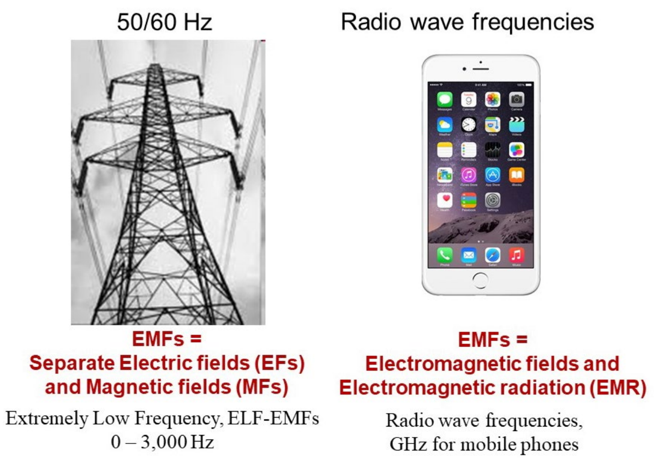
Introduction

The term *Electromagnetic Fields* (EMFs) embraces a wide terminology in the subject area of *Electromagnetism* (Fig. 1). This includes *Electric Fields* (EFs), *Magnetic Fields* (MFs*), Extremely Low Frequency Electric and Magnetic fields* (ELF-EMFs) such as those associated with powerlines, and *Radio Frequency Electromagnetic Fields* (RF-EMFs) associated with mobile phones together with their *Electromagnetic Radiation* (EMR). Most research into the biological effects of EMFs has concerned the MF component. This will be the main focus of my talk.

Fig. 1. What is an EMF?



When the Earth was formed 4.5 billion years ago, MFs were already present. Life developed in the presence of MFs to which all forms are able to respond. Some birds detect MF changes as low as 2 nanotesla (nT) or 0.002 microtesla (μT), around four orders of magnitude below the strength of the geomagnetic field of 43 μT in Bangkok. It should come as no surprise that humans too are able to detect MFs and EMFs, albeit unconsciously, as evidenced for example by the established adverse health effects associated with solar-geomagnetic storms and carefully controlled laboratory experiments.

ELF-EMFs – associated with powerlines and electricity supply in general

Adverse health effects of exposure have been reported at all stages of life. In the earliest stages, a number of studies have associated exposure with miscarriage, in particular where personal exposure was measured[1–3]. Pooled analysis of studies suggest a robust association with MFs typical of those found in the home[4].

In childhood, there is a particularly robust MF association with the incidence of leukaemia[5–9] (Fig 2). Given that the disease is mercifully rare, even national studies can lack adequate statistical resolving power. Nevertheless, pooled analysis of international studies indicate a 2-fold increase in risk with time-weighted exposure above 0.4 μT and 1.2-fold above 0.2 μT. Taking into account advances in mechanistic understanding, this association should be regarded as causal.

Pooled analyses of childhood leukaemia

Published analysis	Included studies	Ref	ORs at magnetic flux levels <0.1	0.2-0.29	0.3-0.39	=>0.4 uT
Ahlbom et al 2000	9	a	1.0	1.0	1.0	2.0
Greenland et al 2000	15	b	1.0	1.1	1.7	1.6
Greenland et al 2000	(ALL only)	c	1.0	-	-	2.4
Schuz, et al 2007	9	d	1.0	1.1	1.2	2.0
Kheifets et al 2010	7 since 2000	e	1.0	1.1	1.2	1.5
Zhao et al 2014	9	f	1.0	1.0	1.4	-
Seomun et al 2021	33	g	1.0	1.3	1.2	1.7

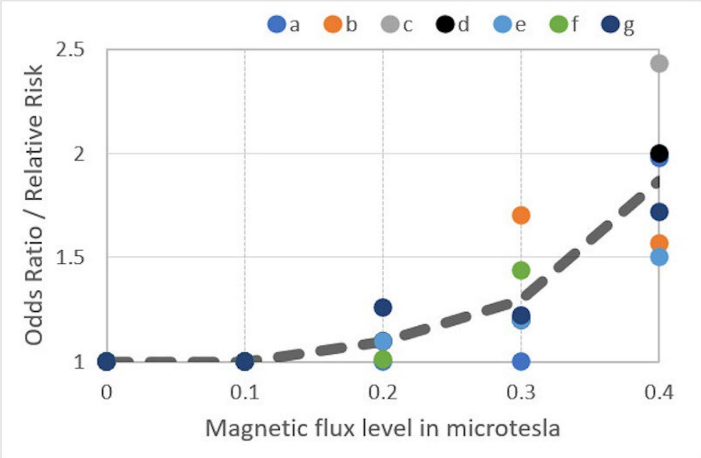


Fig 2. (from Henshaw, Belpoggi, Mandrioli & Philips, 2024[9])

RF-EMFs – from mobile phones and related wireless devices

Exposure to RF-EMFs is complex, comprising not just from mobile phones and WiFi, but to secondhand exposure from surrounding mobile phones users, particularly in crowded environments. The nature of RF exposure from mobile phones has also changed radically with the progressive introduction of 2G through to 5G systems, together with the advent of smart phones and many uses apart from voice telephony.

In humans, a clear observation with RF-EMR exposure is the effect on male fertility. Pooled analysis of studies suggest reduction in both sperm motility and viability[10].

A link between mobile phone use and the risk of brain tumours is equivocal. Between 1995 and 2015, data for England shows a 2-fold increase in the incidence of rapidly fatal glioblastoma multiforme brain tumours[11,12]. Risk factors for brain tumours include ionising radiation, notably from diagnostic and treatment exposures, and air pollution as an emerging factor. Studies in adults report an association with use of earlier generation cell phones[13,14].

Elaborate studies report an increased incidence of brain and heart tumours in RF-EMF/R-exposed Sprague-Dawley rats[15,16]. These tumours share the same histological type as those observed in some epidemiological studies on cell phone users.

In children, brain and spinal (CNS) tumours account for around 26% of cancer incidence. A large 14-country study found no association with incidence in childhood and adolescence with respect to mobile phone use[17]. This may be unsurprising. Exposure to ionising radiation in childhood for diagnostic and treatment purposes, is known to increase brain tumour risk many decades later, testifying to the long latency period for the disease.

Regarding other adverse effects on child health, there is much discussion concerning so-called '*addiction'* to mobile phones, in particular leading to attention deficit at school. Some countries, including the UK are banning student use of mobile phones in school time. While the number of published studies in this area is numerous, it is difficult to ascertain whether adverse health effects can be attributed specifically to the phones' EMFs/EMR as opposed exposure other factors such as light exposure from the phone display, or access to social media. However, maternal cell phone use during pregnancy may be associated with an increased risk of behavioural problems in the offspring, particularly hyperactivity/inattention problems[18]. A review of adult health risk from mobile phone base-stations, showed three types of effects: radiofrequency sickness, cancer and changes in biochemical parameters[19].

Mechanisms - advances in understanding (see ref 9 for full references)

ELF-MFs engender *genomic instability* in biological cells testifying to their carcinogenic potential, with the delayed *de novo* appearance of genetic alterations multiple cell generations after exposure, a characteristic of most cancer cells[20–23].

A key mode of interaction is the so-called Radical Pair Mechanism (RPM). MFs can increase the lifetime of free radical pairs by altering their spin states from the short-lived (~nanoseconds) singlet state to the long-lived (~microseconds) triplet state and consequently their reaction products and the potential to cause biological damage.

The RPM has been particularly successful in explaining magnetoreception in animals and how avian and other species detect changes as low as 10 nT in the Earth's MF for the purposes of navigation and migration[24,25]. Here, radical pairs are activated by blue light within cryptochrome (CRY) protein molecules in the eye. MF-induced changes in reaction products act as a signal in the proposed magnetic compass in birds. Crucially, human cryptochromes (specifically CRY2 - present in most human tissues) have been shown to be magneto-sensitive[26]. Mammalian-type cryptochromes appear to function independently of light and would be expected to retain the characteristics to respond to MFs. Thus, the ability of MFs to increase the lifetime of free radicals, may allow those radicals to be more available to cause biological damage in general.

EMFs and the release of free radicals – role of cryptochromes

The ability of ELF-MFs to release reactive oxygen species (ROS) is well documented[27]. Of relevance to childhood leukaemia, 50 Hz MFs release reactive oxygen intermediates in human umbilical cord blood-derived monocytes and in Mono Mac 6 cells[28]. This constitutes a reasonable carcinogenic mechanism, because these cells would be recruited to sites of inflammation and proliferation where their ROS could generate genetic aberrations. MFs have since been shown to induce human cryptochromes to modulate intracellular ROS[29]. This profound observation makes it conceivable that carcinogenesis associated with power lines, pulsed MF-induced ROS generation, and animal magnetoreception share a common mechanistic basis.

Cryptochromes, Melatonin and Circadian Rhythm Disruption

Cryptochromes are best known for their control of circadian rhythms, notably the nocturnal production in the pineal gland of the powerful natural antioxidant and anti-cancer agent, melatonin. Nocturnal pineal melatonin is fully suppressed once exposure to light-at-night (LAN) exceeds 200 lux (about 300 mW m^{-2}, e. g. in a low-lighted hallway). Cryptochromes are extremely sensitive to blue light and even a single, blue-LED light visible from the bed will affect nocturnal melatonin synthesis (and hence sleep quality) in a young child. In adults, IARC classes nightshift work as a 2A Probable Carcinogen.

MFs appear less effective than LAN in melatonin suppression, with maximum suppression in the range 20–30%. However, people exposed to elevated fields living under high voltage powerlines for example may be chronically exposed, so the overall effect may be greater than LAN. Nocturnal melatonin levels are typically assayed from the metabolite 6-sulfatoxymelatonin in morning urine. Demonstration of MF-suppression must overcome the wide natural person-to-person variation in nocturnal melatonin production. Consequently, studies with only a few tens of subjects lack the resolving power to detect an effect. Overall however, studies are inconsistent with no effect. In a well-conducted study involving 203 women and a dose-response design, melatonin suppression was noted for nocturnal exposure as low as 0.2 μT, with an overall 14% reduction.

The hypothesis that MFs may at least in part increase childhood leukaemia risk by melatonin and circadian rhythm disruption[30] (increased risk may also apply to miscarriage) has been progressively developed to include action via the RPM on cryptochromes, DNA damage and genomic instability, adding to the pathway of ROS release discussed above.

RF-EMF frequencies are considered too high to affect the RPM directly. However, biological effects in general of RF-EMFs tend to mirror those at lower frequencies. This may be attributable to the lower frequency modulation carried by RF signals.

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Novel Toxicological Effects and Personalized Health Hazard in Workers Exposed to Benzene

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Novel and traditional toxicological effects were detected in workers who were exposed to benzene (BZ) at below occupational limit. These toxic/genotoxic effects were increased mitochondria copy numbers, prolongation of telomeres, impairment of DNA damage repair response (DDRR), perturbations of expression in non-coding RNAs, and epigenetic changes. These abnormalities were associated with alterations of gene expression and cellular signaling pathways which affected hematopoietic cell development, expression of apoptosis, autophagy, etc. The overarching mechanisms for induction of health risk were impaired DDRR, inhibition of tumor suppressor genes, and changes of MDM2-p53 axis activities that would contribute to perturbed control for anti-cancer pathways. Evaluation of the unusual dose-responses to BZ exposure indicates cellular over-compensation and reprogramming to overcome toxicity and to promote survival. However, these abnormal mechanisms also promote the induction of leukemia. Further investigations indicate that the current exposure limits for workers to BZ were unacceptable. Based on these studies, the new exposure limits should be less than 0.07 ppm rather than the current 1 ppm. These studies emphasize the need to conduct appropriate bioassays, and to provide more reliable decisions on health hazards as well as on exposure limits for workers. In addition, it is important to use scientific data to provide significantly improved risk assessment: i.e., shifting from a population- to an individual-based risk assessment.

Plenary Lecture

PL-4

High-resolution Mutational Fingerprints Identify Past Exposures to Environmental Carcinogens

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DNA acts as a recording device that progressively accumulates mutations over our lifetimes. These mutations are often caused by the mis-replication or mis-repair of DNA adducts formed by the reaction of environmental toxins and toxicants with the genome. The mutational spectra of carcinogenic agents are very distinctive, reflecting three factors. First, DNA damaging agents react with target bases in a manner in which the context (the bases on either side of the target base) influences the likelihood that a given base will react. Second, DNA repair proteins preferentially repair DNA lesions in some contexts better than others. Lastly, DNA polymerases bypass adducts and make mutations frequently in some sequence contexts but cause fewer mutations in other contexts. This presentation will focus on two environmental carcinogens, aflatoxin B_1 (AFB_1) and N-nitrosodimethylamine (NDMA) in a mouse model of cancer. AFB_1 is a powerful liver carcinogen produced by a food spoilage fungus. Using a sensitive DNA sequencing tool that is four orders of magnitude more accurate than conventional methods, it is shown that AFB1 produces a very distinctive mutational spectrum, when viewed by measuring mutations across all 96 possible 3-base contexts. A strong hotspot involving a G→T mutation in 5'-C<u>G</u>C-3' contexts is observed (the underscored <u>G</u> is the position of the mutation). Using informatics tools, the mutation shows cosine similarity to a mutational signature of liver cancers from areas of the world that have known AFB_1 exposure. The distinctive pattern is evident as early as 10 weeks following AFB_1 administration and it is durable; it is undiminished at 72 weeks, when tumors are frequent. The second agent studied, NDMA, is also a liver carcinogen. Human exposure occurs via water or air pollution, through contaminated medications and from reactions that occur in nitrite-containing processed food products. As with AFB_1, a distinctive mutational pattern emerges at 10 weeks after administration, but this time the mutations are G→A and occur mainly in 5'-(purine)<u>G</u>-3' contexts. The pattern observed shows high similarity to that seen in brain cancers. Taken together, the work on AFB_1 and NDMA show that distinctive mutational "fingerprints" emerge soon after exposure and hence represent early onset biomarkers that can be used to determine prior exposure to genetic threats.

Ambient Air Pollution and Adverse Health Effects

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Ambient air pollution is a complex mixture of many different chemical compounds. WHO has estimated that roughly 9 million people globally will die prematurely each year as a result of ambient air pollution exposure, and as such it is one of the world's largest single environmental health risk. The source of air pollution can be either anthropogenic, e.g., pollution from transportation, energy production and "slash and burn" Agriculture, or naturally, e.g., forest fires and volcanic activity. The exposure shows large seasonal and spatial variation and the chemical composition and source contribution can be attributed to the social and economic development of the country.

Exposure to air pollution has been associated with an increased risk for many adverse health effects such increased mortality due to stroke, cardiovascular diseases, as well as cancer and respiratory diseases. WHO has established Guideline Values for air the pollutants. The International Agency for Research on Cancer (WHO) has classified ambient air and diesel exhaust, and some of the chemicals present in the air, e.g., benzene as human carcinogens (IARC group 1).

Recently, the focus has been on the health effects of particulate matters, e.g., PM2.5, but exposure to the classical criteria pollutants, nitrogen oxide and sulfur dioxide is associated with some health effects. An important issue is the interaction between the different pollutants (complex mixtures).

The major sources of PM2.5 is agriculture burning, residential wood combustion, diesel car exhaust and crude oil combustion.

The PM2.5 is of special concern as they are easily inhaled and can reach the lower part of the lung from where they can enter the systemic distribution and induce biological processes, i.e., oxidative stress and inflammation, that are involved in many pathological processes. Due to their small size the particles have a large surface area to which other pollutants, e.g. carcinogenic polycyclic aromatic compounds formed during the combustion process can associate with the surface of the particle, that thus serves as a carrier.

Exposure for ambient air is associated with increased risk for many types of cancer. In a large cohort study with good exposure information, a significant increase risk was seen for lung, cervix and brain cancers.

We are all exposed to air pollution, and the health risk depends on the concentration in the polluted air, thus it is important to identify vulnerable and susceptible groups. These include pregnant women, as they experience a higher risk of infant mortality, pre-term delivery, and their off-springs have an increased risk for neurological effects and autism during childhood. Children are also more susceptible, i.e. asthma due to higher dose level of exposure, and elderly people have an increased health risk especially if they have some predisposing diseases. Poor people also have an increased risk as they normally reside in highly polluted environments

The adverse health risk depends on the concentration and the type of the toxic compounds in the polluted air. In order to protect the population and future generation, it is imperative to reduce the exposure. Focus areas for reduction of exposure to ambient air pollution should be industry, agriculture management, transport and urban planning, personal protection and regulation.

PL-6

No Small Matter: The Potential Hazards of Engineered Nanomaterials for Human Health

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Engineered nanomaterials (ENMs) interface and interact with biological systems and this could potentially be harnessed for biomedical applications (drug delivery, imaging, etc). However, ENMs may also cause unexpected and unwanted effects on cells and tissues. The present lecture will provide an overview of studies on the potential hazards of ENMs for human health with particular emphasis on the effects on the human immune system.

Metal and metal oxide nanoparticles are widely used in different applications, and close attention to potential health effects is therefore warranted. Silicon dioxide (silica) occurs in amorphous and crystalline forms, and crystalline silica has long been recognized as a major occupational hazard. Recent evidence suggests that nano-sized amorphous silica also could elicit cytotoxicity and immunotoxicity in human immune cells. Furthermore, our laboratory has been actively involved in the EU-funded Graphene Flagship project during the past 10 years (2013-2023). Here, recent studies on the impact of two-dimensional (2D) materials on the human immune system will be discussed, taking graphene-based materials (GBMs) and transition metal carbides and nitrides (MXenes) as examples. Emphasis will be placed on the activation of the inflammasome, a cytosolic multiprotein complex expressed in immune cells that serves as a key instigator of inflammation. Finally, an outlook on micro- and nanoplastics (MNPs) is provided. The ubiquitous presence of MNPs in the environment is undeniable, but the impact on human health remains unclear. MNPs are distinguished from ENMs by their marked heterogeneity in terms of size and shape, though it may be argued that some of the lessons learned from the past decade of nanotoxicological research may be relevant for MNPs.

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Bioaccumulation at the Intersection Between Ecological and Human Health

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The 1962 publication of "Silent Spring" by Rachel Carson raised awareness about the harmful effects of indiscriminate pesticide use, particularly dichlorodiphenyltrichloroethane (DDT), and documented how pesticides were causing environmental damage, including the decline of bird populations. This work catalyzed the modern environmental movement and highlighted the importance of understanding the properties and processes that affect the fate and behavior of chemicals, including their bioaccumulation potential, when evaluating impacts to ecological and human health. Bioaccumulation is the net result of competing rates of chemical uptake into, and elimination from an organism, and its assessment is an essential endpoint in national and international chemical regulatory programmes and treaties, such as the Stockholm Convention on Persistent Organic Pollutants (POPs) and Persistent, Bioaccumulative and Toxic (PBT) criteria. Bioaccumulation is also a key intersection point within the One Health paradigm, which is an interdisciplinary approach recognizing the interconnectedness of human and ecological health. Potential health risk for both humans and the environment from these types of chemicals can be evaluated using various approaches and metrics to understand bioconcentration, bioaccumulation, biomagnification, and biotransformation of chemicals in both aquatic and terrestrial environments. Although some chemicals that bioaccumulate have resulted in food consumption advisories (e.g., mercury, PCBs, dioxins), there are many additional chemistries with potential to impact both the ecological and human health food chain that warrant additional evaluation. This presentation will highlight various approaches and advances to evaluate bioaccumulation, emphasizing the critical importance of problem formulation and context to evaluate exposure, fate, and health impacts.

PL-8

The Last Mile Challenge (and Opportunity) in Environmental Health Sciences

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Many grant, publication, and professional recognition systems prioritize first-in-class research methods and studies, yet translating these achievements into effective practices for environmental health protection remains a significant challenge. This talk will explore the 'last mile' problem in health protection sciences, drawing parallels from the energy distribution sector where logistical challenges hinder the movement of energy from large-scale generation sites to individual homes. In the context of health protection, this concept reflects the difficulty of translating scientific innovations into actionable practices to address real-world human and environmental health needs.

The presentation will leverage the speaker's 25 years of experience in collaborative safety sciences at the international non-profit, Health and Environmental Sciences Institute, to offer insights into addressing the last mile challenge. Through case studies and practical examples, the speaker will highlight strategies for bridging the gap between scientific discoveries and practical implementation in environmental health protection. The presentation will also emphasize the importance of stakeholder engagement, sustainability strategies, and social determinants that impact the uptake and impact of environmental health protection interventions.

This talk serves as a call to action for researchers, practitioners, policymakers, and stakeholders to collectively address the last mile gap and maximize the impact of environmental health discoveries on community well-being. By prioritizing the translation of scientific knowledge into actionable practices, we can better protect our communities and foster sustainable environmental health outcomes.

Carcinogenic Effects of Genotoxic Chemicals in Early Life Stage

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In this presentation it is argued that children are significantly more vulnerable to developing cancer later in life caused by genotoxic compounds, those that damage DNA. It explores the biological reasons behind this increased risk and analyzes evidence from various studies to support this view. One key factor is the rapid cell division that occurs during a child's growth. The fast-dividing cells are more susceptible to DNA damage from genotoxic carcinogens. Additionally, children's natural DNA repair mechanisms may not be fully developed compared to adults, leaving them less equipped to address this cellular damage. The presentation also examines differences in the role of metabolism in both children and adults. The body processes chemicals through two main phases: phase 1 (bioactivation) and phase 2 (detoxification). While children have sufficient levels of enzymes for bioactivation, the results on the effectiveness of their detoxification mechanisms are inconclusive. This presentation will dive further into carcinogenicity studies with animals at different life stages. Rodent studies clearly demonstrate a higher incidence of tumors in young animals exposed to genotoxic compounds compared to adults exposed at similar dose levels. In addition, these tumors appear sooner and with a higher frequency in juvenile animals. Human cancer epidemiology studies also support this notion of higher sensitivity. Children treated with genotoxic chemotherapy or radiotherapy have a higher chance of developing secondary tumors compared to adults undergoing the same treatment. Similarly, exposure to UV radiation during childhood is a stronger risk factor for skin cancer than exposure in adulthood. Despite this compelling evidence for higher sensitivity of children, the presentation highlights a concerning gap in the regulatory arena. Regulatory agencies, though aware of the increased risk in children for over two decades, have not consequently implemented any specific safety factors to account for this higher vulnerability. It is proposed to finally adopt a regular "Aged Dependent Adjustable Factor" (ADAF) to ensure a more robust risk assessment process for children, particularly for food and environmental pollution regulations. In conclusion, it is argued that children are not simply small versions of adults when it comes to cancer risk from genotoxic compounds. Their developing bodies make them more susceptible to the harmful effects of genotoxic compounds. This vulnerability should be acknowledged more commonly by regulatory agencies and stricter safety measures should be implemented to protect children's health.

Session 1:

Environmental Health Issues of Concern in Developing Countries

S1-1

The Status of Water, Sanitation and Hygiene in Botswana

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Every year, 1.4 million people die from lack of access to and use of water, sanitation, and hygiene (WASH) as reported by WHO in the GLOBAL Health Observatory. Around 1.2 million of these are attributable to gastrointestinal disorders like diarrhea and acute respiratory diseases (World Health Organization, no date). Diarrheal deaths as a result of inadequate WASH were reduced by half during the Millennium Developmental Goal (MDG) period of 2019-2015 (WHO, 2023). The current Sustainable Development Goal (SDG) 6 calls for the cessation of open defecation, and universal access to safely managed water and sanitation facilities, and basic hand hygiene by 2030. Inadequate WASH utilization and access also lead to poor nutrition and educational outcomes, as well as risks and stress for vulnerable groups, particularly women and girls mostly in Sub-Saharan Africa and South Asia. According to the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation, and Hygiene, two billion people still did not use safely managed drinking water in 2020, 771 million did not use at least basic drinking water services, and nearly half of the world's population, or 3.6 billion people, used sanitation services that left human waste untreated, endangering human and environmental health. To meet the SDG targets and guarantee that people have access to WASH services at home or if they are in healthcare facilities, schools, workplaces, places where food is prepared, markets, refugee camps, or prisons, there should be at least a quadrupling of progress made on WASH globally, with more in particularly fragile regions and countries. Globally, only 45% of the countries are on track to meet their national water coverage targets whilst only 25% are set to meet their sanitation targets. Less than a third of the countries have the human resources to achieve their set national goals.

Since 1981, Botswana has acknowledged the human right to water and sanitation. Health officials are authorized by section 57 of the Public Health Act to take all legal actions to guarantee the purity of water intended for home use and consumption by the general public. Additionally, Botswana National Policy for Wastewater and Sanitation Management (August 2001) highlights conservation of the environment as a national priority and an infinitely long-term commitment. To this effect, the collection, treatment, recycling and reuse of wastewater are given high priority in the protection and conservation of water resources. Botswana's vision 2036 advocates for a clean and health environment through improvement of human dignity, increased access to improved drinking water sources (Botswana Government, 2016), Improvement in compliance to drinking water (BOS 32:2015)(Botswana Bureau of Standards, no date a), Increased access to improved sanitation and improvement in wastewater treated and complying to National Discharge Standards (BOS 93:2012)(Botswana Bureau of Standards, no date b) in order to have healthy citizens.

Botswana has achieved notable progress in enhancing the availability of potable water sanitation serves. Approximately 80% of the 2.7 million population has access to basic sanitation services whilst 10% has no form of sanitation facilities and practice unsanitary hygienic practices. The remaining 10-12% has access to shared or improved sanitation facilities. Open defecation rates currently stand at 10% from 54% in a 30 year period (Statistics Botswana, 2022).

There are specific plans to rehabilitate broken public latrines by local authorities. Full latrines are safely emptied or replaced when full. For private toilets, the water authority safely empties at a fee. However, the current tariffs do not cover the cost of operation. Accessing on-site sanitation can prevent water pollution and environmental degradation. Households with better sanitation facilities and hygienic practices are less at risk to public and environmental health issues. Sanitation has been described as a "demand-driven and off-budget initiative to assist rural and peri-urban communities to improve their quality of life by gaining access to a basic service". The implementation of the National Sanitation and Hygiene Communication Strategy is key to changing knowledge, attitudes, and practices that will result in increased use of sanitation facilities and improve hygiene behavior to reduce the WASH-related burden of disease.

Institutional, financial and technical responsibilities within the wastewater/sanitation sector at present are fragmented, resulting in uncoordinated planning, design and implementation, as well as unsatisfactory operation and maintenance. Currently, six ministries/institutions are responsible for the WASH sector in Botswana. The Water Utilities Corporation in the Ministry of Land Management, Water and Sanitation Services is the lead for drinking water and wastewater management. The National Wastewater and Sanitation Policy and National Master Plan for Wastewater and Sanitation were developed by the Ministry of Land Management, Water and Sanitation Services for the sustainable management of wastewater and sanitation in Botswana. The Ministry of Health leads hygiene promotion initiatives and has a number of responsibilities in sanitation and water such as surveillance of both portable and wastewater quality. Additionally, the Ministry of Health coordinates the management of WASH related outbreaks and diseases. However, there is inadequate coordination between the key stakeholders but reporting and meetings take place on an ad hoc basis as needed.

There are specific plans implemented addressing the issues of reliability and continuous water supply in both urban and rural areas. The main water sources are groundwater, surface water and wastewater. The total renewable water resources available to the country are in the order of 12.2 kilometres per year, of which the total internal renewable water resources are estimated at only 2.4 kilometres per year. The internal renewable surface water resources are estimated at only 0.8 kilometres per year(Statistics Botswana, 2022)(Mogomotsi, Mogomotsi and Matlhola, 2018). The renewable water resources are scarce like in Botswana with only 1064.74 cubic meters per capita water availability. The total water demand in the country currently stands at 272 million cubic meters per year. The demand is expected to increase to 340 million cubic meters per year by 2035. Approximately 10% of the total treated wastewater generated in country is being utilized for non-potable use. The current water supply status is estimated at 225 million cubic meters in a year with an average water loss from our supply systems standing at 35%. The current water supply situation poses a risk of Botswana meeting her WASH plans and targets. The projected target for urban sanitation by 2030 is 90% while rural sanitation is at 75%.Other targets such as sanitation in school, health facilities have 100% targets. According to a University of Botswana research, many primary schools have the necessary facilities for hygienic practices, such as sinks, toilets, and latrines, but they don't always have the funding to make sure the facilities are operating as intended. The survey discovered that there was restricted access to handwashing supplies and that 80% of toilets did not flush correctly(Ngwenya *et al.*, 2018). Although elementary school pupils are taught cleanliness, there is still a higher need for execution and good hygiene habits. According to the Okavango Research Institute, just 70% of pupils "always wash their hands," even after using the toilet, if one is accessible, and before eating(Ngwenya *et al.*, 2018).

The Botswana government is striving to guarantee that these circumstances are improved by means of supplementary financing and updated infrastructure. For drinking water supply in both urban and rural areas, the target is 100% by 2030. Currently, the proportion of piped water in urban areas is 63% while in rural areas is 23%(Statistics Botswana, 2022)

Botswana National Water Conservation and Demand Management Strategy of 2021 promote water efficiency and the exploration of alternative water sources, such as greywater recycling, rainwater harvesting, storm-water collection, saline water and wastewater utilization, thus reducing pressure on the fresh water sources. In line with the above strategy, 30% of the Development Budget has been dedicated to Water and Sanitation Infrastructure the past 2 years. More than 40 water and sanitation projects are under implementation in order to meet the projected targets. Additionally, The North South Carrier (NSC) transfers 90ML/day water from the North to the South of the Country (about 400 km) in order to improve water security in the south of the country. The Second NSC under construction at a cost of P5.5 billion or US$415 million to increase water from the scheme to 200 ML/day.

In Botswana, drinking water is becoming a more expensive and limited resource. The cost of exploiting water resources is rising along with their distance from demand centers. Thus, actions to preserve these essential resources are required. Around the world, wastewater is recycled for a wide range of uses, including highly advanced treatment for "direct portable use" as drinking water and the use of untreated effluent to irrigate forest plantations. In Botswana, public worries about possible health hazards have prevented practical adoption of treated effluent and sludge use, despite technical acceptance of these benefits. Only 10% of the total treated wastewater generated in country is being utilized for non portable use. Currently, there is a managed acquifer recharge project to investigate the feasibility of using borehole injection to improve ground water sustainability (storage systems and additional yields).

There is limited data availability for decision making for sanitation and drinking water. Water quality is tested by local authorities, however it is not consistent due to lack of resources and trained personnel. There is limited data on independent water quality treating against national standards. There is no independent audit management and verification processes in place. However, the water authority has internal monitoring services for the quality of drinking water. The outcomes of the monitoring processes and performance of sanitation water services are not made public. Customer satisfaction reviews are also not available to the public. There is limited data for policy and strategy formulation, resource allocation, and national standards. The Ministry of Health responds to WASH related disease outbreaks with the support of WHO. According to Statistics Botswana, the prevalence of diarrhoeal cases in Botswana was 458/100 000 cases in 2016. This was a reduction from 1224/100 000 in 2011.Deaths due to diarrhoea for the same period reduced from 194 to 49(Statistics Botswana, 2022).

WASH have received little attention or importance, as in many other nations. The industry thus faces a severe lack of local workers with the necessary training and expertise. Technical and professional personnel are not adequate for the needs of the country. There is also emigration of skilled workers abroad. For the industry to be viable in the long run, Batswana skills must be improved to a sufficient degree and employment in the industry must be acknowledged as a vital service. Although there are no specific human resources strategies for WASH, there is a National Human Resource Development Strategy of 2009-2022 that caters for sector specific human resource strategies. Coordination of WASH would benefit from increased human resource capacity.

There is a budget for WASH areas across the relevant ministries. However, there is reported insufficient funding to meet the MDG targets. According to the (WHO, 2020) Water Global Analysis and Assessment of Sanitation And Drinking Water (GLAAS) survey, Botswana's budget for WASH services is 50% of what is needed by the industry. However, 30% of the Development Budget has been dedicated to Water and Sanitation Infrastructure the past 2 years. There was no data available to indicate the proportion of this budget coming from donors and partners.

In order to address equity in access to WASH services, six vulnerable groups were identified. The groups are poor populations, remote populations, indigenous populations, displaced persons, ethnic minorities and people living with disabilities. In Botswana, the legislation recognizes human right to WASH services and there is a clear procedure for participation. However, the extent of the users' participation in planning is not clear as well as the mechanisms for raising complaints. According to (Statistics Botswana, 2022),22% of remote populations had improved sanitation access as compared to the 64% in urban areas.

Botswana has government agencies dedicated to improving WASH conditions notably the two Ministries of Land Management, Water and Sanitation Services and The Ministry of Health. This Ministry has worked with the U.N. to participate in the Water Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS) survey. For future, the Ministry of Health has developed Environmental Health Indicators which will be reported by districts through the District Health Information Software. The indicators include sanitary facility for human excreta disposal, households access to safe drinking water, household access to domestic waste management, clinical waste management in home-based care, hand washing facilities and management of household pests. These developments will assist the country in achieving the SDGs for WASH.

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State of Environmental Health and Pollution in Ethiopia

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1. Country Background

Ethiopia is the second most populous country in Africa, with a current population of approximately 104.1 million, in 2022, which is expected to surpass 200 million by 2050. Ethiopia has a population growth of about 2.4% annually and is expected to continue growing in the coming decades without reaching a peak. Ethiopia is the fastest-growing economy in the region, with 6.3% growth in 2020. However, it is also one of the poorest, with a per capita gross national income of USD 1218, in 2022. Ethiopia aims to reach lower-middle-income status by 2025 (LEDS, 2023). Ethiopia rate of urbanization grows at 5.4 percent a year which would triple the urban population by 2034. Addis Ababa, Ethiopia's capital, is the most economically and politically significant city in the country. agriculture, where over 70% of the population is employed, was not significantly affected by the pandemic, and its contribution to growth slightly improved in 2021 compared to the previous year. The government has recently launched a new 10-Year Development Plan (10YDP) that aims to sustain the remarkable economic growth of the previous decade while facilitating the shift toward a more private-sector-driven, competitive, and resource-efficient economy (LEDS, 2023).

Industrialization has been a national strategy of Ethiopia, playing an important role as a springboard for economic development. Rapid economic development and urban expansion have drastically increased the demand for motorization. For example, the number of registered vehicles in Addis Ababa increased by 40% between 2016 and 2020. Ethiopia's economic growth has also resulted in natural resource depletion, pollution problems, and environmental degradation which threaten to slow or impede development gains. The cycle of economic growth, population growth, urbanization, and industrialization with inadequate environmental management in Ethiopia has corresponded with an increase in air, water, and waste pollution.

2. Air Quality

Air pollution refers to the excessive presence of certain substances in the atmosphere, such as gases, particulate matter, and radioactive materials, which can have harmful effects on humans and the environment, despite most of these substances being naturally present and considered harmless. These pollutants emanate from different sources: Indoor activities like Housing materials and activities are contaminated with pollutants like natural radiation, domestic combustion, coal gas, and tobacco smoking etc. and Outdoor activities transportation, automobiles, industries, refineries, street cleaning services, and environmental mixings are major contributors.

African countries with growing populations are experiencing increased exposure to household air pollution, with Ethiopia experiencing a 96% increase in people exposed to this issue due to its reliance on solid fuels, (HEI, 2019). The World Health Organization (WHO) classified air quality as "moderate" at the end of 2020, with a concentration of 24 $\mu g/m^3$ of fine particulate matter PM2.5 (IQAir, 2022)

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Ethiopia's average PM2.5 level was 20.1 μg/m³, ranking it as the 46th dirtiest city globally, a significant increase from previous years' levels of 27.1 μg/m³ and 26.9 μg/m³ (IQAir, 2022). However, the annual average PM2.5 exposures, ranging from a slight decrease of 0.24 $\mu g/m^3$ to a steep increase of 27% from 34.9 ppb in 2010 to 44.3 ppb in 2019, have seen significant increases in ozone concentrations, including cities like Sodo, Gonder, Hossaena, D/markose, Arbaminch, and Nekemt (HEI, 2020).

The study reveals that 28%, 18%, and 17% of particulate matter pollution in Ethiopia is emitted from vehicular sources and biomass burning soil dust. Ambient and indoor air pollution levels are typically investigated in urban and rural areas. Indoor air pollution, especially in slum neighborhoods and for women using biomass fuels, poses a significant health risk, with concentrations reaching 280 $\mu g/m^3$ for 24-hour measurements. PM2.5 concentrations in main city Addis Ababa vary between 42.4 and 24.2 $\mu g/m^3$, with household air pollution ranging between 413 and 818 $\mu g/m^3$. The city's Climate Leadership Group set an annual average baseline value of 33 $\mu g/m^3$ for Addis Ababa. Air pollution in Ethiopia is estimated to be 10% of DALY'S in 2019 and contributes to 14% of deaths.

Rapid economic growth and urbanization in led to environmental deterioration, including urban air pollution. This issue threatens public health and local ecosystems. Unregulated urban sprawl, increased mobility, and transportation contribute to pollution, traffic congestion, and land degradation, with transportation-related air pollution emerging as the primary source. Ethiopia lacks sufficient data on air pollution emissions inventory and source apportionment, which hinders pollution control planning in Addis Ababa (WBG, 2021). Ethiopian citizens face health risks from air pollution due to industrialization, agriculture, and urbanization. Promoting air quality management is crucial to reduce costs and improve health, ensuring a clean environment.

Ethiopia's air quality is deteriorating, affecting citizens' quality of life. Addis Ababa's visibility data shows a decline since the 1970s, with average air quality 1.6 times worse. Despite the capital's largest monitoring network, it lacks long-term data to determine temporally and spatially significant variations. Air quality management faces challenges due to limited stakeholder engagement, access to new technology, and financial resources, hindering effective implementation of air monitoring, data management, and reporting. Because of Lack of awareness about Air pollution and its impacts, Shortage of Budget, Staff turnover and Low capacity of staff, Lack of laboratory or equipment, High cost of fixed monitoring stations and information system development, High cost of portable monitoring equipment, Absence of accountability to enforce regulation, etc. are the main presser to air pollution management in Ethiopia.

Air pollution is the third leading risk factor for premature death, accounting for nearly 8% of deaths in Ethiopia in 2017. Exposure to outdoor PM2.5, household air pollution (HAP), and ozone has been linked to increased hospitalizations, disability, and early death from respiratory diseases, heart disease, stroke, lung cancer, diabetes, and communicable diseases. In 2019, around 67,800 deaths were linked to household air pollution (HEI, 2022). Urbanization and industrialization in Ethiopia significantly impact air pollution, with daily PM2.5 concentrations causing 502 deaths in Addis Ababa from 2017-2021 (Werku, 2022). Non communicable maternal neonatal and nutritional disease Particulate matter air pollution in 2019 around 3,067,193 people were died, Non communicable disease Ambient ozone air pollution around 13,595, Non-communicable disease particulate matter air pollution 916,359, Among the 67,826 (12.15% attribution) deaths annually in Ethiopia household air pollution attributes as risk factor for, LRI (Lower respiratory infection) 47.7, Stroke 35.3%, IHD (heart disease 29.5%), Neonatal death (21.9%), Diabetics 20.9%, Menegiets 2.03%, Diarrhea 1.16%.

Acute upper respiratory infection in 2018, 2019, and 2020 were 2,731,226, 2,825,389, and 1,367,258 respectively. Air pollution is also risking factor for both adults and children, contributing to 10% of Disability Adjusted Life Years (DALYs) and 14% of deaths in 2019. It is linked to respiratory diseases, lung cancer, and cardiovascular diseases, making it a silent killer that affects the healthy population.

The economic loss due to air pollution is estimated to be USD 3.02 billion in 2019. Ethiopia is committed to meeting SDG 6 goals and targets through green strategies and human rights to a clean environment. Ethiopia experienced economic losses of $2.71 billion due to premature death due to air pollution, 1.04% of GDP, and 180.5 million Performance IQ points of children.

The legal frameworks for preventing and mitigating environmental pollution in Ethiopia are well-documented, but enforcement is hindered by limited manpower, monitoring capacity, poor stakeholder partnerships, and biased perceptions of air pollution compared to economic-social developments. There is plenty of policy and regulatory supportive legal framework to enhance actively the activities related to air pollution management. These include: FDRE constitution, Environmental policy, The health policy, The Environmental Pollution Control Proclamation 300/2002, Environmental Impact Assessment Proclamation 299/2002, Ambient Environmental Standards for Ethiopia, Commitments of stakeholders are exist enabling conditions for implementation of the air pollution management in Ethiopia.

3. Water Quality

The physicochemical quality of drinking water sources in Ethiopia is an important aspect to consider for public health. the key points regarding physicochemical quality of drinking water sources in Ethiopia: Microbial Contamination, Turbidity, PH Levels, Dissolved Oxygen (DO) Levels, Chemical Contaminants. Ethiopia faces water pollution issues due to rapid industrialization, agricultural activities, improper waste management, and limited access to clean water resources. Major water bodies like rivers and lakes are significantly affected by pollution, primarily from industrial discharges, untreated sewage, and agricultural runoff containing pesticides and fertilizers. Inadequate waste disposal systems in urban and rural areas also contribute to the problem. Industrial activities, such as distillery, tannery, pulp and paper, textile, food, iron and steel, and others, release toxic chemicals, organic and inorganic substances, toxic solvents, and volatile organic chemicals. population growth continues to strain water and sanitation facilities, with only 7% of the population having access to basic sanitation services. Despite efforts to reduce open defecation, 38.4% of rural and 7% of urban populations still practice it, contributing to child mortality, illness, undernutrition, and stunting due to poor hygiene habits and environmental faecal contamination. The country's 90% of water withdrawals are for agricultural use, despite accounting for only 4% of renewable water resources. This is due to the leakage of fertilizers and pesticides, which cause water pollution and eutrophication, which stimulate algae growth in surface waters, threatening aquatic vegetation's survival. Addis Ababa hosts 65% of Ethiopia's industries, with 90% of them dumping waste into nearby rivers without proper treatment, potentially causing frustration and migration for better water resources. Approximately 49.6% of people have basic water and sanitation coverage, with 60% of communicable diseases due to limited access (UNICEF Ethiopia,2023).

87%of population without safe drinking water. In Ethiopia, 60%-80% of health issues are communicable diseases caused by unsafe water supply, unhygienic waste disposal, and environmental factors like poor hygiene and lack of access to water and sanitation.

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Diarrhea is Ethiopia's second leading cause of under-five mortality, accounting for 14% of all deaths, affecting over 25,000 children annually. 79%of deaths from diarrhea caused by unsafe drinking water, sanitation and inadequate personal hygiene. And 27 million population lives in high water stress areas, threatening its Sustainable Development Goal of water, sanitation, and hygiene by 2030, with rapid urbanization threatening urban water resilience (MOWIE, 2018). Ethiopia is facing a severe La Niña-induced drought, affecting over 8 million pastoralists in Somalia, Oromia, SNNP, and the South-West regions. The drought has led to 2.1 million livestock deaths and 22 million at risk, causing food insecurity and malnutrition, with 7.2 million people needing food and 4.4 million needing water assistance.

Ethiopia's government, in collaboration with international organizations, has addressed the fluoride issue by drilling boreholes in low fluoride concentration areas and promoting alternative water sources. Awareness campaigns and healthcare professional training are being implemented to educate the public about fluoride risks and the importance of safe water sources. Progress in providing safe drinking water to communities is hindered by limited resources, infrastructure, and vast affected areas, necessitating continuous government intervention and community involvement. The MoWIE 2022, 11,639 rural drinking water facilities were completed for 2,697,357 residents, including 1,375,652 women, and 11,684 facilities for 2,662,933 residents in 45 cities, ensuring 2,595,364 women have access to clean drinking water. report shows that 394,839 women in medium and small towns have access to clean drinking water, with 118,161 using rural facilities. Additionally, 5,035 women completed projects like Bu Market, Arda Dawa, and spring development, contributing to a total of 146,390 women in the society. to ensures equitable access to water, sanitation, and hygiene services for vulnerable groups, including women, children, and adolescent girls, through the ONEWASH National Program. focuses on sanitation promotion, hygiene, and Baby WASH in high-prevalence areas. They innovate to improve water supply, expand urban sanitation, and support climate resilience through sustainable boreholes and multi-village supply systems. with 38,800 Health Extension Workers, promotes hygiene and sanitation through a National Sanitation Marketing guideline and a National Urban Sanitation Strategy, addressing gaps and challenges in urban sanitation. Also enhances the WASH sector's capacity through strategic planning, coordination, and implementation of development and emergency interventions. It focuses on improving knowledge management through data generation. Ethiopians face vulnerabilities and large-scale emergencies, and UNICEF prioritizes saving lives in complex humanitarian crises.

4. POPs Chemicals

the current status of POP management and regulatory infrastructure in Ethiopia banned the import of pesticides listed under Annex A (i.e., those to be eliminated), except endosulfan, which was imported at around 200,000 L of endosulfan Between 2015 and 2020, were imported. which is used in Ethiopia's agricultural sector to control cotton pests. Ethiopia has 2,435 PCB-containing transformers, 92% of which are in use These transformers and capacitors contain 1,031,661 kg and 1,255 kg of dielectric fluids, respectively. As for Annex B POPs (i.e., those to be restricted), there are between 928,509 kg and 1,383,095 kg of active and obsolete dichloro-diphenyltri-chloroethane found in different stores across the country currently the country is working to eliminate PCB pollution by 2028 at national level. 337,000 kg of products containing perfluoro octane sulfonic acid from 2000 to 2020 with an annual average of 16,850 kg of photographic film, paper, and plates. Ethiopia's imports of synthetic carpets between 2000 and 2020 showed a potential annual consumption of 3.3-33.6 kg of PFOS, assuming all imported carpets contain PFOS.

Other sources of PFOS include imported carpets and pulp and paper production. Ethiopia's pulping industry is in its infancy, using mostly imported paper and recycled materials. Some plants use PFOS-containing packing materials, which can enter the environment when disposed of as garbage. POPs are detected in various environmental matrices and human blood. However, regulation and management of POP waste and stockpiles are inadequate. Improving monitoring, management, and regulation could be achieved by strengthening collaboration, harmonizing laws, and building institutional capacity. the implementation of chemical management measures. The management of contraband and adulteration is hindered by a shortage of inspectors and monitoring vehicles, and there is no structured information exchange on POP chemical movement.

Chemical safety data in Ethiopia is not systematically organized and easily accessible, with a lack of information on industries suspected of using POP chemicals, their production levels, and estimated environmental release. Ethiopia lacks a chemical disposal facility, leading to chemical accumulation in the county. Ethiopia's POP situation, management, and regulatory infrastructure, aiming to develop evidence-based policies to reduce exposure and contamination, updating Ethiopia's NIP 2.

The POP concentrations in various environmental matrices, including soil, waterbodies, sediments, food items, air, and human blood, from various Ethiopian locations.

Soil from agricultural, urban, and industrial areas in Ethiopia is a major source of organic pollutants, including pesticides and PCBs. A study in Addis Ababa industrial soil found PCB levels ranging from 1.027 to 4.862 mg kg-1, with dioxin-like levels ranging from 1.6036 to 0.56128 mg kg-1. POP pesticides like endosulfan, aldrin, dieldrin, DDT derivative, and heptachlor were detected in upper Awash agricultural soil, with urban concentrations lower than industrial areas. Eight regions in Ethiopia are potentially contaminated by PCBs, with equipment kept in open-filled storage.

Ethiopia lacks specific legislation for managing other POP chemicals, except for pesticides, highlighting a gap in regulation. There is weak coordination among responsible institutions, such as the Ministry of Agriculture, Customs and Revenue Authority, and EPA, causing concerns about Ethiopia's laws on the management and control of POPs are signatory and amended the Stockholm, basal and Rotterdam conventions. Legal frameworks for handling, importing, handling, transporting, and disposing of hazardous chemicals. Also regulated the hazardous waste management and disposal regulation 1090/2018 and is active for work.

5. Heavy Metals Pollution

The exposure of humans to heavy metals can occur through a variety of routes, which include inhalation as dust or fumes, vaporization, and ingestion through foods and drinks. Workers who have exposure to different chemicals used in industry and enclosed spaces can also be exposed to heavy metals through the skin and inhalation.

in Ethiopia the level of metals existed in vegetables, Zn (112.7mg/kg), Cr (47.7mg/kg), Pb (17.76mg/kg), and Cd (0.25mg/kg), with the highest concentrations. They have negative effects on public safety, environmental security, and nutrient levels in horticultural crops. Hence, Ethiopia has no permissible standards for vegetable consumption and hazard analysis, critical control point, or food safety system. Health impact 8 out of 100,000 children under five dies from poisonings every year Ethiopia compared to regional values: 80 Min 15 Max 36th of 47 countries in the African Regio.

The country's chemical management technical infrastructure is weak, with industries lacking necessary experts and professionals lacking necessary knowledge and skills, and chemicals not properly labeled. Despite this, some mitigation strategies, such as industrial waste treatment activities, are underway in Ethiopia's universities and beer and sugar factories. The regulation for Lead in paint is in place which in not permit the manufacturing of paints the lead level is 90ppm. Also adopt the Minamata convention to protect the pollution from the mercury. Additionally, physical, biological, and natural remedial strategies such as phytoremediation, phytoextraction, Phyto stabilization, rhizofiltration, bioremediation, and phytovolatilization are not applied to curtail deadly substance contents in Ethiopia.

6. Conclusion

The country is focusing on protecting the environment and human health, human activities, such as climate change, pollution, and biodiversity degradation. However, it lacks a national pollution management policy and a coordinated coordination platform among institutions working on environmental and human health issues. This lack of coordination hinders effective policy implementation and collaboration.

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Environmental Health Issues in India: Concerns, Challenges and Their Mitigation

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India stands as one of the fastest-growing countries in the world. The process of urbanization and industrialization contributes to the high levels of contamination and degradation of the environment, which result in poor quality of air, water, and land. Environmental pollution refers to the accumulation of unwanted material in the environment due to natural or human activities that lead to uninvited changes in the environment and ecology. These contaminants are introduced into the environment through multiple sources, including natural, anthropogenic sources like mining, thermal power plants, the use of agri-chemicals, the disposal of untreated industrial effluents, and urban waste. Air and water pollution continue to be one of the most pressing and encompassing environmental issues in India.

Global water usage has increased multifold across the world. The issue of low supply of treated water to all, causes immense dependency on groundwater. According to a report by the Ministry of Jal Shakti (Dynamic Ground Water Resource Assessment Report 2022), the total annual groundwater recharge is 437.60 billion cubic meters (BCM). The quantity of groundwater extracted stood at 239.16 BCM. High levels of arsenic, fluoride, iron, and uranium exist naturally in some geological formations, contaminating groundwater. At the same time, groundwater contamination due to arsenic is prevalent in 230 districts across 25 states of India, and over 50 million people are currently at risk from groundwater arsenic contamination. While that caused by fluoride is prevalent in 469 districts across 27 states, The middle and lower Gangetic planes and some central and south India areas are characterized by hard rock terrain, and people residing in such areas are worse affected by arsenic and fluoride contamination. The studies also suggest that the alkalinity of the groundwater facilitates the mobilization of fluoride (F^{-}) from sediments and rocks. The F^{-} concentrations are high in alluvial areas falling in the arid and semi-arid regions, followed by the hard rock's regions.

The next foremost environmental pollution in the region is urban as well rural air pollution. The various reasons are contributing viz., transportation, use of various forms of generators, use of biomass in households etc causes air pollution. The current concentration of PM 2.5 in India is 30 (μg/m³). The World Health Organization (WHO) recommends 15 μg/m³ as the threshold concentration of PM 2.5 for 24 hours. Currently, the concentration is 1.20 times the recommended limit. Concentrations of PM 2.5 and PM 10 at Delhi, capital of country are reported as 111 and 292, respectively, 3.2 times higher than the recommendation limits of the WHO 24-hour air quality guidance value. Though we face several challenges, due to various strict measures taken by government the air quality is increasing, and community have started realizing the hazards of these pollutants and they are participating in the actions of government. The situation of these above-mentioned contaminants and air pollution will be discussed in detail with the data during the conference.

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Environmental Health Status in Indonesia

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The environmental health status in Indonesia faces significant challenges, impacting the well-being of its population. Key issues include air pollution, water contamination, and waste management.

Air Pollution: Indonesia's urban areas, particularly Jakarta, suffer from high levels of air pollution. Major sources include vehicle emissions, industrial activities, and biomass burning. The country's frequent forest fires, often due to land clearing practices, exacerbate air quality, causing respiratory problems and other health issues.

Water Quality: Access to clean water remains a critical concern. Many water sources are contaminated by industrial waste, agricultural runoff, and domestic sewage. Poor water quality leads to waterborne diseases such as diarrhea, which is a leading cause of child mortality in Indonesia.

Waste Management: Inadequate waste management infrastructure contributes to environmental pollution. Improper disposal of solid waste and plastics leads to widespread littering, particularly in rivers and oceans, affecting marine ecosystems and human health.

Climate Change: Indonesia is highly vulnerable to the impacts of climate change, including rising sea levels and extreme weather events, which threaten food security, livelihoods, and health.

Efforts to address these issues include government regulations, public health campaigns, and international collaborations aimed at improving environmental standards and reducing pollution. However, effective implementation and community engagement are crucial for sustainable improvements in Indonesia's environmental health.

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Addressing Environmental Health and Toxicology Challenges in Malaysia: Towards Sustainable Solutions

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Environmental health and toxicology pose significant challenges in Malaysia, stemming from diverse sources such as industrial activities, urbanization, agricultural practices, and natural resource exploitation. The National Environmental Health Action Plan (NEHAP) Malaysia identified the top 10 priority environmental health threats in 2020, including children's environmental health, vector-borne diseases, contamination of drinking water sources, emerging water pollutants, urban health issues, climate change, food safety and contamination, and human exposure to pesticides and other contaminants. Of these threats, air pollution emerges as a pressing concern for children's environmental health, with both localized and transboundary sources contributing. For instance, the illegal chemical waste dumping incident at Sungai Kim Kim, Johor in 2019 garnered national attention due to its impact on thousands of school children, causing symptoms such as nausea, dizziness, shortness of breath, and myokymia due to exposure to toxic chemicals. Infectious diseases also continue to pose significant threats, exemplified by the devastating impact of COVID-19 on both public health and the economy. Concurrently, diseases like dengue, hepatitis B & C, tuberculosis, and emerging threats such as dog-mediated human rabies and antimicrobial resistance challenge public health efforts. Water pollution further compounds these challenges, with untreated sewage, industrial effluents, and agricultural runoff contaminating drinking water sources. Emerging pollutants like pharmaceuticals, personal care products, endocrine disruptors, and microplastics also present a growing public health risk. Addressing these complex challenges necessitates a comprehensive approach integrating scientific research, policy interventions, public awareness campaigns, and stakeholder collaboration. It is imperative for multiple stakeholders to work collectively towards holistic solutions that safeguard the well-being of both humans and the environment in Malaysia.

Keywords: environmental health, toxicology, Malaysia, NEHAP, emerging pollutants

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Public and Environment Health in Myanmar

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Myanmar is located in Southeast Asia and sanctified with diverse ecosystems, rich biodiversity and plentiful natural resources. These ecosystems are essential for health of the country's development and the public's wellbeing. Our country has a lot of vulnerable natural resources and environmental effects are strived on a number of different causes such as deforestation, mangrove loss, illegal wildlife trade, unrelated mineral extraction and environmental quality deterioration are just some of the ongoing threats to environmental issue of health. And also industrial activity and rapid urban expansion are bring additional environmental challenges such as water and air pollution, land contamination and hazardous waste. Our country, Myanmar is one of the countries most vulnerable to climate change. Widespread natural disasters caused by extreme weather events and predicted future affected climate change are major challenges for economic and social development. Environmental issues in Myanmar include air pollution, water pollution, deforestation, and issues relating to climate change.

The main source of critical survival to the people, animals and planet is water and sanitation. It is core of sustainable development on Goal 6 not only address the issue relating to drinking water, sanitation and hygiene, but also the quality and sustainability of water resources worldwide. Nowaday, 663 millions of population are not received to improve drinking water sources and at least 1.8 billion people globally use a source of drinking water that is contaminated with excreta and 2.4 billion people lack access to basic sanitation services such as toilets or latrines. Almost 1000 children die due to improper water and sanitation related diseases on each day. Diseases associated with water are Water-borne diseases (typhoid), Water-washed diseases (scabie), Water-related diseases(malaria). Any physical, biological or chemical alteration in water quality that adversely affects living organisms or renders the water unsuitable for consumption. Diarrhoea are included in top fourth in top ten leading ten leading cause of morbidity in Myanmar and according to Health in Myanmar 2014 published by Ministry of Health.

Acceptability aspects of water include physical parameters for turbidity, colour, taste and odour and temperature. According to sediments suspended in the water is free from turbidity< 5 NTU (nephelometric turbidity units). Water should not be utilized smelled and no colouring problem for ground water but its smell and taste. Chemical features for hardness, conductivity, nitrogen, chloride, iron, manganese, arsenic, fluoride, sulphur and lead. Effect on health impact for hardness water is including salts of Ca and Mg that may cause bladder stone. Conductivity is the ability of water to carry an electrical current that indicates the physical presence of dissolved chemicals in the water. Generally, nitrite and nitrate are not dangerous on health, however if overdose (>10mg/L) may result in "Blue Baby" and convulsion and may die. And also water containing subtle chloride is harmless but it is unsuitable for consumption because of the considerable quantity. Tiny amount of iron is not harmful on health but cause color and smell of rust. A few amount of manganese and radioactive species (eg. Uranium) can cause cancer. Arsenic is discoloration of the skin, stomach pain, nausea, vomiting, diarrhea, linked to cancer of the bladder and others. Right quantity of fluoride can protect the teeth however too much fluoride can cause the lined teeth and under quantity causes decayed teeth. Lead is toxic and is a cumulative poison that may come from industrial, mining and smelter discharges. Water containing Sulphur causes a diarrhea. Presence of bacteria indicative of pollution with excreta such as Coliforms organisms that related water diseases.

According to support this guideline, OEHD conducted Drinking Water Quality Surveillance in Mon state in 2016 as a pilot project and distributed Water Quality Testing Equipment for all 10 townships of Mon State. Total 358 samples mainly from common water sources of villages were tested for the parameters of pH, Total Dissolved Solid (TDS), Turbidity, Nitrate, Chlorine, Iron, Manganese, Hardness, Sulphate, Arsenic and Coliform levels. As that result of 358 samples, Nitrate - 10 samples > 50 mg/L, Manganese- 69 samples > 0.4 mg/L, Iron – 48 samples > 1 mg/L, Coliform – 34 samples > 20 coliforms /100 ml, TDS – 5 samples > 1000 mg/L, Turbidity – 2 samples > 5 NTU. As a subsequent activity sanitary survey by a qualified person, water quality testing training for basic health staffs, entire water supply system was conducted with delivering of field testing equipment for each township in November, 2017.

In addition, OEHD tested arsenic mitigation project in Bago region, 91475 samples in 15 Townships. Among tested samples,37994 samples (41.53%) has arsenic level > 10ppb and 7665 samples (8.38%) has Arsenic level >50 ppb. In Ayeyarwaddy region, about 75% of sources are tube well and about 22% are dug well. Approximately 97% of domestic water are groundwater. The total 29.18 % of tested water sources revealed arsenic content of > 10 ppb (WHO Standard) and 8.19% had that of >50 ppb (National Water Quality Standard) respectively. Specificially, total 2085 (10.87 %) of deep tube wells, 7826 (10.36 %) of shallow tube wells and 244 (0.91%) of dug wells were found to have arsenic content of >50 ppb in that survey. OEHD developed National Drinking Water Quality Standards and it was approved by National Standard Council and published in 22 February, 2019 as "MMS 2:2019 Drinking Water Quality Standard". OEHD also tested fluoride content in 1114 samples at Wetlet Township in 2012. Among the samples tested, 720 samples (64.64%) had fluoride level of <1.5 mg/L and 394 samples (35.36%) had fluoride level of >1.5 mg/L. In Bowsai Lead Mine, Kalaw Township, Shan State (South), OEHD took water sample from 10 drinking water sources in 2017. The tested water lead level in all water sources are within normal reference value <10 ppb. OEHD is also taking activities for surveillance of Bacteriological (presumptive coliform test, multiple tube method, colony count), Biological examination (an index of pollution), and Chemical surveillance.

In our country, Myanmar has to achieve MDG Goal 6 which is "Clean Water and Sanitation" in 2030, Myanmar National Strategy and Investment Plan for Rural Water Supply, Water Sanitation and Hygiene Activities (WASH) in Schools and WASH in Health Facilities 2016 - 2030, signed by ministers from 3 ministries, including Ministry of Education, Ministry of Agriculture, Livestock and Irrigation and Ministry of Health was published in 2016.The Ministry of Health is mainly responsible for WASH in all health care facilities. The objective of WASH in health care facilities is to have adequate water supplies, toilets and hand washing facilities for patients, caregivers and staff, and clinical and hazardous waste disposal facilities, waste water drainage and treatment appropriate for the type of health facility, and maintain a clean environment. OEHD developed National Guideline on WASH in Health Care Facilities and now already approved by Ministry Of Health and plan to distribute printed versions to States and Regional Public Health Departments. The scope is from sub-health center up to township hospitals, including private health care sector. OEHD also developed Rural Sanitation and Hygiene Policy and now still editing from related organizations.

According to WHO, air pollution is a growing concern globally. Air pollutants can be classified as primary or secondary. Primary pollutants are directly emitted from a process such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. Secondary pollutants are not emitted directly, they form in the air when primary pollutants react. Air pollution is associated with respiratory and cardiovascular diseases. Approximately 6.5 million population were premature deaths about the ambient and indoor combination effects of air pollution in every year. That is largely as the result of increased mortality from stroke, heart disease, chronic obstructive pulmonary disease, lung cancer and acute respiratory infection. More than 80% of people living in urban areas especially in low and middle income countries were exposed to contaminants in ambient levels above the WHO guideline.

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Annually, the total 3 million populations were death as a result of exposure to ambient air pollution and indoor exposure to smoke from dirty cook stoves and fuels were 4.3 million. In Myanmar 2017, The World Bank estimated more than 45000 death about air pollution. Moreover, early life of aged 5 to 14 years were particulate matter pollution is the leading risk factor of death among all risk factors. Yangon, is the largest city in Myanmar, the primary source of air pollution is traffic, diesel, generators, construction, power plants, factories, burning of waste and agricultural practices. The air quality changes from season to season markedly increased when the winter passes and reaches a peak in the middle of summer, during the February-April.

Occupational and Environmental Health Division (OEHD) under the Department of Public Health (DOPH), Ministry of Health in Myanmar is currently carrying out indoor and ambient air quality monitoring activities with aim to reduce health problems resulting from air pollution supported by WHO. OEHD conducted indoor air quality monitoring survey at selected townships in Myanmar in 2017. Total 57 houses from the rural areas of 4 townships were selected central dry region. The survey included monitoring of parameters related to indoor air quality namely, total suspended particulate matter, PM2.5, carbon monoxide and carbon dioxide. OEHD regularly monitor ambient air quality at Nay Pyi Taw and Yangon office twice per week (total dust, PM10, SO_2 and NO_2) and send the air quality data to WHO every year to estimate on the health risks due to exposure to household and ambient air pollution. OEHD developed surveillance system for air pollution and its health impact and monitored the environmental health problem among the children. Since project-related activities may directly, indirectly and even cumulatively change community exposures to environmental-based health risks, so to ensure safeguarding and promoting community health and safety in infrastructure development. OEHD is at present movements on the process of the national Health Impact Assessment (HIA) guideline.

In addition, our country is facing considerable challenges in the area of waste management including health care waste management (HCWM). OEHD is conducting to ensure a policy including standard operating procedure (SOP) and guidelines on health care waste management (HCWM) in Myanmar under the World Bank supported. OEHD is currently receiving the monthly reports about the poisoning cases from all public hospitals in Myanmar with collaboration of medical care service department. Moreover, OEHD has toxicological and environmental health laboratory attached to Yangon sub-office and perform some investigations of poison cases admitted to the poisoning treatment center, New Yangon General Hospital (NYGH). On the other hand, OEHD promote mercury free health care sector since 2013.

Myanmar has a tropical climate with three seasons: a hot summer season in March and April, rainy season from May to October and a cool winter season from November to February. It is highly vulnerable to climate change. Climate change leading to rainfall pattern variation may significantly increase the risk of flooding, rising temperatures and drought, together with increased risk of cyclones and strong winds. Moreover, Health impact on the body the incidence of vector-borne diseases and food and water insecurity are expected to increase in our country. The major mechanism behind climate change is the increased "greenhouse effect". The six main greenhouse gases are Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O) or laughing gas, chlorofluorocarbons (CFCs) and Ozone(O_3). Carbon dioxide and Nitrous oxide are mainly released the burning of fossil fuels. CFCs and similar substances are used chidfly as refrigerants, air conditioners as propellants in aerosols and in the production of foam plastic.

Carbon dioxide and Nitrous oxide are mainly released the burning of fossil fuels. CFCs and similar substances are used chidfly as refrigerants, air conditioners as propellants in aerosols and in the production of foam plastic. Ozone(O_3) generated via a series of chemical reactions involving Nitrogen Oxides (NOx), Carbon Monoxide (CO), and Volatile Organic Compound (VOC). The ozone precursors are produced mainly by the transport and industrial sectors.

Climate changes are Impact on human health such as heat stroke affecting mainly children and elderly, increase in respiratory diseases. cardio-vascular illnesses, vector-borne diseases, contaminated water (water-borne) and to unsafe food (food-borne). Intense weather events (cyclones, storms) cause Loss of life, injuries, life-long handicaps. damaged public health infrastructure such as health centers, hospitals and clinics.

The Government of the Republic of the Union of Myanmar has responded to these environmental challenges by adopting new National Environmental Policy with the aim of mainstreaming environmental considerations into economic and social development. National Environmental Policy's Vision is a clean environment, with healthy and functioning ecosystems, that ensures inclusive development and welling for all people in Myanmar. National Environmental Policy's Mission is to establish national environmental policy principles for guiding environmental protection and sustainable development and for mainstreaming environmental considerations into all policies, laws, regulations, plans, strategies, programmes and projects in Myanmar. National Environmental Policy's Principles is committed to putting into action through guiding framework for achieving sustainable development goals for a clean environment and healthy, functioning ecosystems; sustainable economic and social development and mainstreaming of environmental protection and management. The Ministry of Agriculture, Livestock and Irrigation carried out some climate-changes related measures such as adjusting cropping systems, using stress resistant plant varieties and maximising water use and efficiency.

OEHD is recommended for personal action “A to Z” tips on what YOU can do NOW, to help reduce the adverse health impacts from climate change. These are (1) Act Now!, (2) Buy energy efficient appliance. (3) Calculate your personal carbon footprint. (4) Debate, discuss, and distribute leaflets and posters on climate change and environmental health issues. (5) Enjoy the sun! (6) Fit solar panels on the roof of your home. (7) Go Green! (8) Halve your emissions by moving your air conditioner thermostat up by 5 degrees Celsius in summer. (9) Involve your family, friends, children and neighbors! (10) Join an environmental group (11) Lamps; replace the bulbs you use most with compact fluorescent lamps (12) Minimize the use of toxic chemicals. (13) Network with specialized agencies, non-profit organizations and engaged communities. (14) Offset your carbon footprint. There are many cost-effective energy saving and carbon reducing steps anyone can take (15) Plant trees; tree planting (16) Quit using plastic bags (17) Recycle, repair and reuse materials (18) Tips, tricks and ideas for sustainable living (18) Save paper; Print on both sides of the paper (19) Turn off televisions, videos, stereos and computers (20) Use less energy, and conserve more of it! Do not waste water-close your tap while brushing your teeth, and while soaping clothes, body or dishes (21) Value wastes! Do not dump your home wastes everywhere (22) Write letters about the health impacts of climate change to the local newspapers (23) Xpress your concerns on environmental health issues and solutions and stay informed.

In 2018-2019, the work plan of OEHD in relation to climate change activities supported by WHO. These activities included (a) Advocacy seminar for health adaption on climate change (b) Development of a national strategy for climate change and its health impact (c) Development of the National Health Adaption Plan for Climate Change (d) Development of SOP for managing the climate sensitive diseases (e) Provision of training on climate change models and risk assessment to public health staffs (f) Awareness raising among the community on health impacts due to climate change (g) Creation of the integrated surveillance database system for climate change and health issue.

Our country, Myanmar is need to enhance the education, science and technology sectors. These are pivotal for a significant role in formal education, professional development and awareness raising to build a climate smart society, sustainable green growth and adaptation. Moreover, our country also needs to strengthen institutional capacities to ensure that timely manner, satisfying people's aspirations.

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Environmental Health Issues in Nepal: An Overview

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Country Profile

Nepal, located in the midst of the Himalayas, is a landlocked country. It shares borders with China to the north and India to the south, east, and west. It has a population of 29.2 million and with a human development index of 0.579, it ranks 146th among 193 nations and territories. The country has a diverse terrain ranging from fertile plains, sub alpine forested hill to high Himalayas. In fact, Nepal is a home to eight of the world's ten largest mountains, including Mount Everest, the highest peak on the planet.

Nepal faces various environmental health issues ranging from water pollution, hygiene and sanitation, climate change, soil contamination, solid waste management, etc. However, issues related to air pollution, water pollution, municipal waste management and climate change stands out as the most significant environmental health challenges, endangering the well-being of its people and the viability of the ecosystems.

1. Air Pollution and Nepal

1.1 Status of Air Pollution in Nepal

Nepal’s air quality is considered among the worst in South Asia. According to a recent report by BreathLife, a partnership campaign of WHO, UN Environment, World Bank and Climate and Clean Air Coalition, a total of 37,399 deaths in Nepal are caused annually due to air pollution.

The country faces a significant burden of both indoor and ambient air pollution. Rapid urbanization coupled with increasing number of vehicles running in poorly maintained roads, concentration of industries in urban areas, uncontrolled waste management practices and human-induced forest fires are the primary drivers of ambient air pollution. For instance, brick kilns (40%), motor vehicles (37%) and biomass/garbage burning (22%) have all been recognized as the substantial sources of black carbon in the Kathmandu, the capital city. Whereas, the use of solid biomass fuels such as wood, cow-dung, and agricultural residues as source of energy for cooking and heating purposes particularly in the poorly ventilated houses is the primary source of indoor air pollution in rural Nepal.

Further, Nepal's geographical features, with its valleys and mountainous terrain, exacerbate air pollution, particularly during the winter months, by trapping pollutants and creating stagnant air masses. Even when the local emissions are modest, such meteorological conditions and temperature inversions contribute to the formation of haze and smog, further deteriorating air quality. For instance, the bowl-shaped Kathmandu valley covers three districts (including Kathmandu, the capital city) stands very high in particulate matter pollution with levels even five times more than the acceptable guidelines. Similarly, Lumbini, a birth place of Lord Buddha in southern Nepal, is a UNESCO (United Nations Educational, Scientific and Cultural Organization) world heritage site and a touristic destination site also has the degraded state of air quality. A study conducted in 2017 had observed that the 24h average PM2.5 and PM10 concentrations exceeded the World Health Organization guideline very frequently (94% and 85% of the sampled period, respectively), inferring substantial health risks for the residents and visitors in the region. These two instances of urban areas air pollution in Nepal reflect the broader picture of urban air pollution in Nepal.

Most of the districts in Nepal also had a high burden of indoor air pollution. The majority of Nepalese residents in rural areas suffers from indoor air pollution since they rely on biomass fuel for cooking and heating. Such crude fuel emits pollutants like carbon monoxide, sulfur oxide, particles, and volatile organic compounds, all of which are responsible to produce different disease and illness in human.

Furthermore, Nepal is exposed to the Indo-Gangetic Plain, one of the world's most polluted regions. As a consequence, the country is also vulnerable to transboundary air pollution. However, a detailed assessment of the effects of such pollutants has yet to be done in Nepal.

1.2 Burden of Diseases due to Air Pollution in Nepal

Various studies carried out in Nepal has shown visible impacts of air pollution on human health. A study carried out among traffic police in 2015 found pulmonary functions of traffic police in Kathmandu significantly weakened indicating that the continuous exposure in the urban areas of Nepal would pose serious respiratory problems. Similarly, a study in brick kiln workers in Kathmandu reported being severely affected by the airborne particulate matter.

In 2012, WHO projected that the total number of deaths in Nepal attributable to ambient air pollution was 9943 per 100,000 population. The same study also found Year of Life Lost (YLL) attributable to ambient air pollution was 296,130 YLLs per 100,000 people. Among this, Chronic Obstructive Pulmonary Disease (COPD) was solely responsible for 1770 fatalities and 37,949 YLLs per 100,000 people.

Similarly, several studies on rural communities in Nepal that uses solid biomass fuel as a primary source of fuel were found more likely to suffer from respiratory diseases such as Acute Respiratory Infection (ARI), Acute Lower Respiratory Infection (ALRI), pneumonia, asthma, and other lung function deficits. Similarly, persons who used traditional mud stoves and unprocessed biomass reported health issues such as eye irritation, difficulties in breathing, and a productive cough. The majority of research conducted on indoor pollution and health implications in rural Nepalese communities revealed that increased exposure to traditional biomass burning methods had a direct influence on the health of children and women.

1.3 Government Initiatives against Air Pollution

The country has adopted a variety of efforts to address air pollution concerns. In order to minimize reliance on fossil fuels and reduce air pollution related with energy production and use, Nepal has implemented a number of regulations and incentives to encourage the use of renewable energy sources (water, solar, wind). It has also adopted National Ambient Air Quality Standards, which aim to restrict the concentration of contaminants in the atmosphere and protect human health. Nepal has also implemented vehicle emission limits to control emissions from motor vehicles and prevent air pollution. The government has launched subsidies in the electric vehicles and has implemented programs to promote cleaner technologies, such as improved cookstoves and biogas systems, to reduce indoor air pollution from traditional biomass fuels.

2. Water Pollution and Nepal

2.1 Drinking Water Supply Coverage

Despite the abundant water resources in Nepal, it has the poorest drinking water and sanitation coverage in South Asia. Majority of the population still lacks basic drinking water supply service, depending on unimproved and unreliable sources of water such as pond, unprotected well, and stream. Water supply is inadequate, unreliable, and low quality even in the capital city of Nepal.

Data from the Department of Water Supply and Sewerage Management in 2019 reported, merely 51.69% of the population have piped water coverage and the remaining 48.31% are relying on un-piped locally and privately managed systems like private tube wells. Even if Nepal achieved the water supply related MDG goals, when analyzed by facility type, non-piped coverage has increased from 36% in 2000 to 44% in 2017. Similarly, when analyzed by the service level, during these last two decades, safely managed improved water supply sources have just decreased from 24% to only 18%.

2.2 Drinking Water Quality

The quality of drinking water from surface as well as ground water sources is of growing concern in urban Nepal. Water quality mainly that of the accessible water bodies to the urban centers and dense human settlement are highly polluted.

Arsenic (As) contamination is a major issue of current drinking water supply systems using groundwater and has become one of the major environmental health management issues especially in the plain region, i.e., in the Terai districts, where the population density is very high. The Terai inhabitants still use hand tube and dug wells (with hand held pumps that are bored at shallow to medium depth) for their daily water requirements, including drinking water. The National Sanitation Steering Committee (NSSC), with the help of many other organizations, had carried out arsenic blanket test in 25 districts of Nepal by analyzing 737,009 groundwater samples. The study found that 23% of the samples were containing 10–50μg/L of As, while 8% of the samples contained more than 50μg/L of As. Similarly, 52% sample collected from deep groundwater of Kathmandu valley was found exceeding the WHO standard for As.

Numerous cases of water-borne diseases like cholera, dysentery, typhoid, and skin diseases are reported every year. In Kathmandu valley, continuously pumped groundwater leads to surpassing the natural recharge resulting in depletion of ground water table.

3. Municipal Waste Management:

Effective management of Municipal Solid Waste (MSW) is one of the major environmental health issues being faced in several urban centers in Nepal. The country generates around 1,435 tons of municipal waste daily with the highest amount being generated from the Kathmandu valley which accounts for 620 tons per day. These wastes consist of a large percentage of organic wastes (66%), plastics (12%), paper products (9%), metals (3%), and miscellaneous materials (5%). The complex waste composition and ineffective handling techniques had challenged majority of municipalities of Nepal for efficient solid waste management.

In majority of municipalities there were no adequate and efficient systems for the management, storage, collection, and transportation of solid waste. In fact, the municipalities have not been able to collect and dispose of the enormous quantity of waste being generated. Most of the municipalities are found giving preferences only on collecting the waste and dumping it rather than going for the other viable scientific and environment-friendly way of waste management practices. Furthermore, out of the total waste generated less than 50% is only collected. The major challenges of municipal waste management include unavailability of sanitary landfill sites, lack of composting facilities, and absence of source segregation and efficient collection system at local level.

In Nepal, the federal laws and policies provide a framework to set up municipal laws and regulations and to establish and implement the MSW management system. In contrary, there are no special policies formulated at local and regional levels even after the restructuring of the federal government. Thus, there require an appropriate policy and strategic framework for three tiers of government viz., federal, provincial, and local to address the issue in a more sustainable manner.

4. Climate Change and Nepal

Nepal's share of global greenhouse gas emissions is minimum, accounting for approximately only 0.027 percent of total emissions. However, when it comes to climate change vulnerability, the country ranked fourth place in the global climate risk index 2019. Nepal is experiencing more unpredictable weather phenomenon and extreme weather events frequently in the forms of heavy rainfalls, floods, landslides, frequent and severe droughts, and heat waves, due to climate change.

4.1 Trend of Climate Change

Data on temperature trend from 1975 to 2005 indicated an annual increase of 0.06oC, while mean rainfall has shown a notable decrease averaging 3.7 mm (3.2%) per month per decade. Looking ahead, under different climate change scenarios for Nepal, mean annual temperatures are expected to rise by 1.3-3.8°C by the 2060s and 1.8-5.8°C by the 2090s. Additionally, there's a projected annual precipitation reduction ranging from 10 to 20% across the country.

4.2 Impacts of climate change

Nepal’s varied topography, fragile geological structure, sensitive ecosystems, and variety of microclimate zones and climates makes the country extremely vulnerable to the effects of climate change.

Impacts of Climate Change on Environment

Droughts and increasing temperatures are already causing various water sources to dry up. Further, the impacts of climate change on the snows and glaciers of Nepal's Himalayas, the water tower of South Asia, are distinctly visible. Between 1977 and 2010, there has been rapid melting of ice cap with a notable 29 percent decrease (equivalent to 129 km3) in the total ice reserve of the Himalayas, accompanied by a significant upward shift in the permanent snowline. If this trend persists, it could have profound consequences for the water resources of the ten major river basins originating in the Hindu Kush Himalayan region.

The rapid melting of ice has also led to the formation of numerous new glacier lakes and is expected to increase the occurrences of Glacier Lake Outburst Floods (GLOFs) resulting in catastrophic flooding downstream, while glaciers recede at an average rate of 38 km2 per year, the number of glacier lakes has surged by 11 percent. Further, 204 glacial lakes are deemed potentially hazardous, susceptible to bursting and triggering a GLOF.

Nepal is estimated to experience around 500 disaster events annually, which have been increasing as the changing climate affects natural hazard frequency and intensity. Climate change is anticipated to exacerbate inland flooding, putting an estimated 200,000 additional people at risk of river floods each year. Data from 1971–2007 show that floods tend to affect a large number of people (over 4.6 million), but cause fewer deaths (per event), yet cumulatively cause a significant number of lost lives (3,902 people in 1971–2007).

Impact of Climate Change on Human Health

Climate change is likely to result in a shift in vector-borne diseases in the highlands of Nepal. Currently, vector-borne diseases such as Dengue Fever, Japanese Encephalitis, Malaria, and Visceral Leishmaniasis are endemic to the lowland Terai and hills of Nepal. However, as climate change is shifting and expanding the vectors of these diseases into highland areas, the population at risk is expected to rise.

Similarly, water-borne diseases are also likely to increase with the increasing water stress accompanied by the lack of safe drinking water and basic sanitation in the region.

Deaths and morbidity associated with extreme and erratic weather are also likely to increase. Climate change have differentiated impacts which is more severe for women, poor and marginalized groups.

4.3 Major Responses against Climate Change

Nepal has taken decisive actions in terms of formulating legal frameworks and policies to address the effects of climate change. With the ratification of the Paris Agreement in 2015, Nepal has intensified its climate goals to implement pathways for low-carbon, climate-resilient development. During the 26th Conference of Parties (COP 26) in United Nations Framework Convention on Climate Change meeting, the Government of Nepal made commitments, including pledging to i) achieve a cumulative 'net zero carbon' status by 2045 and transition to carbon negativity thereafter; ii) halt deforestation and increase forest coverage to 45% by 2030; and iii) ensure the protection of all vulnerable populations from the impacts of climate change by 2030.

5. Conclusion

Nepal is committed to promoting environmental health by formulation and implementation of several policies, regulations, Acts and action plans. In fact, Article 30.1 of the Constitution of Nepal 2015 entitled every citizen to have the right to live in a clean and healthy environment, and it shall be the duty of the State to create a clean and healthy environment by adopting necessary policies and laws, and by making the public aware of the importance of environmental conservation. Further, Article 30.2 has also made provision for the victim to have the right to obtain compensation, in accordance with law, for any damage caused by environmental pollution or degradation.

In recent years, Nepal has made considerable progress in addressing environmental health issues of the country. However, much work is yet to be done. Despite possessing a variety of environmental regulations and legislation, its enforcement is rather weak. There could be a variety of underlying causes, including inconsistencies in policies and priorities, low stakeholder engagement, limited financial or human resources, weak institutional capacity, limited coordination and inter-sectoral collaboration among line ministries, low public awareness and participation, etc. The government must continue to prioritize environmental health issues and allocate resources to ensure that policies are properly implemented and enforced. Additionally, education and awareness campaigns should be prioritized to ensure that the public understands the importance of environmental health and approaches to protect it.

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Health Impacts of Environmental Issues in Pakistan: Challenges and Solutions

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1. Introduction

Pakistan, a rapidly developing lower-middle-income country in South Asia, is divided into three major geographic regions: the Baluchistan plateau, the Indus River plain, and the northern highlands. Its climate varies from temperate to tropical and arid, with seasonal monsoons. Despite minimal global greenhouse gas emissions, Pakistan is highly vulnerable to climate change and extreme weather events. Challenges include melting glaciers in the Himalayas, threatening river flows, increased monsoon severity, cyclones, and saline intrusion, all posing significant risks to the environment and economy.

2. Pakistan's Socioeconomic Snapshot

In 2017, Pakistan had a population of 241.5 million, growing at a rate of 2.1%, with 37.9% urbanization. The population was youthful, with 13.3% under five and 4.5% over 65. Despite a large population, GDP per capita was low at $1,275 USD. Healthcare expenditure was 2.8% of GDP, indicating some investment, but income distribution was skewed, with the lowest 20% receiving only 9.6% of income. The Human Development Index (HDI) was 0.537, showing slight improvement, yet disparities in income distribution and healthcare accessibility persisted, highlighting challenges amidst growth potential.

3. Pakistan's Climate Resilience Strategy: Vision 2025 and INDC Integration

Pakistan faces additional health risks such as expanding vector-borne diseases and heat stress due to climate change. Its national development strategy, 'Pakistan Vision 2025', prioritizes sustainable development alongside economic growth and social inclusion. Recognizing the urgency, Pakistan's Intended Nationally Determined Contributions (INDC) emphasizes integrating climate change actions into policies across government levels and prioritizing adaptation in vulnerable sectors.

3.1 Climate Change Impact Projections for Pakistan: Temperature Rise and Weather Extremes

Climate change poses significant risks to Pakistan, leading to more frequent and intense climate hazards and extreme weather events such as heat waves, heavy rainfall, and droughts. Under a high emissions scenario, mean annual temperature is projected to increase by approximately 6.1°C by the year 2100, compared to a rise of about 1.7°C under a rapid emissions decrease. This increase in temperature would lead to a substantial rise in the number of days experiencing warm spells, from about 150 days in 1990 to around 350 days on average in 2100 under high emissions but limited to about 185 days under rapid emissions decrease.

3.2 Urgent Need for Climate Change Mitigation in Pakistan: Impact on Precipitation Events and Dry Spells

Frequency of very heavy precipitation events, potentially leading to floods, is expected to rise by about 4 days on average by 2100 under high emissions, with some models suggesting even greater increases. Similarly, the longest dry spells are projected to increase slightly under high emissions, from approximately 115 days to about 120 days on average, with considerable year-to-year variability.

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However, these risks are significantly reduced if emissions decrease rapidly, with no change in the average length of dry spells. These projections highlight the urgent need for mitigation efforts to curb emissions and mitigate the adverse impacts of climate change in Pakistan.

3.3 Climate Change and Human Health: Understanding the Threats and Imperative for Action

Weather and climate have a profound impact on human health, and climate change poses a significant threat to exacerbating existing health challenges. This includes increasing the risk of deaths from extreme weather events, as well as the prevalence of cardiovascular and respiratory diseases, infectious diseases, and malnutrition. Climate change also undermines essential aspects of society such as water and food supplies, infrastructure, health systems, and social protection systems, further compounding health risks. Therefore, addressing climate change is crucial not only for environmental sustainability but also for safeguarding human health and well-being.

3.3.1 Addressing Malaria Risk in Pakistan: Role of Emission Reduction and Population Management

By 2070, under a high emissions scenario, approximately 46 million people are projected to be at risk of malaria annually. However, if global emissions decrease rapidly, this number could be reduced significantly to about 12 million annually by 2070. It's important to note that population growth can also contribute to increases in the population at risk, particularly in areas where malaria presence remains static in the future. Therefore, alongside emission reduction efforts, effective strategies for managing population growth and implementing robust malaria prevention and control measures are essential to mitigate the risks associated with this disease.

3.3.2 Climate Change and Diarrheal Mortality in Children: Projections and Urgent Interventions

In 2008, there were an estimated 94,700 diarrheal deaths in children under 15 years old. Under a high emissions scenario, it is projected that diarrheal deaths attributable to climate change in this age group will constitute approximately 11.7% of the over 48,200 diarrheal deaths projected in 2030. Despite an expected decline in overall diarrheal deaths to about 21,200 by 2050, the proportion of deaths attributable to climate change is forecasted to increase to approximately 17.0%. These projections underscore the significant impact of climate change on diarrheal mortality among children, necessitating proactive measures to mitigate its effects and improve public health outcomes.

3.3.3 Mitigating Heat-Related Deaths in the Elderly: Importance of Emission Reduction Efforts

Under a high emissions scenario, it is projected that heat-related deaths in the elderly (65+ years) will increase significantly to about 63 deaths per 100,000 by 2080. This is in contrast to the estimated baseline of under 10 deaths per 100,000 annually between 1961 and 1990. However, a rapid reduction in global emissions could mitigate this increase, limiting heat-related deaths in the elderly to about 17 deaths per 100,000 by 2080. These projections highlight the critical importance of emission reduction efforts in addressing the health impacts of climate change, particularly among vulnerable populations such as the elderly.

3.3.4 Climate Change and Food Security: Challenges and Urgent Action Needed

Climate change, characterized by higher temperatures, land and water scarcity, flooding, drought, and displacement, poses significant challenges to agricultural production and food systems. These impacts disproportionately affect vulnerable populations, increasing the risk of hunger and food insecurity. Vulnerable groups are particularly susceptible to deterioration into food and nutrition crises when exposed to extreme climate events. Without substantial efforts to enhance climate resilience, global hunger and malnutrition risks could escalate by up to 20 percent by 2050.

3.3.5 Addressing Childhood Malnutrition in Pakistan: Climate Change Impacts and 8Solutions

In Pakistan, the prevalence of stunting in children under the age of 5 was 45.0% in 2013. Additionally, the prevalence of underweight children and wasting in children under 5 was 31.6% and 10.5%, respectively, in the same year. These statistics underscore the urgent need for effective measures to address both the immediate and long-term impacts of climate change on food security and nutrition in vulnerable populations.

4. Current Exposures and Health Risks Due to Air Pollution

Air pollution has emerged as one of the most significant global health risks, resulting in approximately seven million deaths annually. This highlights a crucial opportunity to advocate for policies that not only mitigate climate change on a global scale but also yield substantial and immediate health benefits at the local level. By addressing these interconnected issues, policymakers can effectively safeguard both the climate and public health, promoting a healthier and more sustainable future for all.

4.1 The Health Impacts of Outdoor and Household Air Pollution: Vulnerabilities and Consequences

Outdoor air pollution poses direct and severe health consequences, particularly through fine particles that can deeply penetrate the respiratory tract, leading to increased mortality from respiratory infections, lung cancer, and cardiovascular disease. Women and children are particularly vulnerable to health issues arising from household air pollution, which contributes to a higher proportion of deaths from diseases such as ischemic heart disease, stroke, lung cancer, and chronic obstructive pulmonary disease (COPD) compared to men.

4.2 Air Pollution in Pakistan: Sources, Impacts, and Public Health Concerns

In Pakistan, sources of air pollution include vehicle emissions, industrial activities, brick kilns (with approximately 19,000 operating in the country), and thermal power plants. It is estimated that every year, around 135,000 deaths occur due to ambient air pollution in Pakistan. Gases emitted from these sources, including nitrous oxides, carbon monoxide, Sulphur oxides, and ozone, pose significant health risks. Furthermore, household air pollution contributes to a substantial number of child deaths, with 52% of an estimated 68,200 child deaths due to acute lower respiratory infections attributed to it in Pakistan. Cities such as Lahore, Karachi, Peshawar, and Rawalpindi have annual mean PM 2.5 levels that exceed the World Health Organization's guideline value of 10 µg/m3. These findings underscore the urgent need for comprehensive measures to address air pollution in Pakistan, safeguarding public health and well-being.

5. Noise Pollution in Pakistan: Threats to Public Health and Urgent Measures Needed

One of the most pressing issues faced by residents of major cities in Pakistan, such as Karachi (Metropolitan area), is noise pollution, which has reached critical levels according to a study by Samad in 2017. Average noise values recorded in different regions of the country are concerning, with Karachi registering at 76.5 dB, Islamabad at 72.5 dB, and Peshawar at 86 dB. According to the World Health Organization, noise levels above 70 dB are considered painful and irritating.

5.1 Health Impacts of Noise Pollution: Risks and Consequences for Public Well-being

Prolonged exposure to high levels of noise can have serious health implications. Chronic exposure to noise pollution has been linked to permanent hearing damage and an increased risk of hypertension, heart attacks, and other cardiovascular issues. Additionally, it can disrupt sleep patterns, leading to insomnia and other sleep disorders, and contribute to mental health issues such as anxiety and depression.

Moreover, noise pollution may impair cognitive function, particularly in children. The results underscore the pressing necessity for implementing effective measures to alleviate noise pollution in urban areas of Pakistan, ensuring the safeguarding of public health and well-being.

6. Addressing the Health Impacts of Environmental Issues: Challenges and Solutions

Addressing the health impacts of environmental issues presents both challenges and solutions.

6.1 Collaborative Solutions for Mitigating Climate Change and Promoting Public Health

Limiting the temperature increase to 2ºC requires a concerted effort to reduce global CO2-energy emissions from 5.2 to 1.6 tons per capita. In countries like Pakistan, where the agriculture and manufacturing/construction sectors are significant contributors to emissions, tackling this issue becomes even more pressing. However, collaboration across sectors, including healthcare, offers a promising avenue for identifying and implementing policies aimed at stabilizing emissions. By working together, we can not only mitigate climate change but also yield substantial health benefits for communities worldwide.

6.2 Safeguarding Water Quality: Proactive Measures for Health and Ecosystem Protection

The health impacts of environmental issues related to water quality present significant challenges that require proactive solutions. Water pollution, stemming from the release of domestic, municipal, and industrial waste, as well as contamination from pesticides and fertilizers, poses a dual threat to public health and aquatic ecosystems. Moreover, the consumption of untreated drinking water exacerbates health hazards. To address these challenges effectively, various actions can be implemented. These include the institutionalization of a pollution charge system to incentivize industries to reduce pollutants, the installation of additional treatment plants to improve wastewater treatment, and the regulation of untreated domestic wastewater drainage into open streams, especially in areas with existing sewage systems. Furthermore, promoting organic farming practices, along with better application methods for pesticides and fertilizers, can help reduce the runoff of harmful chemicals into water bodies. By adopting these measures, we can combat water pollution and safeguard both human health and aquatic environments.

6.3 Sustainable Transport Solutions

The environmental impacts of transport encompass various facets, each with significant implications for public health and the ecosystem. Annually, transport-related injuries result in 1.2 million deaths. Moreover, the transport sector is a substantial emitter of greenhouse gases, accounting for approximately 14% of global carbon emissions, totaling 7.0 gigatons of carbon dioxide equivalent (GtCO2e). However, there are promising avenues for mitigating these impacts. Encouraging a shift towards sustainable modes of transport such as walking, cycling, and public transit could alleviate illnesses associated with inactivity, air pollution, and noise exposure.

6.4 Transitioning to Clean Energy for Household Air Pollution Mitigation

Addressing the health impacts of household air pollution presents a significant challenge, with 4.3 million premature deaths annually attributed to stroke, heart disease, respiratory issues, and childhood pneumonia. Transitioning to cleaner energy sources such as LPG, biogas, and electricity offers a promising solution to mitigate these dire consequences.

6.5 Transitioning from Coal: Overcoming Challenges for Health and Sustainability

The health impacts stemming from coal combustion pose a formidable challenge, with poor air quality contributing to diseases such as cancer. Transitioning away from coal towards electricity and lower carbon sources, including renewables, offers a viable solution to alleviate these health concerns and bolster economic productivity.

6.6 Sustainable Solutions for Greenhouse Gas Emissions in Healthcare Systems

The greenhouse gas emissions generated by healthcare systems present a pressing environmental challenge, attributed to procurement processes and energy inefficiencies. Implementing low-carbon energy solutions such as solar and wind power, alongside energy-efficient measures, emerges as a viable strategy to substantially curb emissions and enhance energy reliability. This transition holds particular importance in regions with limited electricity access or during emergency situations.

7. Addressing Global Carbon Emissions: The Imperative for Collective Action and Data-Driven Strategies

The escalation of global carbon emissions by 80% between 1970 and 2010 signifies a critical environmental challenge that persists today. Collective action is imperative to address this issue, yet the urgency and potential for reducing greenhouse gas emissions differ significantly among nations. Access to information regarding the contributions of various sectors, including energy, manufacturing, transport, and agriculture, empowers decision-makers to pinpoint the most substantial opportunities for cross-sector collaboration. By leveraging this data, stakeholders can develop targeted strategies to safeguard public health and combat climate change effectively.

8. Pakistan's Climate Change Commitments and Policy Frameworks: A Timeline of Actions

Pakistan has demonstrated its commitment to addressing climate change through various milestones:

- In 1994, it joined the United Nations Framework Convention on Climate Change (UNFCCC), acknowledging the worldwide urgency of tackling climate issues.
- By ratifying the Kyoto Protocol in 2005, Pakistan affirmed its readiness to undertake specific actions to curb greenhouse gas emissions.
- The introduction of Pakistan's National Climate Change Policy in 2012 outlined clear strategies and objectives for both adapting to climate impacts and reducing emissions.
- Pakistan implemented the Framework for Implementation of Climate Change Policy 2014 to 2030, ensuring a systematic approach to executing and monitoring climate initiatives.
- The launch of Pakistan Vision 2025 provided a comprehensive roadmap for economic prosperity, social equity, and sustainable development. This vision aligns with Pakistan's INDC submitted in 2015, illustrating its dedication to sustainable progress within the global climate arena.
- These milestones reflect Pakistan's dedication to addressing climate change and fostering sustainable development through both national and international cooperation.

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Environmental Health Issues in Sri Lanka

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Abstract:

Sri Lanka, known for its natural beauty and rich biodiversity, grapples with a myriad of environmental health challenges that significantly impact the well-being of its population. This report presents a comprehensive analysis of the various environmental health issues prevalent in Sri Lanka, examining their causes, impacts, and potential solutions.

The report examines existing policies, regulations, and initiatives aimed at mitigating environmental health risks in Sri Lanka. It also explores innovative approaches and best practices from other regions that could be adapted and implemented to improve environmental sustainability and public health outcomes in the country.

1. Introduction

Sri Lanka is an island nation located in South Asia with a total area of 65,610 sq. kilometers. It lies in the Indian Ocean off the coast of India and is located between latitudes 5°55′ and 9°51′ N and longitudes 79°41′ and 81°53′ E. Sri Lanka is characterized by tropical weather, with an estimated population of 22.18 million in 2022, where one-third of them are children. Sri Lanka has a literacy rate of 92%.

The Sri Lankan economy relies primarily on tourism, tea export, clothing, rice, and other agricultural production. At present Sri Lanka is facing an economic crisis, where the poverty level nearly doubled from its pre-pandemic level to about 25.6% of the population living below the USD 3.65 poverty line.

Sri Lanka is facing numerous environmental health challenges stemming from population growth, rapid urbanization, industrialization, and natural resource exploitation. Changes in some technology, equipment and consumer goods have led to health hazards of chemical, physical and biological in nature.

2. Air Pollution and Health Impacts:

60% of the air pollution in Sri Lanka is caused due to vehicular emissions, and other contributors are industries, biomass and waste burning.

2.1. Vehicular Emissions: Increasing urbanization and the growing number of vehicles contribute to high levels of air pollutants such as particulate matter (PM), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), leading to respiratory ailments such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD).

2.2. *Industrial Emissions:* Emissions from industries, particularly those burning fossil fuels, release pollutants into the atmosphere, further deteriorating air quality and impacting respiratory health.

2.3. *Indoor Air Pollution:* The use of biomass fuels for cooking in rural areas results in indoor air pollution, exposing individuals to harmful pollutants and increasing the prevalence of respiratory diseases.

Air pollution is a major environmental health hazard to children, largely due to hazardous industries, vehicular emissions and traditional cooking stoves. The health of children living in urban households and attending schools in cities is adversely affected by air pollution.

Usage of polythene and plastic toys, utensils, bags, lunch sheets and other daily essentials leads to over usage improper waste management and open burning. This emits dioxins, which are carcinogens, hormone disruptors, and which can be transferred to the fetus via the placenta.

In rural areas, the burning of agricultural waste and certain agro-forestry activities have also led to air pollution. Indoor air pollution (IAP) remains a large threat as 66% of the population uses biomass for cooking. The use of inefficient stoves and biomass, the poor ventilation and absence of chimneys, contribute to IAP. Other indoor air pollutants such as tobacco smoke, volatile organic compounds, asbestos, pesticides, kerosene, mercury, mosquito coils and biological pollutants also prevail. Biological pollutants, such as dust mites, droppings and urine from pets, insects and rodents, pollen from indoor plants and outdoor air, and fungi, including molds in poorly maintained buildings, can trigger asthma or cause allergic reactions and infections among children inhabiting these environments.

At present Sri Lanka is facing a transboundary movement of Air Pollution from India. At certain periods the air pollution rises to very harmful levels.

The annual mean value of PM 2.5 in Sri Lanka is 24 $\mu g/m^3$ where WHO standard for annual mean value is 5 $\mu g/m^3$ (WHO)

Respiratory disease is the 6^{th} cause of hospitalization in 2020 (Annual Health Bulletin-2020) where total admissions were 224,646. A fraction of this admissions are caused due to air pollution, 45% of deaths from stroke and ischemic heart diseases are caused due to air pollution

69% of the population does not have clean fuels and technology for cooking, which contributes to air pollution and air pollution induced diseases. (WHO)

In order to address these issues, vehicular emission testing programmes have been strengthened, and Environmental Protection License are being issued to Industries to minimize industrial emissions. In addition cleaner cooking fuels, energy efficient cooking stoves and renewable energy are promoted to minimize indoor and outdoor air pollution.

3. *Water Pollution and Waterborne Diseases:*

Access to clean and safe drinking water is essential for public health, yet water contamination is a prevalent issue in Sri Lanka. Pollution from agricultural runoff, industrial discharge, and inadequate sanitation infrastructure contributes to the contamination of surface and groundwater sources. The Ministry of Health, in collaboration with the Ministry of Water Supply and Drainage, conducts water quality assessments and implements water treatment initiatives to address this issue.

Sri Lanka faces significant challenges regarding water pollution, leading to an increase in waterborne diseases and the emergence of conditions like Blue Baby Syndrome, primarily due to the following factors:

3.1. Industrial and Agricultural Runoff: Haphazard/ illegal discharge from industries and excessive use of agrochemicals result in the contamination of water bodies with pollutants such as heavy metals and nitrates, contributing to water pollution.

3.2. Inadequate Sanitation: Poor sanitation infrastructure and improper waste disposal practices lead to the contamination of surface and groundwater sources, increasing the risk of waterborne diseases like cholera, typhoid, and dysentery.

3.3. Urbanization: Rapid urbanization and inadequate wastewater treatment facilities in urban areas lead to the discharge of untreated sewage into water bodies, further exacerbating water pollution.

3.4. Blue Baby Syndrome: The presence of high nitrate levels in drinking water sources poses a risk of methemoglobinemia, commonly known as Blue Baby Syndrome, particularly affecting infants and young children.

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Freshwater pollution: being a country having an average rainfall of 2000 mm throughout the year, there are 103 natural river basins in Sri Lanka. In addition, there are a significant number of reservoirs in the country including ancient and recently constructed water bodies. The total area allocated for these reservoirs is 169,941 hectares. The groundwater resources in the country are estimated at about 7,800 million m3 per year and it is estimated that about 72 percent of the rural population relies on groundwater for domestic use. It is difficult to comprehend the trend of water quality in public water bodies in the country due to insufficient data.

However, the Sri Lanka National Water Development Report (2006) pointed out a variety of quality concerns in Sri Lanka, including contamination by nitrate and bacteria in underground and surface waters mainly due to poor sanitation and untreated wastewater or insufficient wastewater treatment, toxic chemicals (partly including POPs and POPs like chemicals and hazardous pesticides) from industrial and agricultural activities, and eutrophication in lakes/reservoirs (UNESCO and MoAIMD 2006).

The contamination of groundwater used as drinking water with heavy metals such as Cadmium may contributed to the causation of Chronic Kidney Disease of unknown etiology (CKDu) which is critical in certain areas of the country.

Furthermore, plastic is released into surface waters and causes serious pollution and impact to biota. In addition to inland water, such pollution reaches coastal water and even the open sea. In particular, plastic debris contaminates the surface water and today plastic is several times more prevalent in seawater compared to plankton. Due to accumulation of POPs in such plastic debris and the ingestion of macro and microplastics by fish and marine mammals, can lead to the transfer of POPs to wildlife and the food chain.

At present Sri Lanka releases 938.42MT of plastic into the environment as waste per day. Out of this, only 4%-7% is recycled. Primary and secondary micro plastics are a major threat to the environment and health. Microplastics are found in air, water, soil and in food.

The recent Xpress Pearl disaster, which is known as the World's most severe plastic disaster, created a long-lasting challenge on the coastal and marine environments by discharging 11000 MT of polymers, 8000 MT of chemicals, 3400 MT of metals and several other contaminants. Beaches and turtle nesting sites across the area were affected by the deposition of plastic nurdles. Significant chronic effects of the disaster are expected due to bioaccumulation at higher trophic levels. Microplastics will be heavily found in seafood and salt in the future, which can aggravate heart diseases, by blocking the arteries and will face with many more health impacts including the unborn children.

53% of the population does not have safe drinking water and 61% of the deaths from diarrhea are caused by unsafe drinking water, sanitation and inadequate personnel hygiene. The government is in the process of expanding the drinking water supply schemes, including desalinization facilities to improve water supply for drinking purposes.

Water pollution due to industrial discharges too have an impact on health, which can cause allergies, cancer etc. Therefore industries are regulated with waste water discharge standards,

4. *Climate Change:*

Sri Lanka is vulnerable to the impacts of climate change, including rising temperatures, changing precipitation patterns, and extreme weather events namely floods and droughts. Sri Lanka is among the first 10 countries in the Climate Risk Index, though the contribution to greenhouse gas emission is negligible (0.03%).

These phenomena exacerbate existing environmental health risks, such as vector-borne diseases, food and water insecurity, and natural disasters. The Ministry of Mahaweli Development and Environment, in coordination with other agencies, formulates climate adaptation and mitigation strategies to minimize the adverse effects of climate change on public health and the environment.

Climate change poses significant health risks in Sri Lanka, manifesting in various ways:

4.1. Vector-Borne Diseases: Changes in temperature and precipitation patterns create favorable conditions for the proliferation of disease vectors such as mosquitoes, leading to increased transmission of vector-borne diseases like dengue fever, malaria, and chikungunya.

4.2. Heat Stress and Heat Stroke: Rising temperatures exacerbate heat stress, particularly among vulnerable populations, increasing the incidence of heat-related illnesses and mortality rates. High temperatures and inadequate hydration, exacerbated by climate change, may contribute to kidney damage among vulnerable populations.

4.3. Flood-Related Health Risks: Flooding events, exacerbated by climate change, result in water contamination, displacement, and the spread of waterborne diseases, posing significant health risks to affected communities.

4.4. Drought-Induced Nutrition Issues: Prolonged droughts affect agricultural productivity, leading to food insecurity and malnutrition, particularly among rural populations.

As per the predictions, number of warm spell days in 2050 under high emission scenario is 219 days and deaths are expected to be 10 times more in 2050 than in 1961-1990.

In order to mitigate climate change many actions have been taken by the relevant stakeholders. E.g. Promotion of renewable energy etc. Implementation of the Mitigation Action Plan and the Adaptation Action plan are some of them. It is expected to reach net zero status by 2050.

5. Radiation: The Atomic Energy Authority and Atomic Energy Board are taking action to minimize radiation impacts. 01 out of 100,000 die from melanoma and other cancers every year (WHO).

6. Occupational Health: 67% of informal employment is found in the employment sector; they get exposed to pollutants and work in risk environments. Awareness is being created and health facilities are strengthened to address these issues.

Department of Labor is in the process of strengthening the occupational health services in the country in collaboration with relevant stakeholders.

7. Exposure to Chemicals:

In rural areas, chemicals accounted for 30.2% of acute poisonings, with kerosene oil being the most common cause, followed by paracetamol. More than 80% of agricultural workers in the country work in the informal sector with limited personal protective equipment use, while getting exposed to pesticides, where usage is increasing.

At present less than 1 out of 100,000 children under 05 die from poisoning every year. 60% of the chemical event are attended at present.

National Policy on Management of Chemicals has been developed and approved by the Cabinet of Ministers. Therefore action is being taken to minimize chemical exposures. Industries and healthcare institutions are regulated through a licening scheme to minimize chemical incidents. National Poison Information Centre provides 24-hour healthcare service.

7.1. Health Impacts Due to Heavy Metals:

Contamination of soil and water with heavy metals poses significant health risks, including:

7.1.1. Cancers: Prolonged exposure to heavy metals such as mercury, lead, and arsenic increases the risk of various cancers, including liver, kidney, and lung cancer.

7.1.2. Neurological Disorders: Heavy metal exposure is associated with neurological disorders such as developmental delays, cognitive impairments, and neurodegenerative diseases.

7.1.3. Chronic Kidney Disease of Unknown Etiology (CKDu):

CKDu is a prevalent health issue in Sri Lanka, particularly affecting agricultural communities in dry zone areas. The exact causes of CKDu remain unclear, but potential factors include:

7.1.4. Agricultural Chemicals: Prolonged exposure to agrochemicals, including fertilizers and pesticides, may contribute to the development of CKDu among agricultural workers.

7.1.5. Water Contamination: Contamination of drinking water sources with heavy metals and agrochemical residues is suspected to play a role in the prevalence of CKDu.

8. Mismanagement of general and hazardous waste:

Sri Lanka generates around 7,000 Metric Tons (MT) of waste daily, of which only half of the total is collected. 60% (4,200 MT) of waste is generated from the Western Province, posing severe pollution risks; to the environment, communities and those who handle waste.

There are about 300 open dump sites island wide causing pollution of ground and surface water contamination. Open burning of waste is widespread in the country and emits toxic gases and pollutants, including releases of unintentional POPs, PAHs and other pollutants. It contributes to atmospheric pollution (PM10, PM2.5, Dioxin/UPOPs, PAHs, carbon black) and is known to cause serious health issues.

Sri Lanka generates 282,980 T of solid hazardous waste per year, and 14,008,667 m3 of liquid waste per year. Out of this quantity around 35% - 40% is disposed at a cement plant, as this plant accepts selected categories of hazardous waste only. The remaining waste is expected to be safely stored, exported or neutralized, which is not taking place at a satisfactory level, due to the lack of suitable infrastructure and funds.

Disposal of municipal waste and open burning Haphazard disposal of municipal waste can be observed in main municipality areas such as Colombo, Moratuwa, Kandy, Matale, Gampaha and Negombo. Among other reasons, lack of proper landfilling facilities or recycling methods associated with poor attitude of the household are the main causes of the problem. Many drainage channels in urban areas are blocked due to nondegradable waste such as polythene and plastics that slow water-flow and provides breeding places for disease vectors such as rats and mosquitoes.

Haphazard disposal of waste Sri Lanka is developing with increasing population that is generating wastes in the urban centers and rural villages. These generations are now exceeding the capacities of the respective local authorities. Further, general waste collected from the hospitals and industries are sometimes mixed with hazardous waste. Government and private entities have already taken many initiatives to address this issue. However, this condition still remains as one of the main environmental issues in the country.

9. Health Impacts Due to Mismanagement of Waste:

Improper management of solid and hazardous waste contributes to various health issues:

9.1. Skin Diseases: Contact with contaminated waste materials can lead to skin Infections and dermatological conditions.

9.2. Vector-Borne Diseases: Improper disposal of waste creates breeding grounds for disease vectors such as mosquitoes, increasing the risk of diseases like dengue and filariasis. 60 % of the dengue mosquito breeding sites are found to be receptacles found in waste streams. Polluted water bodies facilitates breeding of mosquitos causing Filariasis.

9.3 Healthcare-Associated Infections: Inadequate management of healthcare waste results in the spread of nosocomial infections and the risk of needle stick injuries among healthcare workers.

9.4 Cancer: Exposure to toxic pollutants from waste, including carcinogens such as asbestos and certain chemicals, increases the risk of cancer among affected populations.

9.5 Fly Born Diseases: Food waste promotes fly breeding and fly borne diseases, fungal infections,

9.6 Rabies: Breeding of stray dogs due to haphazard disposal of food waste can increases the incidence of rabies.

9.7 Mental Stress: Communities living near waste dumps face bad odour and face social issues as some would not like to visit them or associate them.

Inadequate waste management practices pose environmental and health risk in Sri Lanka. Improper disposal of solid waste leads to pollution of land, water bodies, and air, The Ministry of Provincial & Local Government along with local authorities, are responsible for waste management and implementing strategies for waste reduction, recycling, and proper disposal.

Over the years healthcare waste management has improved, but improper management has led to spread of infectious diseases and nosocomial diseases. Improper management of hospital sewage leads many disease outbreaks including Anti-Microbial Resistance (AMR) conditions. It is expected to map AMR risk areas take action accordingly to reduce the risk.

Many initiatives have been taken to improve management of waste e.g. waste of Colombo Municipal Council is treated safely through a waste to energy plant, state of the art sanitary landfills and healthcare waste treatment facilities are established. But they are not adequate to address the issues island wide.

10. Current Status of Health Management:

Although Sri Lanka enjoys a remarkably high life expectancy for a developing country, control of vector borne diseases need attention. Countrywide surveillance on vector borne diseases such as Dengue, Malaria, Filariasis, and Japanese Encephalitis is in operation successfully in Sri Lanka. As one of the strategies for controlling the spread of vector borne diseases the authorities Revised National Implementation Plan under the Stockholm Convention on Persistent Organic Pollutants in Sri Lanka – 2015, 20 are compelled to use insecticides on a regular basis.

Sri Lanka's health system today is facing challenges to sustain its performance due to rapidly changing demographics and epidemiological transitions. The cost of health care is increasing due to the sharp rise in noncommunicable diseases (NCD) linked to lifestyles and rapidly aging population. Pollution too causes NCDs. The national health system needs to further improve to expand services to vulnerable populations with lagging health indicators. In addition, there is increased threat of emerging and resurging infectious diseases linked to environmental factors and increased cross-border migration. The status quo of the health system is inadequately prepared to deal with these evolving challenges without significant reorientation and further improvements.

11. Conclusion:

Environmental health issues in Sri Lanka are multifaceted and require integrated approaches involving governmental ministries, agencies, civil society organizations, and the private sector. Efforts to address air pollution, water contamination, waste management, deforestation, and climate change impacts are crucial for safeguarding public health and promoting sustainable development in Sri Lanka.

In conclusion, addressing these environmental health challenges in Sri Lanka requires concerted efforts from government agencies, civil society organizations, the private sector and the community to implement effective policies and interventions aimed at mitigating pollution, improving sanitation infrastructure, promoting sustainable practices, and enhancing public health surveillance and healthcare services.

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Environmental Health Issues in Thailand

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Environmental health issues in Thailand pose significant challenges, with major concerns including $PM_{2.5}$ pollution, climate change effects, and industrial chemical explosions. $PM_{2.5}$, fine particulate matter, severely threatens public health. In urban areas, high levels from vehicle emissions and industrial activities cause respiratory and cardiovascular diseases, increasing hospital admissions and mortality rates. In rural areas, agricultural burning contributes to $PM_{2.5}$ pollution, leading to similar health issues. Climate change exacerbates these problems, as rising temperatures result in heat stress and related illnesses. For example, food delivery drivers in Thailand face serious health and safety concerns from prolonged heat exposure, causing heat stress, dehydration, heat exhaustion, and heat stroke, which impair their efficiency and safety.

Industrial activities further compound these issues, with chemical explosions in factories, particularly in 2024, posing acute and chronic health risks to workers and nearby communities. The release of hazardous substances during such incidents can cause immediate injuries, long-term illnesses, and environmental contamination. Addressing these environmental health issues requires comprehensive policies and interventions. Reducing $PM_{2.5}$ levels through stricter emissions standards, promoting renewable energy, and enhancing urban air quality monitoring are critical. Mitigation strategies for climate change, including measures to protect vulnerable populations from heat stress and ensuring robust food delivery systems, are essential. Additionally, stringent safety regulations and emergency preparedness plans are necessary to prevent and respond to industrial chemical explosions. A coordinated approach involving government agencies, industry stakeholders, and public awareness campaigns is vital to improving environmental health outcomes in Thailand. By tackling these pressing issues, Thailand can safeguard public health and enhance resilience against future environmental challenges.

S1-11

Preliminary Assessment of Personal Exposure to Ultrafine Particles Across Multiple Microenvironments in Phnom Penh

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This preliminary study assessed personal exposure to ultrafine particles (UFP) in Phnom Penh, Cambodia, focusing on varying micro-environments. Utilizing a handheld UFP counter, we continuously monitored particle size, concentration, and Lung Deposited Surface Area (LDSA). GPS data from a GPS watch were integrated with UFP measurements and analyzed using geospatial software to produce detailed spatial exposure maps. Findings indicated significant disparities in UFP exposure, with motorcyclists facing higher levels, particularly on Russian Federation Blvd during peak traffic. Although indoor environments generally offered lower exposure, specific activities led to temporary spikes in UFP concentrations. Notably, exposure was higher on weekdays compared to weekends. Despite its limitations, such as a small sample size, the study provided crucial insights into the spatial variability of UFP exposure, emphasizing the need for further research and targeted mitigation strategies to protect public health in urban settings.

Keywords: Ultrafine particles (UFP); Personal exposure; Geospatial analysis; Urban pollution; Transportation modes

Session 2:

Air Pollution: Solution for the Transboundary Haze Issue in the Mekong Subregion

ASEAN Haze Free Roadmap 2023-2030 and Its Monitoring & Evaluation

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Transboundary haze is a widespread air pollution and smog issue that affects Southeast Asia (SEA), and is primarily caused by land clearing and peatland fires. It causes severe environmental degradation, health hazards, and economic disruptions. The Association of Southeast Asian Nations (ASEAN) Member States (AMS) have taken several measures to tackle transboundary haze and promote regional cooperation to address the problem effectively. The key measures include the signing and ratification of the ASEAN Agreement on Transboundary Haze Pollution (AATHP), adoption of the Roadmap on ASEAN Cooperation towards Transboundary Haze Pollution Control with Means of Implementation (2016-2020) and the ASEAN Peatland Management Strategy 2006-2020 (APMS), which specifically provided a framework of action to address peatland related haze issues.

A review commissioned to evaluate progress and experiences of the First (2016-2020) Roadmap implementation to achieve the vision of haze-free ASEAN has led to the development of a new roadmap. In August 2023, the Second Roadmap on ASEAN Cooperation towards Transboundary Haze Pollution Control with Means of Implementation (Haze-Free Roadmap) (2023-2030) was adopted during the 18th Meeting of the Committee Under the Conference of the Parties to ASEAN Agreement on Transboundary Haze Pollution (COM-18) and 18th Meeting of the Conference of the Parties to ASEAN Agreement on Transboundary Haze Pollution (COP-18). It consists of nine mutually reinforcing strategies.

The Second Roadmap synthesizes lessons learned, best practices, and innovative approaches, charting a course that amalgamates regional aspirations with actionable steps toward a haze-free future. Drawing on the First Roadmap and considering the need to increase stakeholders' awareness of the Second Roadmap, it is crucial to provide a platform for relevant actors to exchange of views on the Roadmap's various strategies and actions for addressing transboundary haze issues. Such platforms enable relevant stakeholders to better understand differing perspectives on aspects such as policy and regulatory framework and law enforcement, sustainable land management practices, community engagement, innovative technologies etc. This can serve as the basis for creating effective policies and implementation.

To promote public awareness of the Second Roadmap and encourage participation of stakeholders in the implementation of strategies and actions, the ASEAN Secretariat together with the Measurable Action for Haze-Free Sustainable Land Management in Southeast Asia (MAHFSA) Programme, hosted a hybrid launch of the Second Roadmap and policy dialogue on 21 February 2024 in Jakarta. The policy dialogue discussed the inextricably linked strategies and actions with exploring the roles of both the public and private sectors in combating haze. The outcome of the dialogue will shed light to the Roadmap monitoring and evaluation, and will be presented during the Symposium in Bangkok.

S2-2

Using Air Quality Assessment for Health Protection in Thailand

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Air quality assessment and management involves many stakeholders in any given country. These may include ministries of the environment, public health, and others. It is important for collection and analysis of data to be done in a systematic manner to create data that can drive policies for protecting human health. One of the difficulties in air pollution research, particularly in human studies, is the disconnect between exposure and disease observation. In this study, 3 air pollutants of interest ($PM_{2.5}$, PM_{10} and ozone) were chosen and air quality monitoring data was assessed, focusing on data from 3 provinces from different geographical regions in Thailand with different expected exposure scenarios: Chiang Mai, Saraburi and Songkhla. Health effects data was also assessed from hospitals in those areas for key diseases traditionally associated with exposure to air pollution. Relative risks associated with exposures to the 3 air pollutants were calculated from air quality and health monitoring data in the three provinces over a period of 5 years. Disability-adjusted life years (DALY) were also calculated for each of the provinces as a sum of the DALYs for each of the disease classifications. Finally, an estimate of the economic benefits from various levels of environmental management, i.e., reduction in exposure concentrations to the World Health Organization (WHO) Interim Targets 1, 2 or 3, or to below the WHO Guidelines values, was calculated for all three provinces. For Chiang Mai province, the economic benefits associated with reduction of $PM_{2.5}$ and PM_{10} levels ranged from 1.86 (Interim Target 1) - 2.18 (WHO Guideline values) billion THB; for Saraburi province, the economic benefits ranged from 2.54 - 2.73 billion, respectively; and for Song Khla province, they ranged from 1.48 - 1.30 billion THB, respectively. With these potential economic benefits, what is needed is a cost analysis to determine at which remediated exposure levels the benefits would significantly outweigh the management/implementation costs. The bottom line, though, is that systematically collected environmental monitoring and health data has the potential to be used for the development of national health protection plans and policies.

Major Air Pollution Issues and Health Impacts in Vietnam

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1. Introduction:

Air quality is always of concern of the entire society. In recent years, the air pollution in Vietnam continues to rise at an alarming rate, and affects economy and people's quality of life. Air pollution is among the most important public health issues in large cities such as Hanoi and Ho Chi Minh City.

Sources of air pollution in urban areas are determined mainly from transportation, construction and industrial production activities. In rural areas, air pollution is localized in industrial clusters and craft villages, or temporary due to the open burning of agricultural residues. In addition, other problems such as photochemical smog, transboundary air pollution, and acid rain also have significant impacts on air quality in Vietnam.

2. Current status and air quality evolution

The current status of air quality in Vietnam is reviewed and evaluated in three main areas: urban, industrial, and craft villages and rural areas.

According to the Vietnam State of Environment Report 2021: Air Quality (*MONR [1], 2022*), air quality in large cities and some industrially developed urban areas happens to be polluted at some periods of the year, when particulate matter (PM) remains the biggest concern. Dust concentrations ($PM_{2.5}$, PM_{10}, TSP) in some zones are at high thresholds, especially at traffic axes, main roads or surrounding industrial parks. In large cities, motor vehicles are the dominant emission source of CO, VOC, HC, SO_2, NOx.... According to the Ho Chi Minh City's State of Environment Report 2021 (*HCMC DONRE[2] , 2021*), mobile source contributes about 75% of $PM_{2.5}$ emission. In Hanoi, road transport is also the largest emitter accounting for 50 - 70% of $PM_{2.5}$ emission (*Hanoi AQMP[3] , 2023*).

In industrial areas, the current prominent problem is also dust pollution. TSP concentrations at many monitoring points around industrial parks exceed the prescribed threshold, even many times higher than the 24-hour average and mean annual limits of national standard (QCVN 05:2013/BTNMT). The monitored concentrations of TSP, PM_{10}, and $PM_{2.5}$ around industrial parks in the Northern region are higher than concentrations in the Central and Southern regions, due to different production types, applied technologies, used fuels and materials, and geological locations of industrial facilities. Specific industries such as mining, coal-fired power, and cement are emitting large amounts of particulate matters into the air.

In craft villages, air pollution continues at high level, especially in craft villages that recycle metal, paper, plastic, and construction materials... In most of the rural areas, the ambient air quality maintains at good level and have no signs of pollution (concentrations of most parameters comply with QCVN 05:2013/BTNMT). However, during harvest times the open burning of biomass still exist in some rural villages effecting air quality in their regions.

The impacts of climatic factors create the air quality evolution corresponding to the seasons of the year. In the Northern region, dust pollution is mostly observed at high

[1] *Ministry of Natural Resources and Environment*
[2] *Ho Chi Minh City Department of Natural Resources and Environment*
[3] *Hanoi Air Quality Management Plan*

level in the dry winter months, while dust pollution in the Southern region decreases significantly in the rainy months and increases in the dry season. Other problems such as transboundary pollution or acid deposition have certain manifestations and affects the air quality in Vietnam. Similar to countries in Southeast Asia, the problem of photochemical smog is increasingly evident in large cities like Hanoi and Ho Chi Minh City.

3. Health effects of air pollution

$PM_{2.5}$, CO, SO_2, NO_x pollution is an urgent issue that has received significant attention due to its adverse effects on global human health and socio-economic development, including Vietnam. According to the 2019 Global Burden of Disease Study (*IMHE*[4], *2019*), air pollution ranks the 5th among the leading risk factors for death and disability in Vietnam, after high blood pressure, diabetes, smoking and unhealthy diet. Air pollution increases the risk of acute lower respiratory tract infections, causing asthma, cough, rhinitis, pharyngitis, bronchitis, pneumonia and even lung cancer; cardiovascular disease, stroke and shortening of human life expectancy.

A study conducted in Ho Chi Minh city shows that 1,397 deaths of cardiovascular, lung cancer, and IHD illnesses were attributed to SO_2, NO_2, and $PM_{2.5}$ exposures (*Assoc. Prof. Dr. Ho Quoc Bang et al, 2020*). According to research results in Hanoi city, $PM_{2.5}$ pollution increases the disease burden related to hospitalization due to respiratory and cardiovascular illnesses. It is estimated that on average each year, there are about 1,062 additional hospitalizations due to cardiovascular illnesses, and about 2,969 due to respiratory illnesses, equivalent to 1.2% and 2.4% of the total number of hospitalizations of these two groups of diseases, respectively (*University of Public Health*[5] *and University of Technology*[6] *: A study on "Health Impacts of $PM_{2.5}$ Pollution in Hanoi").*

In addition, workers in specific industries such as mining, construction, and production of building materials are often at high risk of occupational diseases such as pneumoconiosis, bronchitis, and noise-induced deafness.

A part from the disease burden and premature death, air pollution also causes economic losses due to medical examination and treatment costs, and indirect costs because of lost working days of patients and caregivers. Estimated loss rate is about 20% of income (*Hanoi AQMP, 2023*).

4. Recommendations for cleaner air quality and better health

- Strengthening the air quality control, monitoring and supervision system to detect emission sources. Applying strict measures to minimize air pollutants at the sources
- Promoting cleaner production technology and the use of renewable energy in the manufacturing and transportation sectors. Deploying environmentally friendly transportation systems, especially in big cities
- Increasing the knowledge base and understanding of the health effects of air pollution not only for citizens but also for policy makers
- Establishing emergency response measures in case the Air Quality Index (AQI) values at the health risks, especially for the sensitive groups
- Improving capacity of the health sector to collaborate with other sectors at all levels to deal with health hazards associated with air pollution through capacity building, guidance and national action planning
- Strengthening international cooperation in scientific research on the health effects of air pollution and the solutions to minimize its impacts on public health.

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S2-4

CLEAR Sky Strategy-Joint Plan of Implementation

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During the Trilateral Consultation on Transboundary Haze Pollution held on April 7, 2023, among the Leaders of the Lao People's Democratic Republic, the Republic of the Union of Myanmar, and the Kingdom of Thailand, the three nations acknowledged the prevailing transboundary haze pollution in the region. They exchanged insights and strategies aimed at effectively addressing this issue. Recognizing the significance of collaborative endeavors, they affirmed their commitment to preventing, mitigating, and managing haze pollution across borders. CLEAR Sky Strategy was introduced by Thailand during the consultation.

This commitment aligns with established frameworks such as the ASEAN Agreement on Transboundary Haze Pollution (AATHP), the Roadmap on ASEAN Cooperation Towards Transboundary Haze Pollution Control with Means of Implementation, and the Chiang Rai Plan of Action 2017. In addition to these frameworks, they have crafted a Joint Plan of Action, which complements existing mechanisms by prioritizing practical cooperation among the three nations.

To realize the CLEAR Sky Strategy, the Lao People's Democratic Republic, the Republic of the Union of Myanmar, and the Kingdom of Thailand pledge to collaborate in various key areas. These include implementing corresponding activities aimed at haze prevention, mitigation, and management. They commit to conducting their cooperation in line with their international obligations and domestic laws, ensuring equal benefit and opportunity for all involved parties.

Keywords: CLEAR Sky, Transboundary haze, Pollution

S2-5

Integrated Approaches for Air Quality Management & Climate Change in Southeast Asia – Preparation of a Regional Approach for Southeast Asia

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Executive summary

The main purpose of the report is to offer concrete recommendations to Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) that would support the adoption and spread of integrated solutions to air pollution, climate change, health, and other development priorities in Southeast Asia. With that overarching objective in mind, the report proposes the creation of multi-tiered platform that would help strengthen the above integration at the subregional level.

Initially, the proposed platform would focus on the five countries in Southeast Asia's Mekong Subregion: namely, Cambodia, Lao PDR, Philippines, Thailand, and Vietnam. These countries are selected because they have ongoing activities concentrating on integration between air pollution and climate change (focused on short-lived climate pollutants (SLCPs)) as partners in the Climate and Clean Air Coalition (CCAC). They are also chosen because a subset of countries will be easier to coordinate, creating a subregional base that can be expanded to other parts of Southeast Asia.

The proposed platform would be designed to integrate work on air pollution and climate change not only within but between levels of decision making.

• At the global and regional levels, the platform would contribute to ongoing efforts to provide a concrete example of how to operationalize integration air pollution and climate change for the following initiatives:

1. The United Nations Environmental Assembly (UNEA) (including an upcoming resolution on air quality);
2. The United Nations Environmental United Nations Environment Programme (i.e. Asia Pacific Clean Air Partnership (APCAP));
3. The United Nations Environmental Economic and Social Commission on Asia and Pacific (ESCAP) (Regional Action Programme on Air Pollution)); and
4. The East Asia Acid Deposition Network (EANET).

• At the sub-regional level, the platform would focus on strengthening the implementation the ASEAN Haze Free Roadmap 2023-2030 under the auspices of the ASEAN Secretariat. In this case, the platform would focus would be on supporting and sharing experiences on the following scientific and capacity building activities:

1. Air pollutant and greenhouse gas inventories and regional/global database management;
2. Satellites, drones, and other modern technologies for air quality and climate change monitoring;
3. Airshed mapping and air pollution/climate change source identification and appropriate controls;
4. (Sub)regional guidelines on integrating air quality management and climate change mitigation and adaptation;

5. Assessment of the state of transboundary haze pollution in the Mekong subregion;
6. Examining ways to estimate burned areas and improve evaluations of the sources of haze;
7. Developing air quality forecast for early warning of future levels of air pollution and health impacts; and
8. Establishing a link between urban airsheds and transboundary air pollution.

• At the national and local levels, the platform would also contribute to the above global, regional and subregional initiatives, while aiming to directly influence policy and implementation. In this case, the platform would be designed to support the following knowledge sharing and capacity building activities.

1. Improved institutional arrangements (agencies, laws, regulations, strategies, plans) for an integrated approach to air quality and climate change;
2. Information, knowledge management, and communication techniques to foster greater integration of air quality and climate change; and
3. Local and national capacity building best practices and lessons learned (including from other regions)
4. Management of agricultural residues through a circular economy approach and value chain creation;
5. Strengthening inspection and maintenance of in-use vehicles;
6. Illustrating the advantage of dual technologies such as vehicles; and
7. Promoting solar for schools and education on air pollution, climate change and health nexus.

A select group of activities and projects would potentially received initial funding during the second stage of this GIZ project. However, to help strengthen and then scale these projects, GIZ could also use platform would also aim to strengthen links with climate and other funding mechanisms. Toward that end, efforts would be made to access resources from climate finance flowing from the Green Climate Fund; Asian Development Bank (Future Climate Fund and Blue Skies Programme), Joint Crediting Mechanism (JCM), and Article 6.4 Mechanism (under the Paris Agreement). GIZ could also make a concerted effort to work with are other countries to coordinate Official Development Assistance (ODA) for air quality management in Southeast Asia, including the United States, France, Korea, Japan, and China. Improved donor coordination is needed to ensure the most effective uses of limited funding supports.

S2-6

Experience and Lessons Learnt in Addressing Fires and Haze in ASEAN

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INTRODUCTION AND PROBLEM STATEMENT

The seasonal issues of transboundary haze pollution in ASEAN region have been persisting since the remarkable challenge in 1997-1998, that resulted the signing of the ASEAN Agreement on Transboundary Haze Pollution (AATHP) in 2002. In order to sufficiently coordinate and share update by the ASEAN Member States (AMS) on the haze issue, there has been institutional arrangement of Technical Working Group (TWG) and Ministerial Steering Committee (MSC) Meetings that separate southern and northern subregions. The fires and haze pollution from southern region is mostly originated from peatland, meanwhile most of the fire issues from northern region is mainly from crop and agriculture expansion (such as rice, maize and sugar cane) and waste disposal through burning method. This haze issue has severe impact to livelihood of people in Southeast Asia including the loss of agriculture production and tourism revenue. In conjunction to the issues, ASEAN has produced numerous guiding documents which to guide AMS in tackling the haze related issues, including the ASEAN Haze-Free Roadmap and ASEAN Peatland Management Strategy (APMS), ASEAN Socio-Cultural Blueprint and relevant national action plans. Global Environment Centre (GEC) under Measurable Action for Haze-Free Sustainable Land Management in Southeast Asia (MAHFSA)[1] Programme has been working together with AMS and ASEAN Secretariat on multi-stakeholder approach including community-based fire and haze prevention in the region. This paper is to address the lesson and experience in dealing with fire on peatland.

METHODOLOGY AND DISCUSSION

The main approach used by GEC in combating peatland fire through community-based peatland protection and rehabilitation is mainly from a guiding principle called 5R Approach, that includes: (i) **Rewetting**, (ii) **Reduction of Fire Risk**, (iii) **Revegetation**, (iv) **Revitalisation**, and (v) **Reporting**. In addition to the principle, GEC adds one element which is **Resourcing** to get financial mobilization to support initiatives and programmes in ASEAN.

Rewetting

GEC's approach in restoring degraded peatland landscapes in Malaysia and Indonesia is through rewetting. The water level of the landscape needs to be significantly improved in order to restore the ecological function of peatland. This mechanism directly contributes to carbon emission reduction and improves carbon sink and storage from the atmosphere. The suitable water level for good forest is near surface up to 20cm below ground, whilst for oil palm plantations, it is suggested to maintain water level at 40-60cm below ground. Construction of canal blocks or weirs is often depending on site condition and availability of materials. The blocks or weirs could be manually done by community through their traditional knowledge, and could be supported with some machinery works if happen to collaborate with oil palm plantations.

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[1] MAHFSA webpage at ASEAN Haze Portal https://hazeportal.asean.org/programmes/mahfsa/

Reduction of Fire Risk

A community-based fire prevention programme has been initiated by GEC in encouraging participation of local community in promoting forest stewardship in Malaysia, in particular community groups engaged in Selangor, Pahang and Sabah. The programme includes formation of community patrolling and monitoring team to safeguard their community area and nearby forest boundary. The programme consists of installation of Fire Danger Rating System (FDRS) boards and Water Level Markers (WLM) within village and identified fire risk areas that neighbouring the forested area. The committed community members will perform a regular monitoring and patrolling activities especially during dry season. They will be guided by information of FDRS that changes daily based on open sources from Malaysian Meteorological Department (MET Malaysia). Currently, the information is disseminated online through WhatsApp group and site-check action taken will be based on colour code of the FDRS. Table 1 shows the action per each colour code.

Table 1: FDRS colour code and suggested actions on field for community fire patrollers

FDRS	Suggested Actions to be undertaken on the Field
BLUE (LOW)	1. Establish a patrol group 2. Conduct regular monitoring
GREEN (MODERATE)	1. Monitor buffer area (3 times a week) and inform about the upcoming drought and the use of fire to clear land for agricultural use. 2. Monitor the use of fire for agriculture and hunting.
YELLOW (HIGH)	1. Increase awareness of the use of fire to villagers and private companies in collaboration with government agencies and NGOs. 2. Inform stakeholders about the high risk of fire. Make sure the stakeholders are aware of the dangers of peat and land fires. 3. Monitor and patrol all open burning activities in forest and land by villagers and private companies. 4. Inform the District Forestry Officer and relevant workers to smoke in safe areas and extinguish fire spots altogether. 5. Perform more frequent monitoring i.e. twice a day.
RED (EXTREME)	1. Increase awareness of the use of fire to villagers and private companies in collaboration with government agencies and NGOs. 2. Inform stakeholders about very high fire risk. 3. Monitor and patrol all open burning activities in forest and buffer areas by villagers and private companies. 4. Inform the District Forestry Officer and relevant workers to smoke in safe areas and extinguish fire spots altogether. 5. Perform more frequent monitoring i.e. twice a day. 6. Develop a preparedness plan, for example: Be prepared with an emergency response team to put out the fire, and sufficient equipment and human resources for fire suppression and control.

Revegetation

In line with restoration effort, GEC has been collaborating with communities and various stakeholders including private and government agencies on planting activities. Selection of tree species that is indigenous, resilient and fast growing will be prioritised, depending on site conditions. The saplings are prepared by community in their backyard tree nurseries to support the planting and maintenance of the planting plots to encourage sustainability.

S2-6

Revitalisation

GEC has been promoting Good Agricultural Practices (GAP) to community in order to improve their livelihoods aligns with the effort in reducing risk of fires, also to improve soil nutrients and crops productivity. The mechanism is supporting local authority and agencies including certification schemes such as Malaysian Good Agricultural Practice (MyGAP) and Malaysian Sustainable Palm Oil (MSPO). Some community groups have been trained to sustainably use their land in reducing their contribution in ecosystem destruction. In addition, a paludiculture practice in Indonesia is also one of Best Management Practices (BMP) plant suitable water resistance species on rewet/rewetted disturbed peatland. Aside, ecotourism serves a very good platform for community to generate income especially through water-based activities include river cruise. GEC has produced some guidelines in supporting the BMPs implementation with stakeholders.

Reporting

The effective monitoring, reporting and dissemination of warning is critical to be addressed especially when it is related to fire indication. Through the MAHFSA Programme, GEC had conducted a Capacity Development Needs and Gap Analysis (CDNGA)[2] with input from the AMS and ASEAN Secretariat, as well as inputs from the designated national and regional monitoring centres. With the findings and recommendations from the CDNGA, and through the MAHFSA Programme, GEC had assisted the Government of Cambodia to establish an integrated Air Quality Monitoring System (AQMS) data platform to compile data from many different AQMS devices and models supported by multiple sources. GEC also supports the Government of Lao PDR in setting up a network of 10 cost-effective air quality monitoring devices. In addition, GEC has been working with the designated regional monitoring centres in revamping the ASEAN Fire Alert PhoneApp Tools to have better User Interface and specific localised to the users. The information will be extracted from mandated agencies from the data providers that are all open sources, to deliver the information easily to alert users with warning notification if detected nearby hotspot.

RESOURCING

The ASEAN Investment Framework for Haze-Free Sustainable Land Management (AIF-HFSLM)[3] strategically designed to attract diverse spectrum of green investments aimed at advancing forest and land management, and preventing fire and transboundary smoke haze in the ASEAN region. Rooted in a vision to address the complex challenge of the transboundary haze matter and promote sustainable land practices, the AIF serves as a transformative platform to link and leverage finance from private sector, Government and international community with a target of US$1.5 billion over the period of 2023 – 2030. The AIF has been developed to attract diverse investments, fostering collaboration that encompasses the prevention of land and peatland forest fires, biodiversity conservation and the integrated approach to ensure sustainable land practices. Comprising five objectives supported by different sectors such as sustainable commodity and agriculture, engagement of indigenous peoples and local communities (IPLCs), sustainable forest and land management, sustainable finance frameworks, as well as policy and governance enhancement. The AIF unites and required all stakeholders to play specific roles and responsibility in supporting each other for respective interests, that will definitely contribute to the countries' National Determined Contributions (NDCs) pledges and efforts to Global Goals or Sustainable Development Goals (SDGs).

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[2] CDNGA Report https://hazeportal.asean.org/publications/report-on-capacity-development-needs-and-gap-analysis-main-report/; CDNGA Annexes https://hazeportal.asean.org/publications/report-on-capacity-development-needs-and-gap-analysis-annexes/

[3] AIF-HFSLM https://hazeportal.asean.org/action/investment-framework/

In such, the regional level committed and efforts toward ASEAN Haze-Free vision will be achieved with implementation of the APMS 2023-2030, ASEAN Haze-Free Roadmap 2023-2030 guided by the AATHP.

CONCLUSION AND SUMMARY

Fire and haze are critical issues and challenges that need to be addressed by all parties of different sectors. From the past 40 years of haze episodes, workable strategies and high commitments are needed to build on existing frameworks to resolve critical economic, social and environmental challenges. Aside, the need to identify the root causes and drivers of fire and haze in order to address core problems that has been haunted the region. Countries also need to find economically viable solutions such as incentives/disincentives, secure resources from multi-sectoral bodies, engage multiple stakeholders include relevant government agencies (both administrative and technical), private sector and local communities, for collaborative and integrated actions to develop effective and timely monitoring and dissemination of resources (tools, manpower and information).

Session 3:

Environmental Pollutants Affecting Health

S3-1

Heath Benefits of Air Pollution Interventions at Population and Individual Levels in China

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Background

Accumulating epidemiological evidence has linked air pollution to various cardiometabolic abnormalities, including elevated blood pressure, deregulation of the autonomic nervous system, abnormal glucose and lipid metabolism, systematic inflammation, and increased blood coagulability. However, the high heterogeneity in the associations between single pollutants and various health outcomes poses a challenge for determining potential effect biomarkers that are appropriate for short-term exposure to air pollution, as well as key pollutants that affect cardiovascular and metabolic health. In reality, people are continually exposed to a mixture of many air pollutants rather than a single pollutant. Given the complex chemical linkages between pollutants and their shared biological pathways that affect health, assessing health effects of air pollutant mixtures using powerful mixture analysis approaches, such as Bayesian kernel machine regression (BKMR), is expected to provide novel insights to address these challenges. Identifying key pollutants in the mixture based on their contribution to the total effect can facilitate the development of targeted and efficient environmental governance strategies.

Obesity is a well-established primary risk factor for various cardiovascular and metabolic diseases. In addition, obese individuals are believed to be more vulnerable to the harmful effects of air pollution. However, a significant proportion of obese individuals are metabolically abnormal, and this susceptibility could be due to the fragile homeostasis mechanism caused by metabolic abnormalities. Metabolically healthy obese (MHO) individuals are an important group to consider, as they have the potential to transition from a sub-clinical state to one that requires medical intervention. A prospective cohort study found that stable MHO individuals did not have an increased risk of cardiovascular disease, while those who progressed to a metabolically unhealthy status had a higher risk. However, the cardiometabolic susceptibility of obese individuals to the broader cardiometabolic effects of air pollution in the context of mixtures and the molecular basis of any linked susceptibility under metabolically healthy conditions are not yet fully understood.

Fatty acids play crucial biological roles as constituents of all cellular membranes, energy stores, and precursors of signaling molecules, and are involved in the development of cardiovascular and metabolic disorders. Omega-3 fatty acid supplements have been reported to provide protection against some of the cardiovascular impacts of particulate matter and ozone (O_3) among healthy adults. Since fatty acids are derived from dietary intake and various metabolic processes, circulating fatty acids are a better proxy for actual body levels. However, the role of circulating fatty acids in the effects of air pollution on cardiometabolic status and their potential link to the susceptibility of the obese population are not well understood.

This panel study aimed to address existing knowledge gaps by recruiting metabolically healthy normal-weight (MH-NW) and metabolically healthy obese (MHO) adults. The study objectives were as follows: (1) to estimate the combined effect of short-term exposure to a mixture of seven air pollutants on blood pressure, glycemic homeostasis, lipid profiles, systematic inflammation and coagulation biomarkers; (2) to identify sensitive outcome variables and key pollutants; (3) to assess the effect of the pollutant mixture on plasma free fatty acid (FFA) patterns identified from twenty-eight FFAs using targeted metabolomics; (4) to investigate the associations between FFA patterns and cardiometabolic biomarkers; and finally (5) to integrate these findings to reveal the potential role of plasma FFA patterns in the cardiometabolic effects of air pollutants.

2 Methods

2.1 Study design and participants

This is a repeated-measure panel study conducted among normal-weight and obese adults aged 18 to 26 years. Normal-weight was defined as a body mass index (BMI) of 18.5-24.0 kg/m^2, and obesity was defined as a BMI of $\geqslant$ 28.0 kg/m^2, according to the cut-off point for the Chinese population. A total of 49 metabolically healthy normal-weight (MH-NW) and 39 metabolically healthy obese (MHO) participants were identified and included in the analysis based on the Adult Treatment Panel-III (ATP-III) criteria, which considered the levels of triglyceride (TG), blood pressure, fasting plasma glucose (FPG), and high-density lipoprotein cholesterol (HDL-C). All participants were college students residing near Peking University Health Science Center (PKU-HSC) with similar educational levels and dietary habits (university canteen), never smoked or drank alcohol, had no diagnosed diseases, and did not take medication including dietary supplements (e.g., vitamin C or fish oil). Participants were divided into 10 groups, each with a similar number of normal-weight and obese subjects, and they followed the same schedule for research visits. Subjects undertook three visits from December 2017 to June 2018 with a median interval of 48 days between two adjacent visits. All participants recorded a time-activity log for one week prior to each visit. All visits avoided the exam season to exclude potential confounding of psychosocial stress. For female participants, visits were also avoided during the menstruation period. The study protocol was approved by the Institutional Review Board of PKU-HSC (IRB number: 00001052–16066), and written informed consent was obtained from each participant.

2.2 Exposure measurements

Hourly concentrations of particles with diameters ≤ 2.5 μm ($PM_{2.5}$), particles with diameters ≤ 10 μm (PM_{10}), O_3, nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO) were obtained from the nearest environmental monitoring station to PKU-HSC (approximately 3 km). Daily average concentrations of $PM_{2.5}$, PM_{10}, NO_2, SO_2, and CO, as well as the maximum 8-hour average O_3 concentration (O_3-8h max), were calculated. Personal exposure levels were estimated based on ambient levels of air pollutants, time-activity logs of participants, and infiltration factors for each pollutant in different seasons in Beijing. Black carbon (BC) was monitored using an aethalometer AE-33 located at PKU-HSC, and all subjects completed a 24h personal BC monitoring using an aethalometer AE51. A calibration coefficient between ambient and personal BC was generated and used to calculate the weighted averages of BC. Daily average temperature and relative humidity (RH) were collected from the National Meteorological Information Center (http://data.cma.cn/).

2.3 Cardiometabolic outcome measures

Blood pressure Trained researchers measured resting blood pressure three times following a standardized procedure. The mean values of the last two measurements of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were used for analysis.

Glucose and lipid parameters Participants were asked to fast overnight, and 13 mL of peripheral blood was collected between 8:00 a.m. and 8:45 a.m. Clinical blood biochemistry was performed to measure the levels of fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). To estimate the total amount of proatherogenic lipoproteins containing apolipoprotein B (apoB), non-HDL-C was calculated by deducting HDL-C from TC. Fasting insulin and C-peptide levels were measured using multiplex laser bead technology. Insulin and C-peptide are products converted from proinsulin and secreted in equal quantities. The homeostasis model assessment of insulin resistance index (HOMA-IR) was calculated.

Systematic inflammation Several major groups of inflammatory indicators were examined in this study. Firstly, inflammatory cell differentials were assessed, including white blood cell (WBC), eosinophil, neutrophil, monocyte, and lymphocyte counts, as well as their proportions. Secondly, leptin, a representative pro-inflammatory adipokine, was measured. Thirdly, neutrophil-related inflammatory factors [myeloperoxidase (MPO) and interleukin-8 (IL-8)] and monocyte/macrophage-related inflammatory factors [monocyte chemotactic protein-1 (MCP-1), macrophage inflammatory protein-1α (MIP-1α), and macrophage inflammatory protein-1β (MIP-1β)] were examined. Lastly, other systematic inflammatory factors, including serum amyloid A (SAA), tumor necrosis factor-α (TNF-α), IL-1β, IL-6, soluble intercellular cell adhesion molecule-1 (sICAM-1), and fractalkine, were also assessed.

Coagulation biomarkers Platelet (PLT) counts and related biomarkers, such as mean platelet volume (MPV), soluble P-selectin (sP-selectin), and soluble CD40 ligand (sCD40L), were measured. Additionally, the platelet aggregation rate (PAgT) induced by adenosine diphosphate was measured using turbidimetry.

2.4 Free fatty acid measures

Targeted metabolomics analysis was performed to quantify twenty-eight plasma free fatty acids (FFAs), including eleven saturated fatty acids (SFAs), six monounsaturated fatty acids (MUFAs), five n-3 polyunsaturated fatty acids (PUFAs), and six n-6 PUFAs, using gas chromatography and mass spectrometry (GC-MS). The ratio of C18:1n-9 to C18:0 was also calculated to estimate the activity of stearoyl-CoA desaturase 1 (SCD1), a key rate-limiting enzyme of the *de novo* lipogenesis (DNL) pathway.

2.4 Statistical analysis

The BKMR model was used to estimate the combined effect of seven pollutants on cardiometabolic outcomes. This model allows for non-linear associations between exposure and outcome variables, potential interactions between exposures, and can handle datasets where there may be strong correlations between exposure factors. Covariates included gender, age, BMI, temperature, RH, day-of-week, and time trend variables (day-of-measurement and its square term). Posterior inclusion probability (PIP) was generated through variable selection to identify key exposures. PIP ranges from 0 to 1, with a larger PIP indicating a greater contribution to the overall effect, and a threshold of 0.5 was used to determine whether a pollutant is important. Markov chain Monte Carlo methods with 50,000 iterations were applied to generate a robust estimate. All outcome variables were normalized, and the concentrations of air pollutants were logarithmically transformed to ensure all exposure variables had similar scales. The strongest effects with a cumulative lag of up to 0-7 days were reported. Linear mixed-effect (LME) models were then performed to verify the effect of individual exposure, adjusting for the same confounding variables, and the results were expressed as percent changes with 95% confidence intervals (CIs) per interquartile range (IQR) increment of pollutants.

Factor analysis, a common method for dimension reduction, was applied with orthogonal rotation to identify the main patterns of plasma FFAs. According to the Kaiser-Harris criterion, five factors were extracted in both the MH-NW and MHO groups. The BKMR model was then used to investigate the effect of the pollutant mixture on plasma FFA patterns. Additionally, a linear-mixed effect model was established to estimate the association between FFA factors and cardiometabolic outcomes. False discovery rate (FDR) was used to adjust the P-value for multiple tests. Interaction models were established by including the interaction terms between air pollutants and FFA patterns to determine the potential role of specific FFA patterns. The statistical significance level was defined as P<0.05 (two sided). All analyses were conducted using R software (version 4.0.3).

3 Results

3.1 Descriptive statistics

The mean age of both MH-NW and MHO participants was 23.4 years, with an average BMI of 21.0 kg/m^2 for MH-NW and 28.7 kg/m^2 for MHO. For metabolic health indicators, the MHO group had higher BP, with average SBP, DBP, and PP of 119.9, 72.5, and 47.5 mmHg, respectively, compared to 112.0, 69.0, and 43.0 mmHg in the MH-NW group (*P* = 0.001; *P* = 0.019; *P* = 0.003). The MHO group also had higher LDL-C (*P* = 0.031). For inflammatory indicators, leptin was higher in the MHO group compared to the MH-NW group, with averages of 5185.2 pg/mL and 2231.4 pg/mL, respectively (*P* = 0.001). C16:0, C18:1n-9, C22:6n-3, and C18:2n-6 were found in the highest concentrations of SFA, MUFA, n-3 PUFA, and n-6 PUFA, respectively. During the study period, the median personal exposure levels of pollutants were $PM_{2.5}$ = 31.77, PM_{10} = 38.37, BC = 1.20, O_3-8h max = 24.88, NO_2 = 19.23, and SO_2 = 1.78 (all μg/m^3), and CO = 0.84 mg/m^3, with similar levels between the two groups.

3.2 Joint effect evaluation and identification of key pollutants

Across the various cardiometabolic parameters measured, lipid profiles were most significantly associated with the air pollution mixture. Significant increases in LDL-C in the MH-NW group, decreases in HDL-C in the MHO group, and increases in lipid ratios in both groups were observed with increasing concentrations of the mixture of measured pollutants. According to the PIP value and the exposure-response curves, O_3 played a primary role in the alterations of lipid profiles in LDL-C (PIP = 0.89), HDL-C (PIP = 0.73), TC/HDL-C (PIP = 0.79), and nonHDL-C/HDL-C (PIP = 0.79) among MH-NW participants, and HDL-C (PIP = 0.87), TC/HDL-C (PIP = 0.93), and nonHDL-C/HDL-C (PIP = 0.93) among MHO participants. In the LME models, larger and more significant effect estimates were also generated per IQR increases in O_3. For instance, with an IQR (18.0 μg/m3) increase in O_3 concentration, we observed significant decreases of 20.5% (95%CI: -28.7%, -11.5%) in HDL-C at lag07, and significant increases of 25.9% (95%CI: 4.4%, 51.8%) in non-HDL-C and 25.8% (95%CI: 2.7%, 54.2%) in LDL-C at lag05 among the MHO people. Significant increases were also found in lipid metabolism indicators such as TC/HDL-C, non-HDL-C/HDL-C, LDL-C/HDL-C, and TG/HDL-C.

Furthermore, positive joint effects on neutrophil proportion, SAA, and MCP-1 were observed in the MHO group but not in the MH-NW group. These changes were primarily attributable to O_3 (PIP = 0.72), PM_{10} (PIP = 0.76), and O_3 (PIP = 0.89), respectively. Increased eosinophil counts were found in both subject groups. A greater magnitude of change in platelet and PAgT was also observed in the MHO group than in the MH-NW group. No significant changes in other systematic inflammation or coagulation biomarkers were observed. Regarding glycemic homeostasis, exposure to the air pollutant mixture was positively associated with insulin and HOMA-IR in the MH-NW group, but no key pollutant was identified (all PIPs<0.5).

3.3 Plasma FFA patterns and their association with air pollutants

Factor analysis identified five factors of plasma FFAs, explaining 76.9% and 81.0% of the total variation in FFAs in the MH-NW and MHO groups, respectively. The first factor (F1) had high loading for n-3 PUFAs and n-6 PUFAs, explaining 26.9% and 26.7% of the variation in the MH-NW and MHO groups, respectively. The second factor (F2) was characterized by higher proportions of trans-fatty acids (C14:1 trans-n-5 and C17:1 trans-n-7), C20:1n-9 and C23:0, explaining 14.8% and 15.8% of the variation in the MH-NW and MHO groups, respectively. The third factor (F3) had high loadings of very-long-even-chain SFAs (C20:0, C22:0 and C24:0), accounting for 14.4% and 15.8% of the variation in the MH-NW and MHO groups, respectively. The fourth factor (F4) had high levels of C16:0, C16:1n-7, C18:1n-9 and C18:1n-7, which are related to the DNL pathway, accounting for 13.9% and 20.5% of the variation in the MH-NW and MHO groups, respectively. The features of factor 5 (F5) differed between the MH-NW and MHO groups, with high loadings for C18:3n-3 and C20:3n-3 in the MH-NW group and high levels of C12:0 and C14:0 in the MHO group. BKMR results suggested that short-term exposure to the air pollutant mixture had weak effects on plasma FFA patterns, except for a significant negative association with F1 (PUFA pattern) in the MHO group.

3.4 Modification of cardiometabolic effects by plasma FFA patterns

Significant associations were found between certain FFA patterns and lipid indicators, but not with other cardiometabolic biomarkers. The F4 pattern, which is related to the DNL pathway, was positively associated with TG (MH-NW: β=0.078, P = 0.006; MHO: β=0.148, P < 0.001) and TG/HDL-C (MH-NW: β=0.086, P = 0.006; MHO: β=0.172, P < 0.001) in both the MH-NW and MHO groups. Additionally, the F5 pattern was positively associated with TG (β=0.182, P < 0.001) and TG/HDL-C (β=0.202, P < 0.001) in the MH-NW group.

Notably, both O_3 and the DNL-related FFA pattern were closely associated with lipid profiles. To investigate the potential modifying role of the DNL-related FFA pattern in the effect of O_3 on blood lipids, interaction models were established. The results showed that a higher level of the DNL-related pattern score was associated with a stronger effect of O_3 on TG (P for interaction = 0.040) and TG/HDL-C (P for interaction = 0.020) in the MHO group. Similarly, estimated SCD1 activity significantly augmented the effects of O_3 on TG (P for interaction = 0.027) and TG/HDL-C (P for interaction = 0.014) in the MHO group. However, no significant interaction was observed in the MH-NW group.

4 Conclusions

Through systematic statistical analysis of data from a comprehensive panel of biomarkers, we found that short-term exposure to air pollution was associated with adverse changes in cardiometabolic biomarkers, particularly in obese individuals with an otherwise metabolically healthy status. O_3 was identified as a primary contributor to most cardiometabolic alterations, especially blood lipid profiles, even at relatively low levels. The DNL pathway was found to be an important modifier of the link between O_3 exposure and lipid abnormalities, providing a novel insight into the biological basis of the susceptibility of the obese population to air pollution exposure. These findings may help tailor public health advice and interventions to protect vulnerable individuals from the adverse cardiovascular and metabolic effects of air pollution. In particular, given the increasingly severe O_3 pollution in most countries and regions worldwide, this study highlights the importance of preventing and controlling O_3 pollution to reduce the burden of cardiovascular disease.

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Arsenic Contamination: A Current Scenario in India

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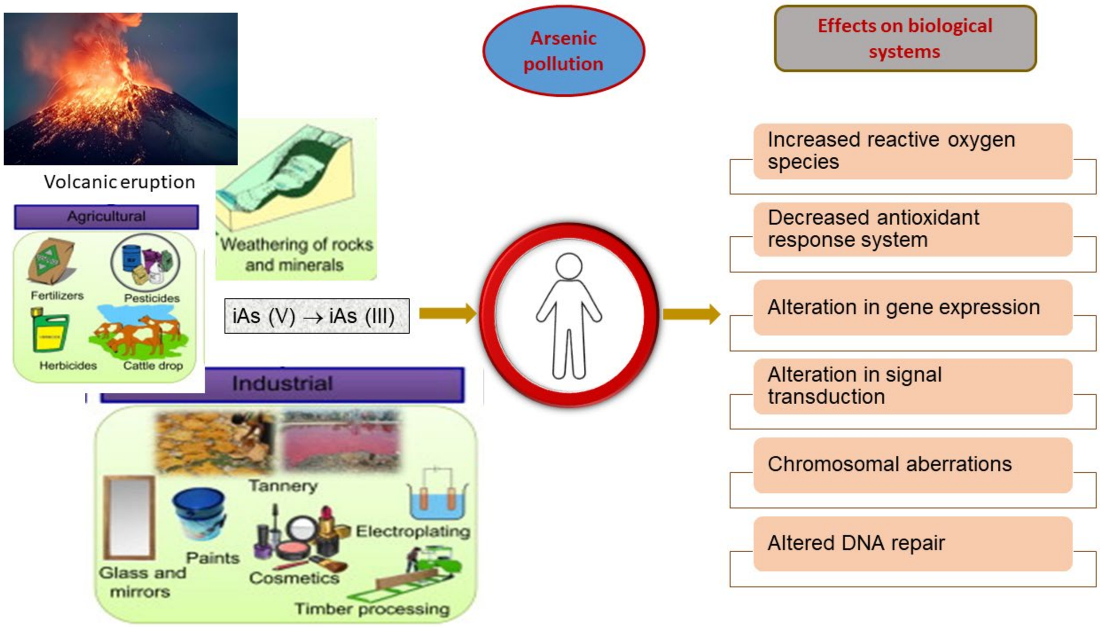
Graphical Abstract



Highlights:

- Arsenic is persistent and bio-accumulative in nature.
- Humans get exposed to arsenic through different sources and routes, and since it is toxic and non-degradable, it has serious health effects on humans.
- To prevent contamination and exposure, there is a need to expand the scope of current standards and statutory restrictions and policies.
- Regions in West Bengal, Bihar, Uttar Pradesh, Assam, and Chhattisgarh are the key states affected by arsenic water contamination in India.

Introduction

Urbanization and industrialization have led to an upsurge in the accumulation of solid waste, which is now an international problem. Leachate leakage from landfills contaminates soil and groundwater, which can seriously affect human health. Heavy metals are major environmental contaminants with a specific density greater than 5 g/cm3 and negatively impact both the surroundings and organisms. When present in very small amounts, these metals are needed to maintain various biological and physiological functions in organisms; yet, when these concentrations are exceeded, they become detrimental. Even though heavy metals are known to have numerous negative health impacts that persist over time, heavy metal exposure is still occurring and worsening in many regions worldwide. Heavy metals are released into the environment naturally and due to human activity. Heavy metals may originate from various sources, such as mining, industrial waste, urban runoff, wastewater discharge, soil erosion, natural weathering of the earth's crust, pest or disease control agents used on crops, and many more (1).

Arsenic, a naturally occurring element in the environment, can enter water through various processes, such as rock disintegration and hydrothermal action. It exists in two forms: inorganic and organic, each with its own implications and sources.

Organic arsenic compounds found in seafood pose less risk to health compared to inorganic arsenic compounds like arsenite and arsenate, which are present in water and other inorganic substances. In areas affected by arsenic, the shift from surface water and shallow open well sources to deep tube wells has led to arsenic pollution in certain regions. Industrial sources of pesticides, herbicides, and rodenticides containing arsenic can also contribute to arsenic leaching. The consumption of contaminated water (mainly groundwater) for cooking, agricultural irrigation, industrial processes, and tobacco use exposes people to high levels of inorganic arsenic, which can have severe health implications.

Additionally, groundwater with an average depth of 10 to 60 meters contains arsenic; deeper groundwater typically contains no arsenic at all. Anthropogenic activities like mining and overuse of groundwater can also lead to arsenic poisoning. Over 85% of drinking water sources in rural regions come from groundwater (2).

Mechanism of arsenic toxicity

In arsenic biotransformation, bacteria, algae, fungi, and humans help methylate toxicinorganic arsenic molecules to produce monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA). During this biotransformation process, these inorganic arsenic species (iAs) undergo enzymatic conversion to methylation arsenicals, the final metabolites, and the biomarker of long-term arsenic exposure.

iAs (V) $\rightarrow$ iAs (III) $\rightarrow$ MMA (V) $\rightarrow$ MMA (III) $\rightarrow$ DMA (V)

Urine excretions containing methylated inorganic arsenic, such as MMA (V) and DMA (V), are bioindications of long-term arsenic exposure resulting from the detoxifying process known as biomethylation. MMA (III), on the other hand, is an intermediate product that stays inside the cell and is not eliminated. Compared to other arsenicals, monomethylarsonic acid (MMA III), an intermediate product, is discovered to be extremely hazardous and may be responsible for arsenic-induced carcinogenesis (3).

Exposure to arsenic via-

1. **Drinking water**

The most significant arsenic hazard to human health is found in drinking water. An estimated 140 million individuals across 50 countries were estimated to have been drinking water that contained arsenic at levels higher than the WHO's preliminary recommended value of 10 µg/L in 2002 (5). Many countries, including Argentina, Chile, China, India (West Bengal), Mexico, the United States of America, and especially Bangladesh, have naturally high concentrations of inorganic arsenic in their groundwater. In 2012, it was estimated that about 19 million people were exposed to concentrations of arsenic in drinking water that were higher than the national standard of 50 µg/L, and 39 million people were drinking water with arsenic levels above 10 µg/L (4). In a severely affected region of Bangladesh, drinking water containing more than 10 µg/L of arsenic was found to be the cause of 21.4% of all deaths in 2010 (5). However, an analysis conducted in 2012 across all districts showed that chronic arsenic exposure was responsible for nearly 43,000 deaths annually, or 5.6% of all deaths(5).

2. **Industrial processes**

The majority of arsenic utilized in industrial processes goes towards making antifungal wood preservatives, which have the potential to contaminate the soil. Additional applications today or in the past include the pharmaceutical and glass industries, alloys, sheep dips, leather preservatives, pigments containing arsenic, paints that resist fouling, poison baits, and, to a lesser degree, the production of agrochemicals (particularly for use in orchards and vineyards). Limited arsenic compounds are also used in the optical and microelectronics sectors. Both the working and surrounding environments of non-ferrous metal smelters, where arsenic trioxide may be produced, and certain coal-fired power plants, particularly those that use low-grade brown coal, have high levels of arsenic in the air (6).

3. **Food**

The majority of a person's daily intake of arsenic is typically derived from food in places where the element is not found in large amounts naturally. The primary food sources include cereals, dairy products, meat, poultry, fish, and shellfish. However, the arsenic found in fish and shellfish is typically present in low-toxicity organic molecules, such as arsenobetaine (7). Food (such as rice) cooked in high arsenic water and food crops irrigated with tainted water further add to the daily consumption of arsenic in places where it is naturally present in high concentrations.

4. **Smoking**

Smokers are exposed to arsenic due to the presence of natural inorganic arsenic in tobacco. In the past, exposures were elevated when tobacco plants were subjected to lead arsenate pesticide treatment (5).

Arsenic Contamination in India

The Bureau of Indian Standards (BIS) has established two categories of values for general physicochemical parameters and hazardous components in drinking water:

The highest acceptable threshold:

The allowable threshold when there are no other options for drinking water sources.

The Bureau of Indian Standards (BIS) has set the specification for drinking water (IS10500:2003) with both levels specified as 0.05mg/l. In 2012, the BIS lowered the recommended level of arsenic from 0.05 mg/l to 0.01 mg/l while keeping the allowable level at 0.05 mg/l.

Arsenic groundwater pollution was initially discovered in India in 1983 when cases were recorded in three families residing in a village in the 24 Parganas region of West Bengal. Subsequently, numerous additional cases were documented in West Bengal and other states such as Bihar, Uttar Pradesh, Jharkhand, and Assam. According to the online Integrated Management Information System (IMIS) of the Ministry of Drinking Water and Sanitation, there are roughly 1800 arsenic-affected rural habitations in the country where 23.98 lakh people are at risk. IMIS 2015 data suggests that 6 states are affected by arsenic concerning groundwater sources (1).

Regions in West Bengal, Bihar, Uttar Pradesh, Assam, and Chhattisgarh are the key states affected by arsenic water pollution, with West Bengal being the most affected. Groundwater in 9 out of 16 districts of West Bengal is significantly contaminated with arsenic, affecting 26 million people (9). In a U.P. Jal Nigam /IITR survey of 66671 samples of water from hand pumps in 20 districts of U.P., 42% were found to contain > 10 ppb arsenic, of which 2610 (4%) had > 50 ppb arsenic. Children ingest arsenic through pica behavior.

The high burden of environmental pollution in countries like India is due to the high level of resource use, obsolete technologies, excessive exploitation of natural resources, and poor environmental rules and enforcement (8).

The Central Ground Water Board (CGWB) generates groundwater quality data on a regional scale from various scientific research and groundwater quality monitoring around the country. These studies demonstrate the prevalence of arsenic over the Bureau of Indian Standards (BIS) acceptable limits in isolated pockets in different sections of the country. Arsenic has been reported from various places in 221 districts in 25 States/U.T.s (9).

Health impacts due to arsenic exposure

The amount, mode, and length of exposure, as well as the kind and source of the arsenic, all affect how sick a person becomes from exposure to it. The first noticeable signs of drinking water contaminated with high levels of arsenic are keratosis, or symmetrically distributed, many little raised sores on the palms and soles, and melanosis, or aberrant black-brown skin pigmentation. Leukomelanosis, the medical term for the white spots resembling raindrops on the skin, results from continued exposure to arsenic. The soles and palms get even thicker, and painful fissures show. Hyperkeratosis is the term used to describe these signs, which may progress to skin cancer. Arsenicosis is a disease state that arises from continuous consumption of arsenic-contaminated water and is caused by chronic arsenic exposure. It is acknowledged that arsenicosis can present with or without cutaneous symptoms. Nonetheless, since skin symptoms are a patient's primary cause of medical attention, these are typically utilized to diagnose arsenicosis based on dermal appearances (1).

Acne and discoloration of the skin. Chronic arsenic toxicity causes a variety of systemic manifestations, in addition to pigmentation and keratosis, which are the specific skin lesions associated with the toxicity. These include chronic lung diseases such as chronic bronchitis, chronic obstructive pulmonary disease, liver diseases such as non-cirrhotic portal fibrosis, and other diseases such as polyneuropathy, peripheral vascular disease, and non-pitting edema of the hands or feet (1).

Trivalent arsenic is thought to be a carcinogen that causes chromosomal abnormalities such as sister chromatid exchanges and alterations in chromosome number and shape. One can develop arsenolysis from pentavalent arsenic. Less is known about the precise chemical process by which arsenic induces cancer (1).

Initiatives on water management in India

Water is a State concern, and measures on water management, particularly preventing groundwater contamination, are primarily the state's duty. However, the Central Government has taken several initiatives in this regard in the country.

The Central Pollution Control Board (CPCB), in collaboration with State Pollution Control Boards/Pollution Control Committees (SPCBs/PCCs), enforces the Water (Prevention & Control) Act, 1974, and the Environment (Protection) Act, 1986, in the country to prevent and control water pollution (10).

The Government of India announced recommendations on 24 September 2020 for managing and overseeing groundwater extraction with pan-India applicability. The recommendations comprise suitable provisions for controlling groundwater pollution (10)(11).

The government of India, in conjunction with the states, is undertaking the Jal Jeevan Mission (JJM), which will begin in August 2019 to provide a potable tap water supply of mandated quality to every rural family in the country by 2024. Under JJM, when planning water supply systems to offer tap water to households, priority is given to quality-affected habitations. While allocating the money to States/ UTs in a specific financial year, 10% weightage is given to those residing in habitations afflicted by chemical pollutants like arsenic and fluoride as of 31 March of the preceding financial year (10). Subsequently, the preparation, execution, and establishment of piped water supply schemes based on a safe water source may take time, purely as an interim measure, States/ UTs have been advised to install community water purification plants (CWPPs) in such habitations, to provide potable water to every household at the rate of 8–10 liter per capita per day (lpcd) to meet their drinking and cooking specifications (10).

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Department of Drinking Water & Sanitation launched a National Water Quality Sub-Mission (NWQSM) on 22 March 2017 as a part of the National Rural Drinking Water Programme (NRDWP), which has now been subsumed under JJM, to provide safe drinking water to 27,544 arsenic/fluoride affected rural habitations in the country (10).

CGWB has constructed arsenic-safe exploratory wells in West Bengal, Bihar, and Uttar Pradesh by adopting a novel cement sealing technique. Further, CGWB is providing technical help to the States for deploying this technique in Gangetic flood plains (10).

Our laboratory work:

Occupational or environmental exposures to heavy metals produce several adverse health effects. We examined some of the natural compounds against chromium and arsenic toxicants, as these are found in various food supplements and may benefit the human population at therapeutic doses in counteracting these toxicants' effects. The study was an attempt to investigate the impact of some common anti-oxidants such as Biochanin A, Phloretin, Coenzyme Q10, and Epigallocatechin-3-gallate (EGCG) on these toxicants in the experimental *Swiss* albino mice model. Our findings so far revealed the beneficial effects of the above anti-oxidants against counteracting the effect of oxidative stress due to chromium and arsenic exposure, and these anti-oxidants hold the potential for future therapies against heavy metal poisoning in the exposed population. The findings of the above project have been published in international journals with good impact factor.

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S3-3

Arsenic Impaired Neuronal Insulin Signaling: A Possible Implication in Neurodegeneration

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Chronic exposure of arsenic has been reported to associate with neurodegeneration and Alzheimer's disease (AD) development. Utilizing differentiated neuroblastoma cell lines in in vitro experiments, we found that prolonged arsenic exposure caused insulin signaling impairment. Interestingly, we observed increases in tau phosphorylation and oligomerization as well as tau kinases, GSK3β and ERK by arsenic treatment. Moreover, we detected increases in tau phosphorylation and activity of tau kinases, specifically ERK1/2 and JNK in the brain of rats exposed to arsenic at 2.5 mg/kg for 28 days. Considering recent evidence showing the roles of insulin signaling impairment in AD, our results suggest a potential mechanistic link between arsenic exposure, insulin signaling disruption, and subsequent neurodegeneration particularly AD.

S3-4

Perinatal Triphenyl Phosphate Exposure Induces Metabolic Dysfunctions Through The EGFR/ERK/AKT Signaling Pathway: Mechanistic *In Vitro* And *In Vivo* Studies

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Triphenyl phosphate (TPhP), a widely used organophosphate-flame retardant, is ubiquitously found in household environments and may adversely affect human health. Evidence indicates that TPhP exposure causes metabolic dysfunctions *in vivo*; however, the underlying mechanism of such adverse effects has not been comprehensively investigated. Herein, we utilized two *in vitro* models including mouse and human preadipocytes to delineate adipogenic mechanisms of TPhP. The results revealed that both mouse and human preadipocytes exposed to TPhP concentration-dependently accumulated more fat through a significant upregulation of epidermal growth factor receptor (EGFR). We demonstrated that TPhP significantly promoted adipogenesis through the activation of EGFR/ERK/AKT signaling pathway as evident by a drastic reduction in adipogenesis of preadipocytes cotreated with inhibitors of EGFR and its major effectors. Furthermore, we confirmed the mechanism of TPhP-induced metabolic dysfunctions *in vivo.* We observed that male mice perinatally exposed to TPhP had a significant increase in adiposity, hepatic triglycerides, insulin resistance, plasma insulin levels, hypotension, and phosphorylated EGFR in gonadal fat. Interestingly, an administration of a potent and selective EGFR inhibitor significantly ameliorated the adverse metabolic effects caused by TPhP. Our findings uncovered a potential mechanism of TPhP-induced metabolic dysfunctions and provided implications on toxic metabolic effects posed by environmental chemicals.

S3-5

Cellular Mechanisms Involved in Protecting Alachlor-induced Proteotoxic Stress

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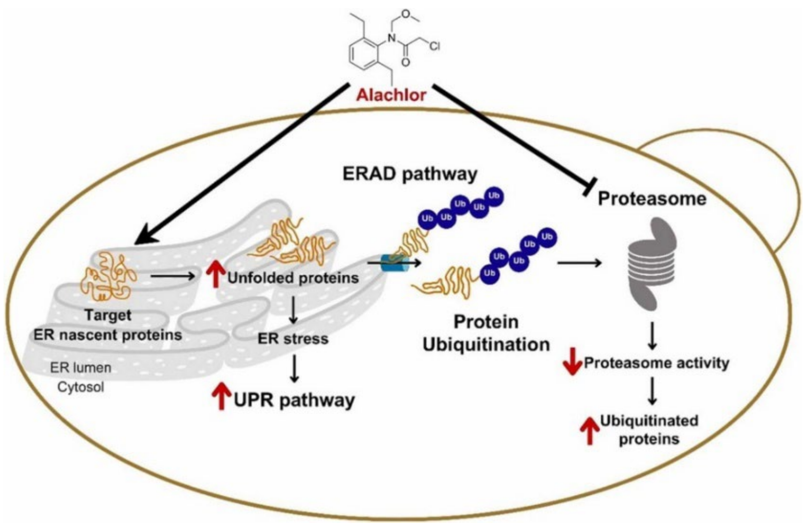
Alachlor, a widely used chloroacetanilide herbicide for controlling annual grasses in crops, has been reported to rapidly trigger protein denaturation and aggregation in the eukaryotic model organism *Saccharomyces cerevisiae*. Therefore, this study aimed to uncover cellular mechanisms involved in preventing alachlor-induced proteotoxicity. The findings reveal that the ubiquitin-proteasome system (UPS) played a crucial role in eliminating alachlor-denatured proteins by tagging them with polyubiquitin for subsequent proteasomal degradation. Exposure to alachlor rapidly induced an inhibition of proteasome activity by 90% within 30 min. The molecular docking analysis suggests that this inhibition likely results from the binding of alachlor to β subunits within the catalytic core of the proteasome. Notably, our data suggest that nascent proteins in the endoplasmic reticulum (ER) are the primary targets of alachlor. Consequently, the unfolded protein response (UPR), responsible for coping with aberrant proteins in the ER, becomes activated within 1 h of alachlor treatment, leading to the splicing of *HAC1* mRNA into the active transcription activator Hac1p and the upregulation of UPR gene expression. These findings underscore the critical roles of the protein quality control systems UPS and UPR in mitigating alachlor-induced proteotoxicity by degrading alachlor-denatured proteins and enhancing the protein folding capacity of the ER. A better understanding of cellular mechanisms involved in preventing alachlor-induced proteotoxicity from this study will provide a promising clue for further development of preventive healthcare and direct targeted therapies for herbicide poisoning.



Limcharoensuk T, Chusuth P, Utaisincharoen P, **Auesukaree C.** Protein quality control systems in the endoplasmic reticulum and the cytosol coordinately prevent alachlor-induced proteotoxic stress in *Saccharomyces cerevisiae*. ***J. Hazard. Mater.*** 2024; 471:134270.

Session 4:

Connecting Health: Exploring Ecological and Human Health Through Contamination in the Food Chain

S4-1

Xenobiotic Compounds and Metals Contamination in the Environment

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Environmental pollution affects several ecosystems such as soil, sediment, air, and water systems. These are due to the growth of the urban along with the transport systems (ships, automobiles, trucks, trains, planes, etc.). In addition, thousands of chemicals have been produced, used and discharged recklessly. These have led to the contamination of the environment including the contamination of agricultural food and crops by pesticides and fertilizers applied directly into the soil. These foreign contaminants can be considered as xenobiotics. Some xenobiotics can cause acute toxicity to organisms but some cause chronic effects or no effect but their concentrations can be magnifying through food chain. There were various contaminations of PAHs, pesticides, toxic metals and TPH in several locations and ecosystems in Thailand. Examples of contamination are: organochlorine pesticides in Mae Klong river, PAHs contamination in Map Tha Put, Cd in Tak province, Pb in Kanchanaburi and toxic metals in the Chao Phraya River. All of them will be discussed here.

S4-2

Per- and Polyfluoroalkyl substances (PFAS) Contamination in Environment, Seafood, and Human Exposure in Thailand

***Tawit Suriyo**[1,2]**, Nuchanart Rangkadilok**[1,2]**, Nanthanit Pholphana**[1]**, Teerapong Lertassavakorn**[3]**, and Jutamaad Satayavivad**[1,2,4]*

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Per- and polyfluoroalkyl substances (PFAS) are a vast group of fluorinated synthetic chemicals widely used in various consumer products (cosmetics and paper-based food packaging) and industrial applications (stain-resistant coatings and firefighting foam). Currently, over 9,000 compounds belong to this chemical group. Various research studies indicate that PFAS impact health by affecting liver function, the immune system, the endocrine system, the reproductive system, the cardiovascular system, and infant growth. The two most widely studied PFAS, perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) are considered persistent organic pollutants (POPs) that contaminate the environment and accumulate in organisms. Research monitoring of these substances is one of the key activities in the Thailand National Management Plan in accordance with the Stockholm Convention on POPs.

Chulabhorn Research Institute (CRI) has conducted research related to monitoring the contamination of PFOS and PFOA in surface water, groundwater, seawater, seafood, and drinking water, as well as performing risk assessments from seafood exposure to these substances. The study area focused on the Map Ta Phut Industrial Estate in Rayong Province, one of the largest industrial estates in Thailand, which hosts various factories, including chemical production, petrochemical activities, and metal plating factories. There is a high likelihood that PFOS and PFOA might be used in production processes or firefighting activities in this industrial area. The study, conducted between 2019-2023, indicated that there was contamination of PFOS and PFOA in both the environment and seafood in the Map Ta Phut Industrial Estate area, which was higher than in samples from nearby areas such as the Rayong municipal community and other provinces like Bangkok and Chanthaburi. The contamination levels of these substances varied among different types of seafood, with the highest PFOS contamination found in squid, followed by sweet clams and oysters. Risk assessment analysis used the contamination levels of PFOS and PFOA in seafood to calculate the exposure assessment from seafood consumption. Preliminary results indicate that the exposure to PFOS and PFOA from seafood consumption is below the European Food Safety Authority (EFSA) guideline level, suggesting that Thai seafood consumption is safe concerning PFAS toxicity.

Additionally, CRI has conducted research on biomarkers of exposure to PFOS and PFOA in humans who live in the Map Ta Phut municipal area. The research is ongoing, and data analysis is still in progress. Preliminary analysis of plasma samples from 50 blood donors to the Thai Red Cross show that 92% and 86% of the samples contained detectable levels of PFOS and PFOA, respectively. Continuous monitoring of environmental contamination, food, and population exposure is essential. All sectors should support ongoing research on these POPs.

S4-3

Environmental Processes and Health Implication of Emerging Pollutants in Coastal Region

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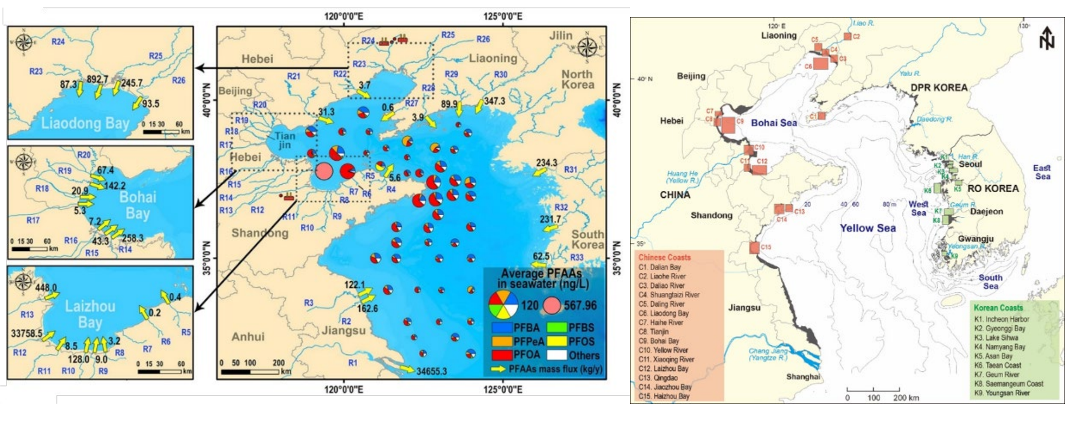
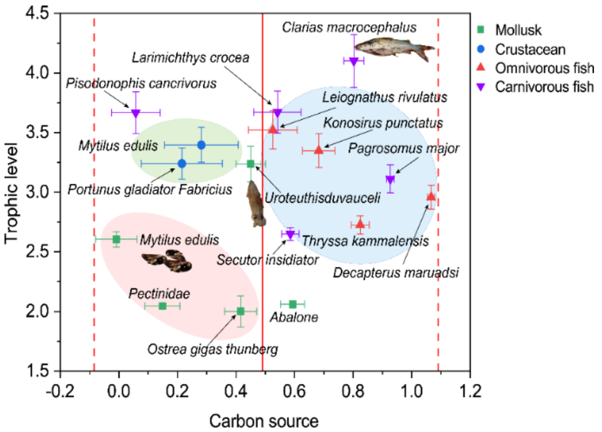
Perfluoroalkyl substances (PFAS) are being increasingly reported as emerging contaminants in riverine and marine settings. This study investigated the contamination level and spatial distribution of 17 PFAS within the depth profile of the Bohai and Yellow Seas using newly detected sampling data from 49 sites. Moreover, the riverine flux of 11 selected PFAS in 33 rivers draining into the Bohai and Yellow Seas was estimated from previous studies in order to establish the relationship between riverine sources and marine sinks. The results showed that the Bohai and Yellow Seas were commonly contaminated with PFAS: total concentrations of PFAS in the surface, middle, and bottom zones ranged from 4.55 to 556 ng/L, 4.61-575 ng/L, and 4.94-572 ng/L, respectively. The predominant compounds were PFOA (0.55-449 ng/L), PFBA (<LOQ-34.5 ng/L), and PFPeA (<LOQ-54.3 ng/L), accounting for 10.1-87.0%, 5.2-59.5%, and 0.6-68.6% of the total PFAS, respectively. The total riverine PFAS mass flux into the Bohai and Yellow Seas was estimated to be 72.2 t/y, of which 94.8% was carried by the Yangtze and Xiaoqing Rivers. As the concentration of short-chain PFAS begins to rise in seawater, further studies on the occurrence and fate of short-chain PFAS with special focus on effective control measures would be very timely, particularly in the Xiaoqing River and Laizhou Bay.

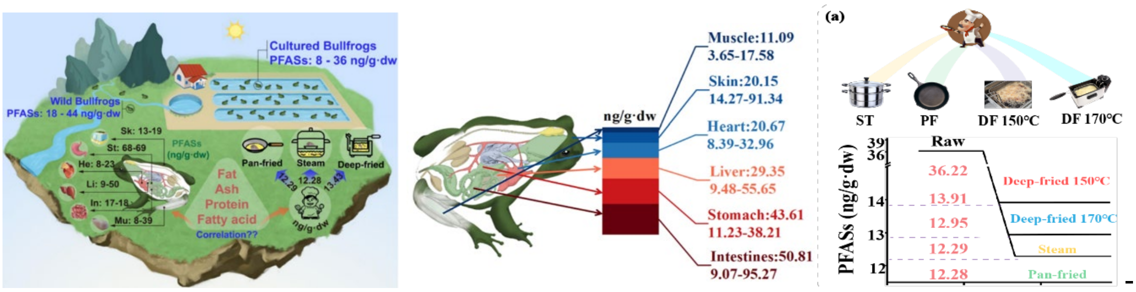


Perfluoroalkyl substances (PFAS) are known to be persistent and toxic, and can be accumulated and trophic magnified in the environments. PFAS are widely distributed, and their coastal input poses a threat to the health of aquatic organisms and local residents. In present study, 17 PFAS including one emerging polyether substitute in water, sediment, and organisms were investigated from the South China Sea. Perfluorobutanoic acid (PFBA) was predominant in water, of which concentration ranged from ND to 10.26 ng/L, with a mean of 5.21 ng/L. Similar to sediment and organisms, PFBA was the substance with the highest concentration detected among PFAS. This result seemingly indicated that use of short-chain PFAS as substitutes for long-chain PFAS in recent years. Trophic magnification factors (TMFs) of PFAS were estimated in the marine food web. TMFs >1 was observed only in perfluorooctane sulfonic acid

(PFOS), indicating a biomagnification potential of PFOS in the given ecosystem. The estimated daily intake (EDI) of PFOS and PFOA were most prevalent in mollusk, whereas the EDI of PFBA was greater in fish and shrimp. The hazard ratio (HR) reported for seven dominant PFAS were lower than 1, which suggests that PFAS via seafood consumption would not cause significant health risk to local residents.



Bullfrogs are regarded as the indicator species to assess ecosystem and human health risk because they are living in a complex environment utilizing both aquatic and terrestrial environments, bioaccumulate contaminants, and increase risk for human health. Bullfrog is one popular aquatic product providing high protein and tasty cuisine, however, its risk-benefit of PFASs and nutrient after cooked has not been well understood. PFAS and nutrients were investigated in tissues of raw and cooked, cultured and wild bullfrogs. PFAS in wild bullfrogs (mean: 44.17 ng/g·dw) were generally higher than those in cultured bullfrogs (mean: 31.87 ng/g·dw). Novel PFAS performed higher detection level and accumulation in wild bullfrogs than those cultured. Fats, proteins, and fatty acids may affect PFAS accumulation in different tissues and by different cooking of bullfrogs. All cooking methods can reduce PFAS in edible tissues while enhance nutritive value significantly compared to raw bullfrogs. Preferring steaming method for cultured bullfrog and avoiding wild bullfrog intake were recommended in terms of risk-benefit concern. Overall, this work provides quantitative evidence for cooking methods altering PFAS and nutrients in cultured and wild bullfrogs.



S4-4

The Risk-Benefit Situation of Dioxin-like Compounds in Human Milk for the Breastfed Infant

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Dioxin-like compounds (DLCs) identified in human milk have sparked concerns regarding the safety of breastfeeding, given their potential health hazards to infants, despite the absence of specific health-based guidance values for this vulnerable population. Global surveys carried out by the World Health Organization (WHO) and the United Nations Environment Programme (UNEP) have been instrumental in monitoring the presence of these compounds in human milk, with the goal of evaluating and alleviating the associated risks linked to breastfeeding.

Health Risks and Benefits of Breastfeeding

While the existence of DLCs in human milk may present health risks to infants, a substantial body of research has demonstrated that the advantages of breastfeeding significantly surpass these possible risks, thereby endorsing the WHO's recommendation to advocate for breastfeeding. Successful endeavors aimed at reducing the levels of DLCs in human milk in certain areas can be attributed to regulatory initiatives targeting the reduction of emissions of these compounds, as evidenced by the decreasing trends of DLCs observed in human milk over time.

Regulatory Actions and Future Directions

The incorporation of dioxin-like PCBs (DL-PCBs) into the risk assessment of DLCs, owing to their comparable toxic properties, underscores the advancing comprehension of the impact of these compounds on human health and the necessity for comprehensive regulatory actions. The utilization of an additive strategy for evaluating the risk posed by mixtures of DLCs, employing toxic equivalency factors (TEFs) advocated by WHO, has emerged as a universally recognized approach for assessing and mitigating the risks linked to these compounds.

Conclusion

Despite the obstacles presented by the presence of DLCs in human milk, the collaborative endeavors of international entities, regulatory authorities, and ongoing investigations persist in striving to minimize these risks while advocating for the invaluable benefits of breastfeeding.

Session 5:

Exposure During Early Life Stage and Its Consequences

S5-1

Exposure to Environmental Toxicants and Immune Dysfunction in Children

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Children are more vulnerable to environmental toxicants compared to adults, and their developing immune system is among the most sensitive targets regarding toxicity of environmental toxicants. Studies have found that exposure to environmental toxicants is associated with impaired immune function in children, but only a few studies have focused on the relationship between environmental toxicant exposure and vaccine antibody potency and immunoglobulin (Ig) levels in children.

These studies investigated the associations of exposure to polychlorinated biphenyls (PCBs), perfluorinated compounds (PFCs), heavy metals (Pb, Cd, As, Hg) and $PM_{2.5}$ with the serum-specific antibody concentrations and Ig levels against different vaccines, such as anti-Hib, tetanus, diphtheria toxoid, and analyze the possible mechanisms underlying exposure-related alterations of antibody titers and Ig levels against different vaccines.

Results suggest that exposure to these toxicants is generally associated with decreased potency of antibodies produced from childhood immunizations and an overall deficiency in the protection the vaccines provide. Toxicant exposure is associated with vaccination failure and decreased antibody titers, and increased risk of immune-related diseases in children by altering specific immunoglobulin levels. Age, sex, nutritional status, and co-exposure may influence the effects of toxicants on the immune function in children.

Epidemiological evidence suggests that exposure-induced changes to humoral immune-related tissue/cells/molecules response to vaccines may have predominant roles in the inverse associations between antibody responsiveness to vaccines and environmental toxicants. These results help us to conduct better immunization policies for children under environmental toxicant burdens.

Key words: environmental toxicants, immunotoxicity, vaccination, antibodies, children's health

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S5-2

Exposure to Toxic Substances and Increased Various Types of DNA Damage in Young Children Living in the Vicinity of Electronic Waste Informal Recycling Site

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Electronic waste (E-waste) has become a global environmental health threats. Informal recycling of e-waste contributes to releasing a large number of hazardous substances including toxic metals, flame retardants such as polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), and toxic metals. High volume of informal recycling has been reported in many countries in Asia including Thailand. Children's exposure to environmental pollutants is a public health concern as children are especially vulnerable to toxic chemicals. This study aimed to investigate the exposure of toxic substances from e-waste recycling and DNA damage in young children.

A total of 105 young children (3-5 years old) consisting of 60 exposed children (living nearby e-waste informal recycling site) and 45 control children (recruited from another community which has no e-waste recycling activities). Air was samples from the ambient air and from personal monitoring were collected to measure PAHs, PBDE and metals. Biological samples such as urine and nails were collected to assess exposure and early biological effects. A significant increase in the ambient level of PAHs, total PBDEs and toxic metals was found in the e-waste recycling community. As a consequence, elevated levels of PAHs exposure and urinary metabolite of PAHs, 1-hydrorypyriene, was also significantly higher in the exposed children. Increased ambient PBDEs were in consistent with increased concentration of urinary bromophenol in exposed children. A significant higher level of various metals in toenails (Mn, Ni, Pb, As and Cd) was observed in the exposed children. More importantly, exposed children had higher levels of various types of DNA damage including oxidative DNA damage, measured as 8-hydroxy-deoxyguanosine (8-OHdG) and 8-nitroguanine, etheno DNA adducts (ethenodeoxy adenosine) and methylated DNA adducts.

These findings indicate that improper management of e-waste can cause significant environmental impacts and health risk, particularly increased genotoxic effects in young children living in the vicinity of e-waste site. Therefore, management and regulations of e-waste must become a priority at national and international policy in order to prevent and reduce health effects of e-waste exposure, especially in children and vulnerable populations.

S5-3

The Impact of Developmental Exposure to Arsenic on the Expression of Genes Related to Metabolic Diseases: Evidences from Differentiated Adipocyte Model and Human Studies

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Early-life exposure to arsenic has been associated with increased susceptibility to the development of several diseases in both childhood and adulthood. However, the mechanisms underlying the pathogenesis of metabolic diseases in relation to prenatal exposure to arsenic have not yet been well characterized and are poorly understood. This study aimed to investigate the expression of genes associated with the pathogenesis of metabolic diseases (*PPARG*, *FABP4*, *SLC2A4*, *LEP*, and *ADIPOQ*) in the newborns and children from our birth cohort who exposed to arsenic since *in utero*. A high arsenic exposed group showed significantly decreased *PPARG* and *FABP4* expression by 1.6- and 2.1-fold, respectively, in cord blood samples from newborns and 3.4- and 6.7-fold in saliva samples from children. By contrast, the expression of the *SLC2A4* and *ADIPOQ* mRNA was significantly decreased (6- and 3-fold, respectively) in high-arsenic exposed children. Furthermore, the levels of toenail arsenic were negatively correlated with the salivary mRNA expression levels of *PPARG* ($r = -0.412$, $p<0.01$), *FABP4* ($r = -0.329$, $p<0.05$), and *SLC2A4* ($r = -0.528$, $p<0.01$). To further elucidate whether dysfunction of fetal stem cells is involved in the altered expression of studied genes observed in children exposed to arsenic since *in utero*, *in vitro* studies utilizing umbilical cord derived mesenchymal stem cells (UC-MSCs) as a surrogate for fetal MSCs were carried out. Arsenite treatment at 1 μM significantly impaired adipogenic differentiation as demonstrated by a significant decrease in lipid content in arsenite treated group compared to that of the control group. Such impairment may be related to a significant decrease in the expression of genes involved in adipogenesis: *PPARγ* (6.3-fold), *FABP4* (33.3-fold), and *SLC2A4* (4.8-fold) observed at 1 μM arsenite-treated group. In addition, a significant increase in the mRNA expression levels of the pro-inflammatory adipokine, *LEP* (6.2-fold), and the inflammatory cytokines: *CXCL6* (5.5-fold), *IL-1β* (7.4-fold), and *CXCL8* (3.3-fold) was observed in differentiated adipocytes treated with 1 μM arsenite. Collectively, our results suggest that such alterations may be a consequence of the effects of arsenic exposure on fetal MSCs and these early impaired adipogenesis together with promotion of inflammation may have persisting effects that contribute to the development of metabolic diseases later in life.

S5-4

Protecting Our Most Vulnerable Populations from Toxics in Drinking Water

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There are many known and emerging environmental contaminants of concern found in drinking water sources worldwide. In the United States, over 43 million people rely on private wells as their drinking water source, and among US states, North Carolina has the highest populations of well water users in the US with 2.4 million people. Private wells are not regulated under the federal Safe Drinking Water Act or through laws in most states. Therefore, it is the well-user's responsibility to test and maintain the quality of the well water and studies on well stewardship have shown that well users face various barriers to testing and do not test their water as recommended. As harmful contaminants can remain undetected in untested well water, private wells are a key source of environmental exposure in North Carolina and beyond. Further, young children are particularly vulnerable to environmental toxicants, many of which have been found in private wells in North Carolina. To better understand exposure patterns among well users in North Carolina and improve awareness about the importance of well water testing in the state, members of the Institute of Environmental Health Solutions at UNC-CH have led multiple projects to quantify exposure and integrate well water testing into existing systems such as statewide home visiting programs and pediatric visits. These studies serve as a model for other states and areas with large populations relying on private well water.

S5-5

Solution-Oriented Fundamental Transdisciplinary Research for Improving Children's Health and the Environment: A Global Environmental Health Network

Wiliam A. Suk

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The Southeast Asia and Western Pacific regions contain half of the world's children. Diseases linked to pollution are responsible for an estimated 9 million premature deaths or approximately 16% of all deaths worldwide. Exposure to environmental chemicals in air, water, and soil contribute to more than 100 diseases. Children, especially those in low- and middle-income countries (LMICs) are especially vulnerable to adverse environmental exposures. The extent to which diseases and poor health can be prevented by focusing on reducing environmental exposure risks points to the need for global efforts to combat these children's environmental health challenges.

The convergence of infectious diseases and environmental contaminants results in novel health threats, especially among our children. The interconnected impact of pathogens and pollutants requires decisive action to safeguard the well-being of future generations. The amalgamation of infectious agents and toxic substances presents a formidable challenge to their health and development.

The undeniable effects of climate change have become increasingly apparent, particularly in the vulnerable region of Southeast Asia. While adults grapple with the environmental and economic ramifications, it's imperative to recognize the disproportionate impact on children's health.

The early identification and prevention of diseases in children are critical for ensuring their health and well-being. However, the fragmented nature of research efforts and the lack of accessible tools hinder progress in this crucial area. Therefore, there is a need for the establishment of a global network of research organizations dedicated to developing informatics-related tools that enable the seamless exchange and utilization of research findings worldwide. By leveraging advancements in informatics, such as data analytics, artificial intelligence, and digital health technologies, we can accelerate the translation of research into actionable solutions.

Imagine a scenario where research conducted in one country on childhood diseases can directly benefit children in another part of the world facing similar challenges. Through collaborative research partnerships and shared data platforms, this network can advance synergy among researchers, policymakers, healthcare professionals, and communities. By breaking down silos and promoting open science principles, we can harness the collective intelligence of the global research community to address pressing health issues affecting children. The research is required to be transdisciplinary/ interdisciplinary, bringing in a variety of disciplines all working together.

Key components of this initiative include the development of standardized data protocols, interoperable systems, and user-friendly interfaces that empower stakeholders to access, interpret, and apply research findings effectively. Moreover, emphasis should be placed on capacity building and knowledge exchange to ensure equitable participation and benefit-sharing across regions and demographics. Together, let us forge a new era of collaboration and innovation in pediatric health research, where borders cease to be barriers and knowledge becomes a universal resource for improving children's lives worldwide.

Session 6:

Collaborative Network in Environmental Health

SESSION 6:

Collaborative Network in Environmental Health

Time: 15:30 – 17:00

The session seeks to build collaborations among countries in this region, as well as with established networks in developed countries.

Topics of discussion will include:

1. Institutions, programs and networks in various areas of environmental health,
2. how to connect to and work with these institutions, programs and networks to advance environmental health in the region,
3. establishment of a database of experts/institutions in this geographical area who specialize in various areas of environmental health and link it to databases in developed countries,
4. mechanisms for communication among network members (countries), and
5. how to maintain this network.

Discussions among participants, guided by a panelist of speakers, will take place on potential collaborations on various topics or issues of common interest in environmental health. This will build upon discussions that have taken place over the course of the conference, including the country presentations on environmental health issues of concern.

The goal is to pool the expertise of the participants attending the conference from all parts of the world towards collaborations that can foster sharing of expertise and knowledge that leads to activities at the sub-regional and regional levels that increase our knowledge and understanding of these environmental health issues, therein creating a network of experts and knowledge (Hub of Talents and Hub of Knowledge).

Moderators: William A. Suk (U.S.A.) **and** Mathuros Ruchirawat (Thailand)

Panelists [10 minutes each]:

- **Syril Pettit** *(Health and Environmental Sciences Institute, U.S.A.)*
- **William A. Suk** *(University of North Carolina in Chapel Hill, U.S.A.)*
- **Supat Wangwongwatana** *(Hub of Talents on Air Pollution and Climate, Thailand)*

Regional perspectives and discussion [5 minutes each]:

- **Rozaini Binti Abdullah** *(Universiti Putra Malaysia, Malaysia)*
- **William W. Au** *(University of Texas Medical Branch, U.S.A.)*
- **Budi Haryanto** *(University of Indonesia, Indonesia)*
- **Xia Huo** *(Jinan University, China)*
- **Daam Settachan** *(Chulabhorn Research Institute, Thailand)*

E-waste Workshop:

Collaborative Efforts for Improving Quality of Life

W-1

Global Distribution and Human Exposure Problems to E-waste

William W. Au

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E-waste or electronic waste is created when electrical or electronic devices are discarded after their use. However, there has been dramatic increase in the generation of e-waste due to Digital Revolution and innovations in science and technology, such as bitcoin, and frequent new model releases. In 2019, there were about 54 million tons of e-waste generated. Unfortunately, most of the waste was generated by consumer (developed) countries and recycled in developing countries such as China, India and African countries. Typically, manual and low-tech procedures have been used in recycling activities, e.g., dismantling of components, burning off plastic components, cleaning components with volatile and toxic solvents, etc. Such effort leads to extensive environmental contamination and human exposure, as well as health consequences. Thus, coordinated international effort is needed to regulate the release and recycling of e-waste.

Response: Emphasize refurbishment and recycling to recover useful materials.

W-2

6PPDQ, PBDEs, PCBs, and Metal(loid)s in Indoor Dust from an E-waste Recycling Area and the Health Risk on Children

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Recycling and dismantling e-waste can release a variety of organic contaminants and metal(loid)s. In addition, indoor dust is a significant source of pollution for children. Therefore, it is crucial to investigate the exposure patterns of various pollutants in indoor dust in the surroundings of e-waste recycling areas and evaluate their impact on children's health. The study found significantly higher levels of various pollutants, including polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), metal(loid)s, and 6PPD-quinone (6PPDQ), in indoor dust samples from the Guiyu (exposed area) compared to Haojiang (reference area). The exposure level was evaluated by the estimated daily intake (EDI). The study revealed that children in the exposed area had higher EDIs of PCBs and PBDEs compared to those in the reference area. Furthermore, a negative correlation was observed between children's head circumference (HeC), chest circumference (ChC), and BMI ($P < 0.05$) and their exposure to various metal(loid)s in indoor dust in the exposed areas. After analyzing gut microbiota and its metabolites, we found a significant correlation between the alpha diversity index, differential metabolites, and the EDIs of 6PPDQ, BDE28, PCB52, Ni, and Cu in single element models. The correlation between the pollutants' EDIs and the diversity of the gut microbiota, as well as its metabolites, was validated using Bayesian kernel machine regression (BKMR) modeling. The findings suggest that increased exposure to pollutants may disrupt the gut microbiota and its metabolites in children, which may lead to health risks.

Key words: indoor dust, e-waste pollutants, health risk, children

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W-3

International, Regional, and Local Collaborations to Minimize the eWaste Problem

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The challenge is very clear: ever increasing amounts of e-waste are being produced. With the transition to renewable energy (solar panels, electric vehicles, etc.), and as technology continues to advance, the problem will keep growing. Successful recycling programs, however, grow at a much slower pace; as a result, the gap widens.
Eighty-one countries have adopted some form of legislation to address the export/import and/or the processing/recycling of e-waste, but there are huge gaps and inconsistencies in how countries have approached this problem; the legislation is rarely comprehensive, it differs from country to country, and implementation is limited.

In the absence of adequate legislative and regulatory controls, international collaborations are increasingly central to address the global e-waste problem. Multiple United Nations agencies as in the UN E-Waste Coalition are central to these efforts. The Global E-waste Statistics Partnership (GESP) is critical for assembling the datasets to track the extent and trends of global e-waste issues. The Global E-Waste Monitor (4th edition, 2024) is a very comprehensive overview of global e-waste issues, including up to date datasets covering all key regions and countries. The UN also has the unique ability to convene countries worldwide for international treaties, as in the Basel Convention signed in 1989 on "Transboundary Movements of Hazardous Waste and Their Disposal".

There are important regional efforts; the EU has been particularly prominent. The private sector is critically important, e.g., as in the Extended Producer Responsibility Directives, and key coalitions have developed within the private sector. At the local level, stakeholder groupings are essential to promote e-waste recycling and to increase public awareness.

The e-waste panel discussion will provide an excellent opportunity for conference attendees from varied countries, regions, and backgrounds to share experiences related to e-waste collaborations and initiatives.

Platform Presentations

Dichloromethane Increases Mutagenic DNA Damage and Cell Transformation Ability in Cholangiocytes: A Potential Environmental Risk Factor for Cholangiocarcinoma Development

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Dichloromethane (DCM) is classified by IARC (2017) as probably carcinogenic to humans. DCM was widely used as a chlorinated solvent in pesticides. Exposure to DCM has been associated with increased incidence of cholangiocarcinoma (CCA) in humans. This study aimed to investigate how DCM could contribute to CCA development by investigating the effects of DCM on DNA damage and cell transformation in cholangiocytes (MMNK-1). MMNK-1 cells treated with the non-cytotoxic concentration of DCM (25 µM, 24 h) significantly increased the levels of mutagenic DNA adducts including 8-hydroxydeoxyguanosine, 8-OHdG, (1.84-fold, $p < 0.01$) and 8-nitroguanine (1.96-fold, $p < 0.01$) and enhanced cell transformation by 1.47-fold ($p < 0.01$). In addition, the expression of various genes involved in carcinogenesis, namely, *NFE2L2* (antioxidative response), *CXCL8* (inflammation), *CDH1* (cell adhesion), *MMP9* (tissue remodeling), and *MKI67* (cell proliferation) was altered in cholangiocytes treated with DCM. When MMNK-1 cells were transformed by DCM, the expression of all the aforementioned genes was also increased after the transformation. Therefore, this study demonstrated how DCM exposure contributes to carcinogenesis, especially in CCA development.

O-2

In Utero Arsenic Exposure Increases DNA Damage and Gene Expression Changes in Umbilical Cord Mesenchymal Stem Cells (UC-MSCS) from Newborns as well as in UC-MSC Differentiated Hepatocytes

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Prenatal exposure to arsenic is associated with an increased risk of disease development such as liver cancer in adulthood. Increasing evidence suggests that fetal stem cells are key targets during transplacental chemical exposure. Our earlier study reported that in utero arsenic exposure caused various types of DNA damage in newborns. In this study, we further investigated the effects of prenatal arsenic exposure on mutagenic DNA damage in umbilical cord mesenchymal stem cells (MSCs) that represent fetal stem cells from the same birth cohort. DNA damage measured as 8-hydroxydeoxyguanine (8-OHdG) and 8-nitroguanine was increased in umbilical cord MSCs of newborns in relation to maternal arsenic levels in a dose-dependent manner. Levels of 8- OHdG and 8-nitroguanine were significantly ($p < 0.05$) and positively associated with arsenic levels in cord blood and maternal toenails. In vitro studies confirmed that arsenite treatment alone (0-5 μM, 24 h) significantly increased the levels of 8-OHdG and 8-nitroguanine in an MSC cell line derived from umbilical cord tissue (UCMSCs). When UC-MSCs were allowed to differentiate into hepatocytes in the presence of arsenite (0.5 μM, 21 days), there were significant increases ($p < 0.05$) in 8-OHdG and 8-nitroguanine compared to those observed in undifferentiated UC-MSCs. Moreover, in these arsenite-exposed differentiated hepatocytes, expression of inflammatory genes (CXCL6 and CXCL8) and an oxidative stress response gene (NFE2L2) was increased, while that of a DNA repair gene (OGG1) was decreased. Arsenite treatment also increased cell transformation ability of hepatocytes differentiated from UC-MSCs. These results suggest that arsenic exposure increases mutagenic DNA damage in fetal stem cells which continued when these cells differentiated to become hepatocytes which have increased cell transformation ability. This study highlights the potential risk of in utero arsenic exposure, which may lead to liver disease and cancer development later in life.

Insight into Ambient Ultrafine Particles ($PM_{0.1}$) in Upper Southeast Asia; Local and Transboundary Effects

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The issue of air pollution in the Upper Southeast Asia (USEA) assumes significant importance owing to its profound implications for public health and the environment. This study aims to examine the origins of ultrafine particles (UFPs), also known as $PM_{0.1}$ (particles ≤ 0.1 µm or 100 nm), and assess their potential contribution to climate change and health impact. Understanding how $PM_{0.1}$ affects global climate, environment, and human health requires physiochemical features, geographical and temporal fluctuations, and comparisons between cities and countries that play a vital role in air quality management. $PM_{0.1}$ mass concentrations in Cambodia, Thailand, and Myanmar peak during the open biomass fire episode in the dry season. A detailed study of carbonaceous $PM_{0.1}$ found that motor vehicles dominate during the wet season. Carbon components from biomass fires increase during biomass haze episodes. $PM_{0.1}$ particles come from regional biomass burning. Smaller PMs absorb energy and warm the atmosphere during MSEA smoke haze, according to the effective carbon ratio. The significant level of exposure to $PM_{0.1}$ from open biomass sources, which may be linked to health hazards, was found to be crucial. In the USEA region, where a comprehensive framework of regulatory measures on air quality management has been established, addressing air pollution necessitates a multifaceted approach that integrates air quality regulations with complementary policies, including traffic and agriculture-related ones. This study will help develop a clean air action plan for USEA.

Keywords: Air quality, Biomass burning, Carbon, Ultrafine particles, Southeast Asia

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Platform Presentation

O-4

Diesel Exhaust Nanoparticle Exposure Induces Small Extracellular Vesicle Secretion in Umbilical Cord-Derived Mesenchymal Stem Cells

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Extracellular vesicles (EVs) are membrane-bound structures secreted by cells under physiological or pathological conditions which contain various cargo molecules such as DNA, RNA, proteins, lipids, and metabolites. Cells also release EVs in response to external stimuli, such as exposure to environmental pollutants. In this study, we analyzed the potential adverse effects of transplacental exposure to air pollutants by using small EVs (sEVs) as biomarkers. Using umbilical cord-derived mesenchymal stem cells (UC-MSCs) as cell models for exposure, we demonstrated that 14-day exposure to diesel exhaust nanoparticles (DEPs), a major component of urban air particulates, induced the secretion of sEVs in a time and concentration-dependent manner. Nanoscale flow cytometry (nFCM) analysis confirmed their vesicular nature while nanoparticle tracking analysis (NTA) identified that the sEVs have a mean diameter of approximately 175 nm across all concentrations and four time points. Mechanistic investigation in the four-day time-course experiments revealed a time and concentration-dependent increase in ROS-positive cells and apoptotic cells. Moreover, DEP exposure showed an increased *AHR*-dependent expression of the *CYP1A1* gene involved in polyaromatic hydrocarbon (PAH) metabolism. Consequently, *NRF2*-regulated antioxidant genes, including *SOD1*, *SOD2*, and *CAT*, were activated. Additionally, the *OGG1* gene involved in oxidative DNA damage repair and the *XRCC1* gene associated with DNA single-strand break repair were upregulated. The *MTOR* gene involved in regulating multiple pathways such as autophagy, growth, survival, proliferation, and senescence was also disrupted. Our results indicate that long term culture of DEP-treated UC-MSCs may trigger cellular senescence via oxidative stress and DNA damage-dependent mechanisms eliciting the secretion of sEVs which can be used as senescence biomarkers. Further investigations on stem cell senescence induced by transplacental exposure to air pollution are necessary to understand the potential adverse health effects on the developing fetus and later in life.

Keywords: diesel exhaust particles, extracellular vesicles, oxidative stress, biomarkers

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Evaluation of Environmental Pollution Using Heavy Metals and Microplastics in Bee Propolis

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Propolis is a natural bee product used for different purposes and contains several biological activities and health benefits. Its composition consists of organic and inorganic elements from the surrounding areas where the bees live, particularly in industrial, agricultural, and anthropogenic regions with higher concentrations of pollutants and toxic chemicals. They may have a high possibility of getting contaminated with these hazardous substances and also carry them back to colonies, resulting in high contamination levels in bee products, especially propolis. Therefore, this study aimed to analyze for metal contents, cadmium (Cd), and lead (Pb) using atomic absorption spectrometry (AAS) in propolis produced by honey bees; *Apis mellifera,* and stingless bees; *Tetragonula pagdeni* collected from different regions of Thailand. Moreover, all propolis samples were also investigated for the accumulation of microplastics using the oxidative digestion method and observed under a stereo microscope. The results showed that Cd and Pb were undetectable in all samples. However, some propolis samples contained a fraction of microplastic fibers. This study suggested no toxic elements in the propolis samples from the collection areas, but some microplastic particles depended on each region's environmental conditions. It may imply that the evaluation of propolis is helpful as a bioindicator of environmental pollution. The discovered microplastic from samples will further identify the type of materials using Fourier-transform infrared spectroscopy (FTIR).

Keywords: Propolis, Honey bee, Stingless bee, Heavy metal, Microplastic

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O-6

Understanding Molecular Basis of Chemical Toxicology through Structural and Computational Approaches

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Recent developments in cryogenic electron microscopy (CryoEM) allow us to visualize the molecular structures of enzymes and macromolecular complexes at near-atomic resolution, thus revolutionizing our understanding of biochemistry and cell biology. By combining structural insights from CryoEM with computational biological approaches, we can predict not only the recognition and interaction of small molecules, including toxic and hazardous chemicals, with proteins but also the molecular behavior of the complex. This enables us to set the stage for a detailed investigation of intricate molecular interactions and the mechanisms of toxicity. In this talk, I will give an overview of the technology and our current progress in utilizing CryoEM and molecular simulations to study the toxic mechanisms of biochemicals and environmental toxicants.

List of Poster Presentations

LIST OF POSTER PRESENTATIONS

P-01

Airborne Particulate Matter and Size-Resolved Metal Content in Urban Bangkok, Thailand

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Airborne particulate matter (PM) is classified as carcinogenic compounds. The inhalation of PM presents a notable health hazard, particularly for urban residents such as those in Bangkok, who are exposed to high concentrations. This exposure has been correlated with respiratory and cardiovascular diseases, as well as cancer affecting the lung and brain. Throughout 2018, PM levels were measured in northern Bangkok near a toll road (13.87°N, 100.58°E) across the cool, hot, and rainy seasons. PM_{10} measurements were obtained from both 24-hour and 72-hour samples. Moreover, aerodynamic size distribution and mass were analyzed as 3-day samples collected from a fixed 5^{th}-floor inlet on selected dates. Particle number concentrations were measured at the 5^{th}-floor inlet and through roadside surveys. The results showed a large fraction of particle number concentration in the sub-micron range, higher than those in larger particles. Metals associated with combustion sources were predominantly found in the smaller size fraction of particles, which may have implications for potential health risks due to aerosol deposition in the distal airways of the lungs. PM_{10} levels ranged from 30 to 100 µg/m^3, peaking during the cool season. The most metal fractions in PM_{10} samples during the hot season included calcium, iron, and magnesium, with average airborne concentrations of 13.2, 3.6, and 2.0 µg/m^3, respectively. Copper, zinc, arsenic, selenium, molybdenum, cadmium, antimony and lead had large non-crustal sources. Principal component analysis (PCA) was employed to identified potential sources of the metals as crustal minerals, tailpipe exhaust and non-combustion traffic. Health risk assessment revealed a heightened risk of both carcinogenic and non-carcinogenic effects during drier seasons compared to the wet season, attributed to the ingestion of nickel, arsenic, cadmium, and lead.

P-02

Health Effects of PM2.5 Exposure: Insights from Chiang Mai, Thailand

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Air pollution is a pervasive issue that impacts both human health and various atmospheric factors; for instance, it can play a role in warming the atmosphere and influencing patterns of rain and cloud formation. Emissions contributing to air pollution originate from a range of sources, both human-made and natural, such as the burning of fossil fuels in electricity production, transportation, industrial processes, household activities, agriculture, and waste processing.

The threat to human health posed by global air pollution has emerged as a significant concern. This issue is particularly pertinent to the emission of fine particulate matter, characterized by an aerodynamic diameter of less than 2.5 µm. These particles stem from incomplete combustion of coal and exhaust from diesel vehicles [1]. It estimates that 3.2 million premature deaths occurred globally in 2020 due to exposure to household air pollution, mainly from the use of inefficient cooking and heating fuels [WHO Household Air Pollution Fact Sheet (2023)]. Southeast Asia experiences recurring air pollution issues annually, notably during the initial months of the year, spanning from January to April. Biomass burning overwhelmingly constitutes the primary source of air pollution, prevailing from the regional to the local scale in Southeast Asia [2].The degradation of air quality in Southeast Asia is significantly influenced by extensive instances of biomass burning and particulate pollutants originating from human activities distinct from biomass burning [3].

In northern Thailand, a combination of these factors is observed. The majority of cities in this region are situated in mountainous areas and are encircled by paddy fields. Larger villages, such as Chiang Mai, encounter growing issues related to traffic congestion. Additionally, during this particular time of the year, farmers burn stubble in anticipation of upcoming rain and rice planting. The narrow valleys in the region create ideal bowls for the accumulation of smog and smoke from these various activities. In Thailand, the air pollution problem associated with fine particulate matter occurs on a seasonal basis, which is different for each area of the country [4].

The climate in northern Thailand is defined by monsoons. The timeframe spanning from mid-February to the conclusion of May marks the transition from the northeast monsoon, which is most dominant in December-January, to the southwest monsoon prevalent in July-August. The peak of the hottest weather is experienced in March-April, aligning with the presence of intense thermal lows in the region [5].

Concern over the harmful consequences of air pollution on human health is developing on a global scale, especially in areas where fine particulate matter (PM2.5) levels are high. Urbanization, industrialization, and agricultural practices are the main causes of the substantial PM2.5 pollution that Chiang Mai, Thailand, is facing.

Chiang Mai has been ranked the most air polluted province in Thailand, exposed to levels exceeding the daily standard of the air quality index (15 $\mu g/m^3$ as per the World Health Organization; WHO and 50 $\mu g/m^3$ as per the Thai Pollution Control Department; PCD). The high concentrations of PM2.5 are associated with human health effects, especially in the sensitive group [6].

Being exposed to elevated levels of air pollution can lead to a range of detrimental health effects. PM2.5 stands out as the most significant air pollutant, exerting a pronounced impact on human health. Recent computations of premature mortality rates worldwide, utilizing high resolution global O_3 and PM2.5 models, reveal that approximately 25% and 45% of global mortality are attributed to Southeast Asia and the Western Pacific, respectively [7].

Of all the environmental health issues Thailand has, air pollution is one of the most serious. The Thai Pollution Control Department (PCD) states that there are serious health concerns associated with PM2.5 levels in metropolitan areas, such as Chiang Mai, which consistently exceed national air quality limits. Numerous investigations and reports support this claim. In a review of the health impacts of PM2.5 exposure in Thailand, for example, Lertnattee et al. (2021) noted the link between PM2.5 and respiratory illnesses as well as unfavorable pregnancy outcomes [8].

Tham et al. (2022) also examined the impacts of air pollution on the cardiovascular system, highlighting the connection between PM2.5 pollution and cardiovascular diseases. These results highlight how bad the PM2.5 pollution is in Thailand and how it affects people's health, increasing morbidity [9].

PM2.5 has the ability to deeply penetrate the respiratory tract and enter the lungs. Exposure to these fine particles can also compromise lung function and worsen medical conditions such as asthma and heart disease. In the early months of 2020, the air pollution measurements of PM2.5 in Chiang Mai, one of northern Thailand's largest cities, peaked at an alarming level of 330 in PM2.5 concentration over the weekend [10].

This elevated the northern city to the status of the world's most polluted city. Concurrently, airborne pollution levels throughout Thailand's northern region ranged between 100 and 390 in concentrations of air pollutants, as per air visual data [11].

In recent years, the connection between the production of PM2.5 and the hazards it poses to public health has garnered growing attention. Numerous toxicological and epidemiological studies have indicated that PM2.5 imparts adverse biological effects on several vital organs, encompassing the lung immune system, cardiovascular system, and nervous system. Among these affected organs, the skin stands out as the primary tissue exposed to ambient pollutants. Similar to the respiratory tract, the skin serves as an interface between the body and the surrounding atmosphere. As per the most recent report, exposure to particulate matter (PM) constitutes the fifth major risk factor for the worldwide burden of disease [12].

Numerous epidemiological studies have indicated a correlation between exposure to particulate matter (PM) and the morbidity and mortality of respiratory and cardiovascular diseases.

As stressed by numerous health and environmental authorities, including the World Health Organization (WHO) in their reports on ambient air pollution and its health impacts, the cumulative evidence highlights the urgent need for effective interventions to mitigate air pollution and protect public health in Thailand.

PM comprises harmful components, including polycyclic aromatic hydrocarbons (PAHs) and heavy metals, primarily originating from industrial emissions and traffic exhaust. While prior studies have predominantly focused on the general population with low exposure, significant research has been conducted on the exposure-response relationship specifically for PM.

In contrast, there is a limited comprehensive evaluation of the exposure-response relationship for individual PM components and their impacts on human health. Furthermore, some studies suggest that oxidative stress and DNA damage may mediate adverse effects due to PM. PAHs, for instance, have been reported to generate reactive oxygen species (ROS) through the redox cycle, inducing oxidative alterations to DNA and lipids in vivo. Similarly, certain heavy metals, such as arsenic, copper, cobalt, and chromium, can generate ROS through the Fenton reaction. The production of ROS contributes to oxidative damage in biological macromolecules such as lipids, DNA, and proteins within the body, representing a crucial early factor in both cardiovascular and carcinogenic impacts [13].

P-02

Oxidative stress manifests when the generation of reactive oxygen species (ROS) and other free radicals surpasses the body's antioxidant defense mechanisms, leading to damage in DNA, proteins, and lipids. While ROS naturally form as part of regular cellular processes, they can also result from exposure to external agents [14].

The monitoring and evaluation of early warning biomarkers of diseases play a critical role in comprehending the pathogenesis following environmental insults. Specifically, health-effect biomarkers serve as valuable tools in elucidating the connections between environmental exposures, human physiology, and disease [15].

PM2.5 comprises various elements and toxic compounds, including toxic metals and polycyclic aromatic hydrocarbons (PAHs) adsorbed onto its surface [16].

Toxicological evidence suggests that benzo[a]pyrene (BAP) is among the most prevalent polycyclic aromatic hydrocarbons (PAHs) detected in the environment, often present in nearly all PAH mixtures at relatively high concentrations (2%–10%) [17].

Human exposure to PAH mixtures typically occurs through the inhalation of polluted air [18]. Similarly, literature reports indicate the utilization of urinary 1-hydroxypyrene (1-OHP) levels as a biomarker for evaluating exposure to polycyclic aromatic hydrocarbons (PAHs) [19].

The oxidation of lipids leads to the production of various biomolecules that are expelled in urine. The oxidation of polyunsaturated acids (PUFA) gives rise to aldehydes, including MDA [20, 21]. Malondialdehyde (MDA) and 8-iso-prostaglandin-F2α (8-isoPGF2α) are most often used to evaluate oxidative lipid damage [22].

As breathing in air with high concentrations of fine particulate matter (PM2.5) has been shown to increase the risk of dying from cardiovascular or respiratory diseases, being admitted to the hospital, and developing lung cancer [23] so, to assess the early warning signs of disease and establish links between environmental exposures, human physiology, and disease, this study will analyze urinary oxidative stress biomarkers, including 1-hydroxypyrene (1-OHP), malondialdehyde (MDA) and 8-iso-prostaglandin-F2α (8-isoPGF2α).

Urine samples are chosen as the preferred specimen due to their non-invasive collection method, high participant compliance, and suitability for measuring crucial oxidative stress markers [24].

By examining these biomarkers, and comparing their levels in high and low pollution seasons, the research aims to provide valuable insights into the health risks associated with PM2.5 exposure in the Chiang Mai community, ultimately contributing to improved public health outcomes and risk mitigation strategies.

This is a pilot study including 25 healthy participants from the Samoeng district of Chaing Mai province in Thailand. Participants were selected in accordance with the inclusion and exclusion criteria set prior to data collection. Inclusion criteria was aged between 25-60 years and participant must be a healthy individual. Exclusion criteria includes, Underlying diseases such as cardiovascular disease, cancer, and kidney diseases, Pre-operation, Liver diseases, gout, thalassemia, Pregnant and breastfeeding, Drug abusers, Psychological disorder and Infections. Blood and urine samples were collected during high (Feb-April 2023), and low (May-July 2023) PM2.5 seasons.

Data collected from participants includes demographics (age, gender, smoking, alcohol drinking, underlying diseases, marital status, education, occupation, family income and financial support), physical examination (height, weight, BMI, waist circumference, hip circumference, diastolic BP, systolic BP, and heart rate). Blood samples were examined for biochemical indicators (fasting blood glucose, lipid profiles, liver function, and kidney function), hormone level examination (insulin, leptin, and adiponectin), and urine samples for biomarkers detection.
For now as the study is going on, the data for demographics, physical examination, hormones, and biochemistry blood test has been collected and analyzed already. Out of 25 healthy participants 10 were male and 15 were female, and for age mean ± SD=48.3±14.3 years. Out of 25 participants, 6 were those who never drank while 19 were drinkers. When

frequency of drinking was asked it was found that, 3 participants were regular drinkers who drink every day, 4 participants drink every week, 9 drink every month, and 3 do not drink at all. The analysis of data collected about smoking reveals that out of all 25, 18 never smoked, 4 have quit smoking and 4 were those who were current smokers at the time of data collection, whereas mean ± SD=2.3±1.5 years for smoking.

From the results of data collected during physical examination, body weight, BMI, systolic and diastolic BP were measured. The mean ± SD for these parameters were 59.4±14.4 kg, 24.3±5.0 kg/m^2, 134.6±19.8, and 83.8±10.6 mmHg, respectively.

During both high and low season blood tests were done for all the participants and the important parameters measured were complete blood count (CBC), fasting blood glucose levels, cholesterol levels and leptin hormone levels. The analysis of data suggested that there were no significant changes in the level of all these during high and low season.

The next step, the urinary biomarkers, 1-OHP will be detected by High Performance Liquid Chromatography (HPLC), malondialdehyde (MDA) will be detected using spectrophotometric analysis and a commercial ELISA kit will be used to detect 8-iso-prostaglandin-F2α (8-isoPGF2α). The laboratory analysis is going on for now at the Environmental Research Unit of Research Institute for Health Sciences, Chiang Mai University. This work was (partially) supported by Research Institute for Health Sciences, Chiang Mai University, grant number 020/2567.

The findings of this research will provide important information about the potential health impact of PM2.5 exposure on a population that is highly exposed to this pollutant. The research will also help to identify individuals who may be at increased risk of oxidative stress-related diseases, such as cancer, cardiovascular disease, and neurodegenerative diseases.

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Submicron Particle (PM_1-$PM_{0.01}$) Measurements on Public Transport in Bangkok, Thailand

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Traffic pollution significantly contributes to deteriorating air quality in megacities, leading to increased personal exposure among commuters, particularly during peak traffic periods. In Bangkok, levels of particulate matter (PM) frequently exceed the limits established by the World Health Organization. Particulate pollution is typically measured in mass concentrations of particles smaller than 10 µm (PM_{10}) or smaller than 2.5 µm ($PM_{2.5}$). Despite being often unnoticed, submicron particles (PM_1-$PM_{0.01}$) may pose significant health concerns and have been associated with cardiovascular conditions, lung cancer, and brain cancer.

In the study, particle number concentration (PNC) was measured during journeys on public transportation in Bangkok. The state railway showed the highest particle concentrations with measured peaks at 350,000 particles/cm^3, followed by buses at 330,000 particles/cm^3, BTS Skytrain at 33,000 particles/cm^3, and MRT underground at 9,000 particles/cm3. However, particle counts exceeding 100,000 particles/cm^3 may be underestimated due to instrument undercounting. Within each mode of public transport, particle number peaked when stopping to collect passengers (doors opening) and decayed with a half-life between 2 and 3 minutes. A weak correlation was observed between particle concentration on buses, trains, BTS, and Skytrain, and carbon monoxide concentration, as measured at a fixed location in the city. These results suggest that personal exposure to particulate matter may significantly differ from regional measurements, either due to smaller particles being omitted from routine measurements, or the importance of local sources, and therefore individual behaviour should be accounted for in exposure estimates.

P-04

Diurnal/Nocturnal Behavior of Particulate Matters during Dry Season in Phnom Penh, Cambodia

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Cambodia is one of the countries with growth of the national economy that has increased activity in key air pollutant emission sources including the number of vehicles, fuel consumption in industries and business, agricultural production, and waste generation. The movement of these activities contributes to arise of the air pollutants concentration. One of the major air pollutants is particulate matters (PMs) which is a complicated mixture of solid particles and liquid droplets suspended in the ambient air environment. Their size, chemical content, concentration level and other physical and biological features vary depending on pollution sources, differences in climate and geographical features, location and time. The authors have monitored PMs in Phnom Penh City for years and found that PMs varies not only seasonally but also differs between daytime and nighttime. One of our interesting findings was that sometimes we saw higher PMs concentration in nighttime than in daytime. The aim of this work is to discuss about diurnal/nocturnal behavior of PMs concentration during dry season in Phnom Penh city. A cascade air sampler called Ambient Nanoparticle Sampler (ANS), is used to analyze EC and OC in $PM_{0.1}$, which is important from aspect of high deposition rate to the human respiratory systems and reflection of local emission sources. A comparison the results of EC and OC in Total Suspended Particle (TSP) samples to discuss about PMs size effect on the carbonous components is covered. Moreover, we compared the carbonous components data with hourly meteorological, and particles monitor information to discuss about the time change of PMs in detail.

The sampling has been conducted at two locations in Phnom Penh; 1) a top-roof of 4-storeys building at the Institute of Technology of Cambodia (ITC) surrounded by universities, business building, coffee and tea shops, restaurants and hospital, 2)a top-roof of 5-storeys building at Ministry of Environment (MoE) of Cambodia nearby the Tonle Sap River where is a good ventilation of the fresh air. The sampling has been conducted around 11-12 hrs during the day and night in January to March in 2024. We used the ANS, trapping $PM_{0.1}$, $PM_{0.1\text{-}0.5}$, $PM_{0.5\text{-}1}$, $PM_{1\text{-}2.5}$, $PM_{2.5\text{-}10}$, and $PM_{>10}$ and a highvolume air sampler to collect (TSP). In ITC, the finding shown that $PM_{0.1}$ during daytime period in January and February are higher than nighttime. In March, the nighttime level was higher than daytime. In contrast, at MoE site where the $PM_{0.1}$ exhibited higher during the nighttime in January and February and the presents higher at daytime in March.

Immunological Impact of $PM_{2.5}$ on Human Peripheral Blood Mononuclear Cells (PBMCs) of Allergic Rhinitis

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Background: At present, air pollution has emerged as a global concern due to the expansion of industries, rapid urbanization, and the occurrence of agricultural burning and wildfires. This has led to a notable increase in deaths due to exposure to fine Particulate matter (PM), especially $PM_{2.5}$ (particles with a diameter of 2.5 micrometers or less), over the past decade. Moreover, a previous report indicated that the social cost attributed to $PM_{2.5}$ pollution was estimated at 2.17 trillion baht annually, nearly 11% of Thailand's 2019 gross domestic product (GDP). Thus, $PM_{2.5}$ poses a significant threat to both economic and public health aspects, particularly affecting the respiratory system. Furthermore, various studies have established a link between $PM_{2.5}$ exposure and the prevalence of allergic rhinitis (AR), prompting respiratory cells to produce allergenic substances. Nevertheless, there remains a scarcity of research on the immunological impact of toxic $PM_{2.5}$ on adaptive immunity in vulnerable populations like AR in Thailand. We, therefore, investigated the impact of $PM_{2.5}$ on inflammatory cytokines production in peripheral blood mononuclear cells (PBMCs) of patients with AR.

Methods: PBMCs of volunteers in the non-AR (n=7) and AR (n=4) groups were treated with 100 μg/ml of $PM_{2.5}$ or PHA (positive control) solution for 4 h and then measured the secretion of six inflammatory cytokines including IL-1β, IL-2, IL-5, IL-6, IFN-γ and TNF-α using multiplex ELISA.

Results: $PM_{2.5}$ exposure significantly increased the secretion of cytokines in PBMCs, particularly IL-1β, IL-2, IL-5, IL-6, and TNF-α (p<0.001) compared with the negative control (unstim), in both groups of volunteers (non-AR and AR). While the PHA solution (positive control) stimulated cytokine secretion in PBMCs in both groups (non-AR and AR), similar to the $PM_{2.5}$ solution, it significantly enhanced the secretion of all six cytokines, including IL-1β (p<0.05), IL-2, IL-5, IL-6, TNF-α, and IFN-γ (p<0.001). However, no significant differences were found in the expression of these cytokines in either $PM_{2.5}$ or PHA-exposed PBMCs when comparing the non-AR and AR groups.

Conclusion: The results suggest that exposure to $PM_{2.5}$ can induce inflammatory cytokines expression, including IL-1β, IL-2, IL-5, IL-6, and TNF-α in both AR and non-AR groups. Since the sample size was small, further studies with a larger sample size may be helpful to obtain more powerful data. Understanding the immunological impact of $PM_{2.5}$ on adaptive immune responses in PBMCs of patients with AR is crucial for elucidating the pathogenesis of AR and developing targeted therapeutic interventions. This serves as a guideline for the prevention, alleviation, and treatment of allergies caused by $PM_{2.5}$ in Thailand.

Keywords: $PM_{2.5}$; Allergic rhinitis; immunity; inflammatory cytokines

P-06

Short-term Exposure to $PM_{2.5}$-bound PAHs Associated with Higher Blood Glucose in Childhood

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INTRODUCTION

Diabetes can originate during early life [1]. Childhood hyperglycemia is a predictor of type 2 diabetes in adults[2]. The incidence of type 1 diabetes in Chinese children in recent years is 2/100,000 to 5/100,000, and the average annual growth rate of the incidence in children under 5 years old is 5% to 34% [3].

According to the Developmental Origins of Health and Disease (DOHaD), environmental factors in early life may contribute to the subsequent risk of metabolic morbidity later in life. The 2019 Global Burden of Disease Study shows that about 1/5 of the global burden of type 2 diabetes can be attributed to $PM_{2.5}$ exposure, that is, about 13.4% (9.49 ~ 17.5) of deaths due to type 2 diabetes and 13.6% (9.73 ~ 17.9) of DALYs due to type 2 diabetes are caused by environmental $PM_{2.5}$. From 2000 to 2020, the annual average concentration of $PM_{2.5}$ in the world's megacities increased by 112% and will continue to remain at a high level. A study on a Chinese general population over 40 years of age shows an association of short-term exposure (30 days) to $PM_{2.5}$ with elevated fasting blood glucose concentrations. Among 4418 adult participants in northern China, short-term exposure to $PM_{2.5}$ was associated with higher fasting blood glucose concentrations. A study involving 47,471 Chinese adults (average around 45 years old) found that 7-day, 21-day, and 28-day $PM_{2.5}$ exposure were all associated with increased fasting blood glucose concentrations. There are limited studies on $PM_{2.5}$ and blood glucose metabolism/diabetes risk in children. A cross-sectional study of children aged 6-13 years in Guangzhou, China (n = 4234) found that 186 days of medium-term exposure to $PM_{2.5}$ was associated with higher fasting blood glucose concentrations. Two long-term exposure studies on the Chinese population both found that the organic components in $PM_{2.5}$ may be the main reason for the association between $PM_{2.5}$ and diabetes, but has not been specifically localized to specific toxic pollutants. In summary, the heterogeneity among studies on markers related to $PM_{2.5}$ exposure and diabetes/glucose metabolism is so high, and related studies in children are so limited that it is necessary to continue to carry out relevant research. Although many studies are focused on the impact of $PM_{2.5}$ exposure on blood glucose, as well as the impact of overall exposure to polycyclic aromatic hydrocarbons (PAHs) (using urinary PAH metabolites as markers and no matter what exposure pathway) on blood glucose, the roles of specific chemical composites of $PM_{2.5}$ on blood glucose are still unclear. In particular, studies on the association of $PM_{2.5}$-PAHs on childhood blood glucose and diabetes are even rarer.

Guiyu town in Guangdong province, China has more than 40 years of e-waste dismantling history, and multiple toxicants have been detected in most local environmental media and biological samples [4,5]. Compared with other cities, higher levels of persistent organic pollutants and heavy metals/metalloids were detected in the atmosphere of Guiyu, mainly due to the informal dismantling and incomplete combustion of e-waste (e.g., plastic fragments, wire insulation materials, PVC materials, and metal scraps) [6]. $PM_{2.5}$ concentration in the Guiyu e-waste dismantling area and the reference area has decreased over the past ten years, but in each year's cross-sectional comparison, the Guiyu area is consistently higher than the reference area [7]. The chemical compositions of atmospheric $PM_{2.5}$ in Guiyu are very diverse, and PAHs play an important role. PAHs are a series of fused aromatic ring compounds that could be released to the environment by industry activities (blast furnace, bituminous grouting, etc.), daily life (cooking, heating, traffic exhaust, etc.), and natural activities (forest fires, etc.). In the past two decades, the concentration of PAHs in the atmosphere of e-waste dismantling areas has been consistently higher than that of other areas, even though the concentration of PAHs in the atmosphere has dropped in Guiyu [8]. This is consistent with the downward trend of global atmospheric PAH emissions, but still higher than the reference area. Guiyu established an official centralized dismantling area in 2014. At the end of 2015, the e-waste recycling industry was large-scale formalized, and many individual informal e-waste dismantling workshops were closed [9]. Based on these policies and approaches, local exposure to several toxicants such as lead has been decreased [10], but the recent trend of the exposure to PAHs in the local population especially in local children is unclear.

Considering that early life is a key time window for disease development and sensitivity to environmental factors, investigating environment-related disease origin is important for the prevention of chronic diseases. We aim to investigate the role of short-term exposure to e-waste $PM_{2.5}$-bound PAHs in elevated childhood blood glucose. We hypothesize that $PM_{2.5}$-bound PAH exposure is associated with higher fasting blood glucose and higher risks of impaired fasting blood glucose and diabetes. Our study would provide a reference for later mechanism research and an effective intervention for diabetes from early life.

METHODS

Study design and population

This is a cross-sectional study including the e-waste exposed group and the reference group. A total of 640 children 2- to 7- years of age were enrolled in 2019, including 440 living in Guiyu (exposed group) and 200 living in Haojiang (reference group).

Outcomes

Fasting blood glucose (mmol/L) was measured in the morning by a portable blood glucose meter and test strips. Impaired fasting blood glucose in childhood was defined as children with fasting blood glucose of 6.1 - 6.9 mmol/L. Childhood diabetes was defined as children with one of the following conditions: fasting blood sugar $\geqslant$7.0 mmol/L, 2 hours after a meal blood glucose $\geqslant$ 11.1 mmol/L, HbA1c $\geqslant$ 6.5%, random blood glucose $\geqslant$ 11.1 mmol/L with symptoms and signs.

Determinants

$PM_{2.5}$ samples were collected by a high volume air sampler with quartz filter membrane through physical examination and blood glucose measurement period (2 weeks around). PAH concentrations in $PM_{2.5}$ samples were measured via GC-MS and an internal standard method. The exposure dose of PM2.5-bound PAHs ($PM_{2.5}$-PAHs) was estimated by calculating the individual chronic daily intake (CDI) using the formula CDI = daily average concentration of $PM_{2.5}$-PAHs $\times$ 24-hour deposition estimation $\times$24-hour inhalation estimation/body weight.

Statistical analyses

Statistical analyses were performed using R 4.0.3, RStudio 1.2.5001, and SPSS 22.0 (IBM Corporation, NJ, USA). Comparisons of fasting blood glucose concentration, impaired fasting blood glucose, and diabetes between groups were conducted between the exposed group

(Guiyu) v.s. reference group (Haojiang), and across $PM_{2.5}$-PAHs exposure levels ($PM_{2.5}$-PAHs CDI tertiles T1 vs T2 vs T3). Correlations between $PM_{2.5}$-PAH exposure and fasting blood glucose were conducted using Spearman correlation in all children, low-exposed children, and high-exposed children separately. Associations of $PM_{2.5}$-PAHs exposure on blood glucose concentration, impaired fasting blood glucose, and diabetes were conducted by linear or logistic regression models with adjustments as follows: Model 1: crude model without adjustment; Model 2: Adjusted for age and gender; Model 3: Model 2 + father's education level, mother's education level, family monthly income; Model 4: Model 3 + family member smoking; Model 5: Model 4+ family history of diabetes.

RESULTS

Population characteristics

The age of the recruited 640 children was 2.50 to 7.22 years, and 47.65% of them were female. Compared with the reference group, children in the exposed group had a higher proportion of living in the workspace, e-waste pollution within 50 meters of the residence, parents engaged in e-waste dismantling-related occupations, passive smoking, lower parental education, and average household monthly income. The height z-score, weight z-score, and BMI z-score of children in the exposed group were all lower than those in the reference group.

Determinants between groups

$PM_{2.5}$-PAHs CDI in the exposed group was higher than that in the reference group ($P < 0.001$). $PM_{2.5}$-PAHs CDI correlated with living in Guiyu, living in the workspace, having e-waste contamination within 50 meters of residence, and having a father engaged in an occupation related to e-waste dismantling.

Outcomes across groups

Fasting blood glucose concentration in the exposed group was higher than the reference group (6.0 mmol/L vs 5.8 mmol/L, $P < 0.001$). However, there was no difference in fasting blood glucose concentration between the high and low levels of PAH exposure groups, but there was a difference between the three levels (Tertiles, T1/T2/T3). The fasting blood glucose concentration of the medium level (T2) $PM_{2.5}$-PAHs exposure group was higher than that of the high exposure group (T3) and than low exposure group (T1) (all $P < 0.05$).

Correlations between determinants and outcomes

Fasting blood glucose concentration was positively correlated with living in Guiyu, and e-waste pollution within 50 meters of residence (all $P < 0.05$). In all children, $PM_{2.5}$-PAHs CDI had no significant correlation with fasting blood glucose ($P > 0.05$); but among children with low exposure to $PM_{2.5}$-PAHs ($PM_{2.5}$-PAHs CDI was lower than median), $PM_{2.5}$-PAHs CDI was positively correlated with fasting blood glucose ($r = 0.13$, $P < 0.05$).

Association of $PM_{2.5}$-PAHs exposure with fasting blood glucose concentration

In all models, with the lowest exposure level (T1 in the $PM_{2.5}$-PAHs tertiles) as the reference, the intermediate exposure level (T2) was associated with increased fasting glucose concentration, whereas the high exposure level (T3) was not significantly associated with fasting glucose concentration.

Association of $PM_{2.5}$-PAHs exposure with impaired fasting blood glucose

In models 3, 4, and 5, with the lowest exposure level (T1 in the $PM_{2.5}$-PAHs tertiles) as the reference, high-level $PM_{2.5}$-PAHs exposure (tertile T3) was associated with an increased OR of impaired fasting glucose.

Association of $PM_{2.5}$-PAHs exposure with diabetes

In models 1 and 2, compared with the lowest exposure level (T1 in the $PM_{2.5}$-PAHs tertiles), medium-level exposure (T2) was associated with an increased OR of diabetes. In models 1 to 5, with the lowest quartile (Q1 in the $PM_{2.5}$-PAHs quartiles) as the reference, medium-level exposure (Q2) was associated with an increased OR of diabetes.

DISCUSSION

The present study is the first to investigate the impact of short-term $PM_{2.5}$-PAH exposure through inhalation on blood glucose in e-waste children.

The $PM_{2.5}$-PAHs CDI of Guiyu children were higher than those of Haojiang children. The $PM_{2.5}$-PAH exposure relates to the local e-waste industry. It indicates that Guiyu children are exposed to higher levels of e-waste-derived PAHs by inhalation.

The correlation between $PM_{2.5}$-PAHs CDI and blood glucose in children was more significant in the low-exposure group instead of in the high-exposure group. It indicates that a low level of PAH exposure could already have an impact on childhood blood glucose.

The associations of $PM_{2.5}$-PAHs CDI with higher blood glucose and with diabetes risk were observed in medium-exposed children, whereas associations of $PM_{2.5}$-PAHs CDI with increased risk of impaired fasting blood glucose were observed in high-exposed children. It indicates that not only high levels of exposure, but also medium levels of exposure to $PM_{2.5}$-PAHs may impact childhood blood glucose.

This study suggested that even short-term exposure to $PM_{2.5}$-PAHs could impact childhood blood glucose.

CONCLUSION

Short-term $PM_{2.5}$-PAH exposure is a risk factor for childhood hyperglycemia.

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P-07

Air Pollution in Sri Lanka: Trends, Impacts, and Policy Responses

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Introduction

According to the World Health Organization (WHO) in 2019, air pollution is responsible for approximately 4.2 million premature deaths globally each year[1,2]. Consequently, ambient air quality management has emerged as a critical issue of concern worldwide. An effective air quality management system encompasses several key components: monitoring the air quality, assessing the data collected, developing appropriate policies, implementing these actions, and evaluating their effectiveness. Each of these elements plays a vital role in the overall strategy to improve air quality and safeguard public health.

Air pollution represents one of the most urgent environmental and public health emergencies in contemporary Sri Lanka. The nation, historically noted for its rich biodiversity and lush landscapes, is now grappling with the adverse effects of rapid urban expansion and escalating industrial activities. As Sri Lanka strides towards economic development, the environmental costs have become increasingly apparent, particularly in the degradation of air quality. This abstract delves into a comprehensive analysis, drawing from recent government reports, to depict a clear picture of the current state of air pollution, examine its health impacts, and assess the effectiveness of the policies enacted to manage and improve air quality.

Air Pollution Trends

The 2022 Annual Air Quality Report issued by the Ministry of Environment shows a concerning picture of the air pollution situation in Sri Lanka, especially within its burgeoning urban centers. Colombo, the commercial heart of the nation, is particularly highlighted for its deteriorating air quality. The Colombo metropolitan area boasts a population density of approximately 10,103 people per square kilometer. According to the Department of Census and Statistics (2017), around 578,400 vehicles are registered in this area. Additionally, each day sees an influx of about 500,000 people and over 100,000 vehicles into the city[3]. The concentration of industries, thermal power plants, and commercial activities within and around the Colombo Metropolitan Region (CMR), along with the presence of Sri Lanka's largest port within its boundaries, significantly contributes to the area's air pollution levels. Among these sources, vehicular emissions stand out as the predominant contributor to the region's air pollution. Figure 1 depicts the annual average SO_2 concentration levels for each selected urban area in 2017. The data shows that the highest average SO_2 level for that year was observed in the Colombo urban area[4].

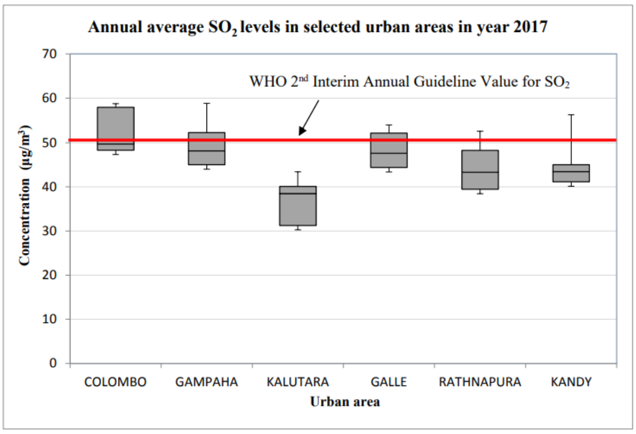

Figure 1: Annual average SO_2 levels in selected urban areas in year 2017 (Air Quality Assessment for Health and Environment Policies Progress Report, 2018, Ministry of Environment)

Spatial analysis in Air Quality Assessment for Health and Environment Policies Progress Report, 2018 reveals that areas with high traffic congestion frequently register pollutant levels that sometimes exceed the WHO's recommended guidelines. Conversely, areas identified as pollution sinks, such as wetlands with water bodies, regions rich in greenery, elevated terrains, and locations distant from urban centers, consistently show lower levels of pollutants. This pattern underscores the significant impact of urban activities on air quality and highlights the natural mitigation provided by certain landscapes[4].

Vehicular Emissions

The growth in vehicular emissions is directly tied to the increasing number of vehicles on the road, fueled by urban expansion and a rising middle class. The proliferation of both private and commercial vehicles, often older models that lack modern emission-controlling technologies, contributes significantly to the concentration of harmful pollutants in the air. These emissions are dominated by particulate matter and nitrogen oxides, which not only degrade air quality but also pose significant health risks to the urban population.

The outcomes of air quality management efforts and associated research activities demonstrate significant reductions in SO_2 levels in the Colombo urban area. These reductions are attributed to targeted environmental policies. Specifically, more substantial declines were observed from 2012 to 2016, where NO_2 levels fell by 45% due to the implementation of vehicular emission reduction programs. This figure 2 highlights the effectiveness of policy interventions in mitigating air pollution in urban settings[4].

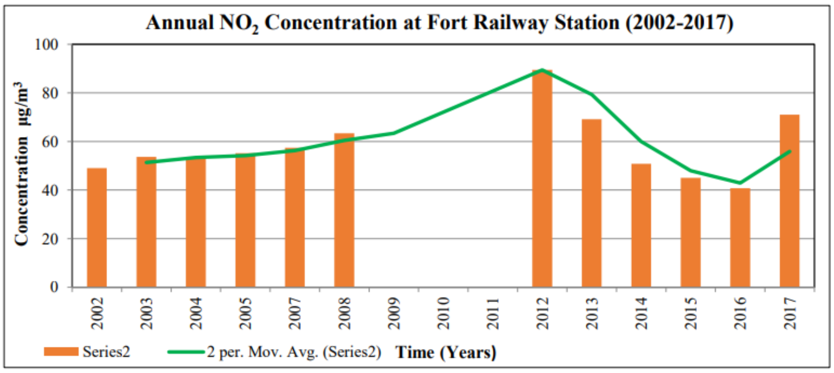

Figure 2: Annual NO_2 Concentration at Fort Railway Station, Colombo from 2012 to 2017 (Air Quality Assessment for Health and Environment Policies Progress Report, 2018, Ministry of Environment)

The relationship between the density of registered vehicles and the annual average concentrations of NO_2 and SO_2 in the areas of Colombo, Sri Jayawardenapura Kotte, Dehiwala, and Kaduwela is depicted in Figure 3. The data reveals a trend where, in all Divisional Secretary (DS) areas except for Kaduwela, there is a negative correlation between vehicle density and NO_2 levels, while a positive correlation exists with SO_2 levels. In contrast, the Kaduwela DS area shows a positive correlation for both NO_2 and SO_2 levels with the density of registered vehicles[4].

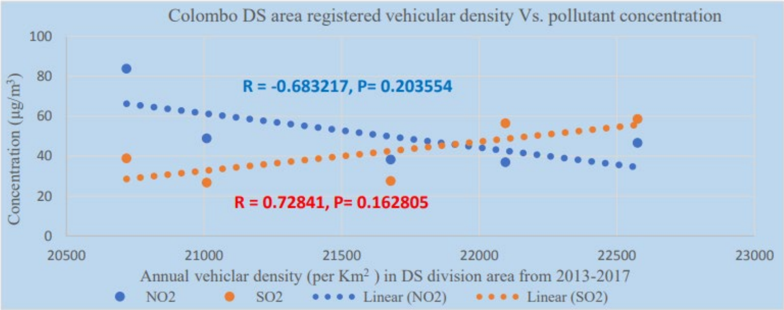

Figure 3: Scattered plot of registered vehicular density and pollutants level respect to NO_2 and SO_2 from 2013 to 2017 in Colombo DS (Air Quality Assessment for Health and Environment Policies Progress Report, 2018, Ministry of Environment).

The air quality data collected from the Ambient Air Quality Monitoring System (AAQMS) site in Battaramulla indicates that there were significant improvements in ambient air quality in Colombo during the period when lockdown (LD) measures were implemented. The reduction in human activity, particularly in transportation and industrial operations, led to a noticeable decrease in air pollutants (Figure 4a and 4b)[5].

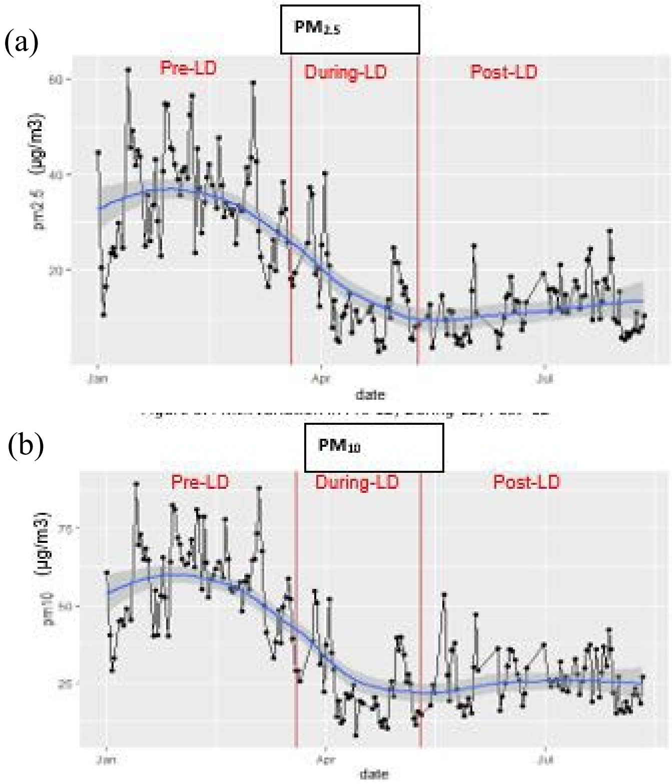

Figure 4: (a) Air quality (Particulate Matter [PM] $_{2.5}$) and (b) PM_{10} during covid 19 lock down period in 2020 (Air Resource Management and Monitoring Unit, 2023)

Industrial Discharges

Industrial activity, a cornerstone of Sri Lanka's economic development, is another critical source of air pollution. Factories and power plants, particularly those relying on fossil fuels, are substantial contributors to the levels of SO_2 and NO_2 in the atmosphere. These industries, often located near or within urban areas to minimize transportation costs of raw materials and finished goods, release a variety of pollutants through their stacks. The regulatory framework overseeing these emissions is often outpaced by the rapid scale and scope of industrial operations, leading to pollution levels that frequently breach safe limits. Thermal power plants and industries, primarily located in the northern part of Colombo city[4].

Seasonal variations

Figure 5 shows the monthly average variation patterns of NO_2 and SO_2 levels from 2013 to 2017 in the Colombo urban area. The data shows that both SO_2 and NO_2 levels begin the year at relatively high points in January, gradually decrease until mid-year, and then rise again towards the end of the year. This pattern suggests a strong influence of local wind patterns on pollutant levels[4].

The increase in pollution levels during the North East monsoon period (November to February) is particularly notable, with levels during this time being approximately 2 to 3 times higher than during the South West monsoon period (May to August). The significant disparity in pollutant levels between these periods can be attributed to the lower dispersion of pollutants during the North East monsoon. This may be caused by wind shear effects due to prevailing sea winds, or possibly due to the transportation of pollutant loads from thermal power plants and industries located in the northern part of Colombo city. These findings indicate a crucial need for targeted air quality management strategies during specific times of the year to effectively mitigate the impact of seasonal pollution peaks[4].

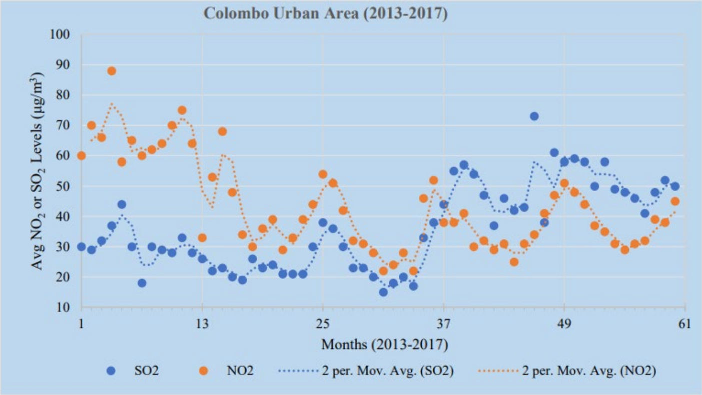

Figure 5: Monthly average SO_2 and NO_2 level trends during 2013-2017 in Colombo urban area (Air Quality Assessment for Health and Environment Policies Progress Report, 2018, Ministry of Environment)

Health Impacts

According to the Ministry of Health's 2021 report, the detrimental health impacts of poor air quality are profound, with thousands of premature deaths and increased incidences of respiratory and cardiovascular diseases reported annually. Particularly vulnerable are children, the elderly, and individuals with pre-existing health conditions. The health data compellingly argue for urgent and effective interventions to reduce exposure to harmful air pollutants, which currently pose significant risks to public health[6].

Governmental Responses

The National Air Quality Action Plan (NAQAP), implemented by the Sri Lankan government in 2020, marks a significant and strategic effort to combat the escalating problem of air pollution across the nation. This plan is a response to the persistent deterioration of air quality, particularly in urban centers, which has been exacerbated by industrial growth and increased vehicular traffic. The NAQAP is comprised of a series of targeted initiatives aimed at addressing the core contributors to air pollution[7].

One of the key aspects of the NAQAP is the focus on improving fuel quality. By setting higher standards for fuel purity, the government aims to reduce the number of harmful emissions released by vehicles and industries, thereby improving air quality. This initiative not only helps in lowering immediate pollution levels but also benefits public health in the long run[7].

Another significant element of the plan is the promotion of electric vehicles (EVs). Encouraging the use of EVs through incentives, tax breaks, and infrastructure development, such as the expansion of charging stations, aligns with global trends towards sustainable transportation. This shift not only helps in reducing dependency on fossil fuels but also mitigates the emission of pollutants like nitrogen oxides and particulate matter from traditional combustion engines[7].

Enhancing the public transportation system is also a crucial strategy within the NAQAP. By improving the efficiency, reliability, and coverage of public transit, the plan seeks to reduce the reliance on private vehicle use, which is a major source of urban air pollution. Upgrading public transit not only makes it a more appealing option for daily commutes but also contributes significantly to the reduction of traffic congestion and associated emissions[7].

Furthermore, the NAQAP imposes stricter emission standards for industries, which are often major sources of air pollution. These regulations are designed to compel industries to adopt cleaner technologies and practices, such as the use of scrubbers and filters, and to adhere to best practices in environmental management. Compliance with these standards is enforced through regular monitoring and penalties for non-compliance, ensuring that industries contribute to the national goals of air quality improvement[7].

Overall, the NAQAP illustrates a comprehensive approach to environmental governance, aiming to weave together the strands of air quality management with broader sustainable development objectives. This plan not only addresses the immediate concerns of air pollution but also sets a foundation for sustainable urban and industrial growth in Sri Lanka, demonstrating a commitment to both environmental stewardship and public health[7].

Despite the ambitious objectives of the NAQAP, its implementation has been marred by several challenges. These include limitations in the current air quality monitoring systems, financial constraints, and a lack of sufficient public awareness and engagement. The Annual Air Quality Reports serve as periodic evaluations of policy effectiveness, revealing some progress but consistently emphasizing the need for a more robust implementation strategy and increased financial and technological resources to meet air quality standards[7].

Conclusion

Colombo holds the distinction of having the highest air pollution rates in Sri Lanka, primarily driven by vehicle emissions. Additionally, the quality of air is significantly influenced by seasonal changes. In response to these challenges, the government has launched decisive policy interventions aimed at curtailing the severe air pollution problem. However, due to the dynamic nature of air pollution, which is influenced by both local activities and global environmental trends, it is essential that these strategies are continually assessed and updated. Strengthening collaboration among government agencies, the private sector, and civil society is crucial for effectively addressing the complexities of air pollution and markedly improving air quality.

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Effects of Chemical Constituents and Sources of Indoor Fine and Coarse Particulate Matter on Cardiopulmonary Function among Patients with Chronic Obstructive Pulmonary Disease in Beijing, China

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Background

Particulate matter is a major environmental issue worldwide, contributing to 4.14 million deaths and 118 million disability-adjusted life years (DALYs) in 2019. Although the level of ambient particulate matter has improved in China and other regions, more than 99% of the population still experiences high exposure that exceeds the WHO Air Quality Guideline. While numerous epidemiological studies have shown that short and long-term exposure to particulate matter is associated with adverse respiratory and cardiovascular effects, most studies have focused on outdoor particles. However, people spend more than 80% of their time indoors, and indoor particulate matter accounts for the majority of individual exposure, making it more closely related to adverse health outcomes. Unfortunately, the decline rate of indoor particulate matter is much slower than that of outdoor particles, highlighting the urgent need to address the health effects of indoor particulate pollution.

Chronic obstructive pulmonary disease (COPD) is a common chronic respiratory disease that has become one of the top three causes of death worldwide and in China, affecting nearly 100 million adults. Patients with COPD may be more susceptible to particulate pollution in terms of cardiovascular and respiratory systems than healthy individuals. COPD patients may spend more than 90% of their time indoors, which means that indoor air pollution is a significant concern. Although limited studies have reported that short-term exposure to indoor fine particulate matter ($PM_{2.5}$) is associated with changes in cardiovascular health of COPD patients even at relatively low concentrations, including altered cardiac autonomic function, decreased pulmonary function, increased respiratory symptoms, and higher risk of exacerbations, little attention has been paid to particles with other sizes such as coarse particulate matter ($PM_{2.5\text{-}10}$). Therefore, it is essential to investigate the health effects of indoor particulate matter of different sizes in COPD patients.

It is important to note that evidence based solely on total mass concentration is insufficient for establishing effective preventive measures to protect susceptible populations from the cardiorespiratory effects of indoor particulate matter. While current studies primarily focus on the mass concentration of $PM_{2.5}$, they overlook the fact that particles are a complex mixture of various chemical constituents due to their diverse sources. Particularly, particulate matter of different sizes is likely to have significant differences in chemical composition and sources, as is the case for indoor and outdoor particulate matter. The chemical components and sources largely determine the effects of particulate matter. However, there is limited evidence on the associations between the characteristics of indoor particulate matter, including size, mass concentration, chemical constituents, and sources, and the cardiopulmonary function of patients with COPD. This lack of evidence has hindered the development of targeted measures to control indoor particulate pollution and improve the life quality of patients with COPD. Therefore, it is crucial to investigate the relationships between the characteristics of indoor particulate matter and the cardiopulmonary function of COPD patients to develop effective preventive measures.

Furthermore, previous studies have only investigated the individual effects of $PM_{2.5}$ constituents, to our knowledge. However, particulate matter is a complex mixture, and potential interactions between different constituents may exist. Therefore, evaluating the joint effects of mixed constituents is necessary to provide additional evidence on their actual health effects. Traditionally, the effect of each constituent in the mixture is estimated using multivariable parametric regression approaches. However, this approach has limitations, such as multi-collinearity and model misspecification, which make it challenging to adjust for other constituents in the mixture. A novel statistical approach, Bayesian kernel machine regression (BKMR), can flexibly model the joint effect of mixture constituents, allowing for potential interactions and nonlinear effects. This approach provides an opportunity to establish new evidence on the cardiopulmonary effects of multiple chemical constituents of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$.

The aim of the present study was to investigate the associations between indoor $PM_{2.5}$, $PM_{2.5\text{-}10}$, and their chemical constituents with cardiopulmonary function in stable COPD patients in Beijing, China. The study identified the sources of these chemical constituents and examined a) the cardiopulmonary effects of each constituent using traditional approaches; b) the overall effect of all measured constituents and the effect of each constituent as part of a mixture using BKMR; c) the differences in the effects of emission sources during different seasons. By using BKMR, the study aimed to provide new evidence on the cardiopulmonary effects of multiple chemical constituents of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$, allowing for potential interactions and nonlinear effects. This approach would help establish effective preventive measures to protect susceptible populations from the adverse effects of indoor particulate matter.

2 Methods

2.1 Study design and participants

The present study recruited 43 patients with COPD from the Peking University Third Hospital in Beijing, China, between November 2015 and May 2016, covering two seasons: heating (November 2015 to January 2016) and non-heating (March 2016 to May 2016). The inclusion criteria were: 1) doctor-diagnosed stable COPD patients, and 2) residents of Beijing for over one year to eliminate regional migration confusion. The exclusion criteria were: 1) patients with other chronic respiratory diseases such as asthma or severe cardiac diseases, 2) patients with a history of lung surgery or occupational dust exposure, and 3) patients taking anti-hypertensive drugs. The study protocol was approved by the Institutional Review Board of Peking University Health Science Center (IRB number: 00001052–14042), and informed consent was obtained from each participant before the study.

2.2 Exposure measurements

Participants' main area of activity was equipped with SKC sampling systems, featuring a flow rate of 3L/min, to collect indoor $PM_{2.5}$ on 37 mm and $PM_{2.5\text{-}10}$ on 25 mm Teflon filters (SKC Inc, Eighty Four, PA, USA) at a height of 1.5 m. $PM_{2.5}$ and $PM_{2.5\text{-}10}$ outside each residence were also collected simultaneously. Daily sampling was conducted from 8:00 a.m. to the next day 8:00 a.m. for five consecutive days in each household. Before and after sampling, filters were weighed in the laboratory to determine daily mass concentrations of $PM_{2.5}$ and $PM_{2.5\text{-}10}$. Twenty-four elements of $PM_{2.5}$ were measured using inductively coupled plasma mass spectrometry, including sulfur (S), sodium (Na), magnesium (Mg), aluminium (Al), potassium (K), calcium (Ca), titanium (Ti), vanadium (V), manganese (Mn), iron (Fe), bromine (Br), lead (Pb), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), strontium (Sr), molybdenum (Mo), cadmium (Cd), stannum (Sn), antimony (Sb) and barium (Ba). Twenty-one elements of $PM_{2.5\text{-}10}$ were measured, including S, Mg, Na, Al, Ca, Fe, Cu, Zn, V, K, Mn, Sr, Ba, Mo, As, Cd, Pb, Co, Ni, Se and chromium (Cr). Field blank filters were also performed to adjust for sampling artifacts, following the same procedures as sampling filters, but the sampling pump was not turned on. Samples with less than 50% sampling time were excluded. Indoor temperature and relative humidity (RH) were measured with a temperature/RH recorder (Model WSZY-1B; Tianjianhuayi Inc, Beijing, China) during the study period.

To identify the preliminary sources of elements, enrichment factors (EFs) were calculated, with EF < 10 indicating crustal origin and EF > 10 suggesting anthropogenic origin. Al was chosen as the reference element based on a previous study. Subsequently, principal component analysis (PCA), a widely used method for source apportionment of particulate matter, was employed to identify the specific sources of measured constituents of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$. The principal components (PCs) with eigenvalue > 1 were retained. Finally, multiple linear regression (MLR) analysis was performed to quantify the contribution of each identified source.

2.3 Health measurements

Following the completion of each daily sampling, a trained technician measured the blood pressure (BP) of participants at least three times using the Omron 705IT automated oscillometric monitor (HEM-759-E; Omron Healthcare Co. Ltd., Kyoto, Japan). The interval between each measurement was a minimum of 1 minute. The average BP values within a 5-mmHg range of difference were calculated and used as the final BP value. Additionally, pulmonary function measurements, including peak expiratory flow (PEF) and forced expiratory volume in the first second (FEV_1), were conducted using the electronic PEF diary meter (Model 2110; Vitalograph Ltd., Buckingham, UK).

2.4 Statistical analysis

Linear mixed-effect models with a random-effect intercept for each participant were utilized to assess the association between indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$ mass concentration and cardiopulmonary indicators. For single constituent analyses, three models were established to estimate the effects of each constituent and evaluate their robustness. Firstly, a single-constituent model was established to investigate the associations between health measurements and each chemical constituent. Secondly, a constituent-$PM_{2.5}$ or $PM_{2.5\text{-}10}$ joint model was built by incorporating indoor $PM_{2.5}$ or $PM_{2.5\text{-}10}$ total mass into the first model to test whether the association of health measurements with the constituent was independent of $PM_{2.5}$ or $PM_{2.5\text{-}10}$. Thirdly, the residual of each constituent was obtained by establishing a linear regression model between each constituent and indoor $PM_{2.5}$ or $PM_{2.5\text{-}10}$ total mass. Then, the constituent in the single-constituent model was replaced with its residual to establish the constituent-residual model to estimate the "independent" health effect of each constituent. The final results were expressed as changes with 95% confidence intervals (CIs) in cardiopulmonary function associated with an interquartile range (IQR) increase in the concentration of indoor $PM_{2.5}$, $PM_{2.5\text{-}10}$, and their constituents.

For the joint effect analyses, BKMR models were employed to estimate the overall effect of all measured chemical constituents on cardiopulmonary function and the effect of each constituent as part of a mixture. A random intercept was incorporated to control within-participant correlation between the repeated measurements. Due to the high correlation between exposures, we fit the model with hierarchical variable selection based on the results of PCA, which allowed us to estimate the group posterior inclusion probability (groupPIP) and the conditional posterior inclusion probability (condPIP) for each exposure. A larger PIP indicates higher importance, and a threshold of 0.5 is typically used to determine whether a constituent is important. The exposure-response relationship between each constituent and outcome was plotted with other constituents fixed at their median concentrations. Then, we estimated an overall effect of the mixture on each outcome by comparing the value of the exposure-response function when all constituents' concentrations are at a particular percentile (e.g., 75th percentile) to when all of them are at their median. Furthermore, we estimated the single-exposure associations by comparing the effect when a single constituent was at the 75th percentile as compared to when that constituent was at its 25th percentile, while all of the remaining constituents were fixed at different levels (25th, 50th and 75th percentile). The potential interaction was evaluated by comparing the single-exposure risk for each constituent (associated with a change from its 25th to 75th percentile) when all of other constituents were fixed to their 75th percentile to when all of them were fixed to their 25th percentile. To facilitate efficient Markov chain Monte Carlo (MCMC) sampling, the exposure and outcome variables were scaled. We ran BKMR models with 100,000 iterations for each outcome variable.

Linear mixed-effect models were also employed to assess the associations between each PC of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$, representing different sources, and cardiopulmonary function. The final results were expressed as a regression coefficient and *P*-value, with a *P*-value of <0.05 (two-sided) considered statistically significant. Furthermore, the joint effects of chemical constituents from different sources were evaluated using BKMR models based on the results of PCA.

In all of the aforementioned models, age, sex, smoking status, body mass index (BMI), and long-term time trend, including day-of-measurement and squared day-of-measurement, were controlled. Additionally, the variables day-of-week, temperature, and relative humidity (RH) were included to account for weekly effects and environmental influences. All analyses were conducted using R software (version 4.0.3) with the "lme4" package for linear mixed-effect models and the "bkmr" package for the BKMR analysis.

3 Results

3.1 Participant characteristics

The study included 43 participants, with 93.0% being male. The average age and BMI were 71.5 years and 24.7 kg/m^2, respectively. The mean SBP, DBP, PEF, and FEV_1 were 129.4 mmHg, 72.3 mmHg, 272.0 L/min, and 1.3 L, respectively. All participants used natural gas or electricity as their energy source for cooking. Based on the daily activity diaries of the participants, they spent over 90% of their time indoors during the study period.

3.2 Source identification of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$ inorganic elements

The mean concentration of indoor $PM_{2.5}$ was 66.13 ± 70.00 μg/m^3 throughout the study period, 91.94 ± 117.84 μg/m^3 during the heating season and 58.60 ± 46.39 μg/m^3 during the non-heating season. The concentrations of S, K, Fe, Na, Al and Mg were relatively high in indoor $PM_{2.5}$, and most elements had high EFs (>10). According to the results of PCA, combustion sources (characterized by high loading for S, K, Mn, Co, Zn, As, Se, Cd, Sn, Sb, Pb and Br), soil dust (characterized by high loading for Na, Mg, Sr and Ba) and road dust (characterized by high loading for Al, Ti, Fe, V and Ni) were identified as the three main sources of indoor $PM_{2.5}$. The contribution of combustion sources to indoor $PM_{2.5}$ in heating season was greater than that in non-heating season (40.74% *vs.* 23.37%). The contribution of combustion sources to indoor $PM_{2.5}$ in heating season was higher than that in non-heating season (40.74% *vs.* 23.37%) while the contribution proportion of soil/dust sources was slightly lower in heating season (49.80% *vs.* 56.31%).

For indoor $PM_{2.5\text{-}10}$, its mean concentration throughout the study period was 30.13 ± 20.94 μg/m^3, and it was higher in the non-heating season (39.99 ± 19.81 μg/m^3) than in the heating season (16.32 ± 12.69 μg/m^3). The concentrations of Ca, Al, Fe, Mg, S, Na and K were relatively high, and most elements had low EFs (<10). Soil dust (characterized by high loading for Na, Mg, Al, K, Ca, V, Mn, Fe, Co, Cu, Sr, Mo and Ba), coal burning (characterized by high loading for S, As, Pb, Cd, and Se) and indoor alloy wear (characterized by high loading for Cr and Ni) were identified as the main sources of indoor $PM_{2.5\text{-}10}$.

3.3 Estimated effects of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$ mass concentration

The study found that indoor $PM_{2.5}$ was significantly associated with decreased lung function in COPD patients, particularly during the heating period. An IQR (102.4 μg/m^3) increase in indoor $PM_{2.5}$ at two-day and three-day moving average was associated with a reduction of 1.7% (95%CI:−2.9%, −0.5%) and 2.3% (95%CI: −4.4%, −0.2%) in FEV_1, respectively. However, no significant effects of indoor $PM_{2.5}$ total mass on SBP and DBP were observed.

During the entire study period, an IQR (23.12 μg/m^3) increase in the 1-day average concentration of indoor $PM_{2.5\text{-}10}$ was associated with changes of 0.88 (95CI: -0.25, 2.01) mmHg in SBP, 1.15 (95CI: 0.25, 2.06) mmHg in DBP, -2.29% (95CI: -4.07%, -0.51%) in FEV_1, and -1.68% (95CI: -3.41%, 0.06%) in PEF. During the heating season, significant negative associations with PEF and positive associations with DBP were observed for $PM_{2.5\text{-}10}$. Additionally, $PM_{2.5\text{-}10}$ was negatively associated with FEV_1 during the non-heating season.

3.4 Estimated joint and individual effects of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$ constituents

Throughout the study period, the overall associations of mixed constituents of indoor $PM_{2.5}$ with SBP and DBP were positive, while the associations with PEF and FEV_1 were not significant. During the heating season, the overall effects of mixed constituents on SBP and DBP were more significant, with positive associations observed when all of the constituents were at their 55th percentile or above compared with at 50th percentile. However, the overall effect on PEF and FEV_1 remained non-significant. Significant effects of mixed constituents of indoor $PM_{2.5\text{-}10}$ were only observed on elevated SBP throughout the study period, with stronger effects observed during the heating season.

The single constituent analyses revealed that multiple constituents of indoor $PM_{2.5}$ were associated with changes in cardiopulmonary health of COPD patients. During the heating season, S, K, Zn, As, and Cd of indoor $PM_{2.5}$ were associated with a reduction in PEF, and most constituents were positively associated with SBP or DBP of COPD patients. During the non-heating season, only the significant association between S and increased DBP was observed. For the constituents of indoor $PM_{2.5\text{-}10}$, S, Zn, and As were associated with decreased PEF, and Ca, Fe, Al, V, Cu, Sr, and Ba were associated with increased DBP during the heating season. However, no significant association was observed between indoor $PM_{2.5\text{-}10}$ constituents and changes in cardiopulmonary function in COPD patients during the non-heating season.

3.5 Effect estimates of sources

To provide more direct evidence for pollution prevention and control, we further estimated the associations between each PC of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$, representing different sources, and cardiopulmonary function. The first principal component (PC1, combustion source) of indoor $PM_{2.5}$ was positively correlated with DBP (β=0.801, P=0.026) throughout the study period and during the heating season. Additionally, the third principal component (PC3, road dust source) was positively correlated with SBP (β=1.798, P=0.023) and DBP (β=1.290, P=0.021) during the heating season. However, this study did not find any significant association between principal components of indoor $PM_{2.5\text{-}10}$ and cardiopulmonary health in COPD patients.

4 Conclusions

The two major sources of indoor $PM_{2.5}$ and $PM_{2.5\text{-}10}$ inorganic elements were soil dust and combustion sources. The chemical constituents of indoor particulate matter had stronger effects on the cardiorespiratory function of COPD patients than their mass concentration, and thus, should be given more attention. The inorganic constituents and certain sources of indoor $PM_{2.5}$ were more closely related to the cardiopulmonary health of COPD patients, especially during the heating season, indicating that this may be a critical period for effective intervention. Combustion and road dust sources and related constituents may play an important role in indoor $PM_{2.5}$ mediated impaired cardiovascular function of COPD patients, but the effects of different sources of indoor $PM_{2.5}$ on lung function require further study. It is important to note that the cardiorespiratory effects of indoor $PM_{2.5\text{-}10}$, especially its effects on increased BP, should not be ignored. These findings suggest that targeted measures to control key toxic components and sources of indoor particulate matter that affect cardiorespiratory health are essential and may be more effective in safeguarding the well-being of susceptible populations.

P-09

Exposure to polyaromatic hydrocarbons, biomonitoring of its metabolites and risk assessment among foundry workers

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Risk associated with the polyaromatic hydrocarbons (PAHs) in workplace environment was very much concern, even with low dose of exposure for carcinogenicity of certain PAHs compounds. The degree of exposure level of PAHs in the work environments also higher than the general population and. Researchers have reported increased incidences of skin, lung, bladder, liver, and stomach cancers, as well as affect the hematopoietic and immune systems in animals. Increased prevalences of lung, skin, and bladder cancers are associated with occupational exposure to PAHs. Once PAHs entered into the body, they are persisting in the body in the form of parent compounds in different organ or metabolised.

Workers engaged in foundries were not considered much important in the aspects on organic pollutants (PAHs) exposure in the workplace. Also, the majority of the industry having lack of data on the PAHs exposure and its effect and risk involving the workplace. Therefore, the present study was conducted to evaluate the exposure to dust, PAHs, bio-monitoring of its metabolites and associated risk in among the foundry workers.

Personal exposure PAHs (both vapour & particulate phase) samples were collected from each worker according to NIOSH Method 5506 during different process iron foundry. The personal sampling system consisted of a PTFE filter paper (Zefluor, Pall Gelman Sciences, Cat. No. P5PJ037) placed in the cassette holder to collect particulate PAHs, connected in series with an XAD-2 Sorbent tube (ORBO 43, Supelco, Cat. No. 2-0258) to collect the vapour phase PAHs near the breathing zone for 8-hours. The flow rate was maintained at 2.0 LPM/min and the flow rates were checked before, during and after sample collection using a calibrated Rotameter. After sampling the filter paper and sorbent tubes were wrapped with aluminium foil to prevent sample degradation due to sunlight. Samples were transported in cold chain and stored in -20°C until analysis. The analysis was carried out at Industrial Hygiene & Toxicology Division, Regional Occupational Health Centre (Southern), ICMR, Bangalore Laboratory.

Processing of Samples & PAHs Analysis: The samples collected on filter paper and sorbent tube was extracted with acetonitrile and cyclohexene in an ultrasonic bath for 30 min at room temperature. The extracts were concentrated under rotary evaporator and changed to acetonitrile. All these concentrated samples were filtered through syringe filter (0.45µm Millipore PTFE filters) before analysis in HPLC. All the samples were analysed for a mixture of sixteen PAHs simultaneously. The sixteen PAHs compounds namely were Naphthalene (NAP), Acenaphthene (ACE), Acenaphthylene (ACY), Anthracene (ANT), Phenanthrene (PHE), Fluorene (FLU), Fluoranthene (FLT), Benzo(a)anthracene (BaA), Chrysene (CHR), Pyrene (PYR), Benzo(a)pyrene (Bop), Benzo(b)fluoranthene (BbF), Benzo(k)fluoranthene (BkF), Dibenz(a,h)anthracene (DahA), Benzo(g,h,i)perylene (BghiP) and Benzo(g,h,i)perylene (IND). The excitation and emission wavelength was 340 nm and 425 nm respectively. Samples (20 µl) were injected using an HPLC system equipped with the fluorescence detector (FLD) with a C18 reversed phase column (250mm x 4.6 nm, 5 µm). A solvent gradient was acetonitrile and deionized water with linear gradient from 60% acetonitrile/ 40% deionized water to 100% acetonitrile at 1.5 ml/min over 50 minutes. The HPLC system was calibrated using an external standard mixture. A standard mixture containing 16 PAHs mixture provided by Sigma Aldrich was used for calibration and quantification. The limit of detection (LOD) of PAHs varied from 0.01-0.20 µg/l, the relative standard deviation (RSD) of PAHs was less than 12% and recovery of the sample from 75-110%.

Dose PAHs was measured using personal air monitoring devices where gaseous and particulate phase of PAHs was trapped on sorbent tube and filters and then analysed for PAH content. The Internal dose was measured as urinary PAHs metabolites which was recommended as biomarkers of exposure. The risk assessment was carried out with help of Risk Assessment Information System toolkit (RAIS 2013) provided by The California Environmental Protection Agency. The risk of PAHs compounds exposure in the indoor workplace through inhalation, formula of Risk Assessment Information System toolkit (RAIS 2013) provided by The California Environmental Protection Agency.

Workplace respirable dust monitoring was carried out in the shop floors of the foundry throughout the full work shift and the levels were found to be relatively higher in the finishing section and it has also exceeded the ACGIH standard (TLV 3.0 mg/m^3) of respirable dust. In the foundry study, we have obtained from the result of prediction about each process unit by Bayesian model that the percentage of the excess rate of respirable dust in the Shakeouts, Felting and Finishing sections.

The PAHs exposure among the foundry workers also found in the various sections of foundries workplace the mean ΣPAHS concentration was 76.36±11.55 μg/m^3 in the foundries with ranged 2.78 - 478.43 μg/m^3. The most abundant PAHs were ACE (14.49±4.09 μg/ m^3), BaP (11.72±1.61 μg/ m^3), NAP (9.45±2.09 μg/ m^3), and ACPy (6.59±1.87μg/ m^3) and BghiP (6.54±1.11 μg/ m^3). Among ΣPAHs monitored for personal exposure, 27% exceeded the value of 100 μg/ m^3 prescribed by The National Institute for Occupational Safety and Health (NIOSH) workplace exposure for 8-hours' Time Weight Average (TWA).

The mean ∑PAHs and total carcinogenic PAHs (BaA, CHR, BbF, BkF, BaP, DahA, BghiP and IND) was 180.21 μg/m^3 and 60.50 μg/m^3 respectively in the molding section and higher than other sections. The personal exposure of BaP which was categorized as a most carcinogenic was 27.64±3.03 μg/m^3 in the blasting section. The exposure loads of ΣPAHs in the finishing section were 84.07±24.12 μg/m^3 followed by blasting (61.10±7.80 μg/m^3), melting (45.19±14.76 μg/m^3) and shaking-out sections (37.06±10.82 μg/m^3). 80% of personal exposure PAHs exceeded the prescribed limits in the molding section, followed by 33% in finishing, 13% in melting,10% in blasting and 7% in shaking-out process section exceed the limits.

An indirect exposure assessment urinary 1-OHP and OHPHE are the indicator of internal dose. It was found that urinary 1-OHP levels were significantly (<0.05) higher among the foundry workers (1.35±1.29 μmole/mole creatinine) than the control (0.38±0.73 μmole/mole creatinine). Also, the OHPHE levels of the workers were at significant higher with control, although it was also elevated than the control group. The 1-OHP level was observed higher among the workers with smoking habits than non-smoker workers as well as controls with smoking habits (0.78±1.20 μmole/mole creatinine) and non-smoker control was 0.28 ±.57 μmole/mole creatinine. In this study, the mean 1-OHP value of the foundry workers was 1.35±1.29 μmole/mole which was below the recommended biological exposure limits (BEL) prescribed by different authors.

Estimates have been made of the burden of cancer attributable to PAHs factors and of the contribution of risk in of occupational cancer because, there has long been concern that airborne carcinogens contribute to the global burden of cancer, especially of the lung, which receives the most substantial inhaled doses. The total unit risk of PAHs among the foundry workers was estimated as $1.55x10^{-02}$ with Bap ($1.05 x10^{-02}$), DahA ($4.14 x10^{-03}$) contributing 94.45% of total risk and the estimated lifetime cancer risk value was $1.55x10^{-02}$ (1.5 people may develop cancer risk among 100 foundry workers exposed by PAHs in the workplace).

The total unit risk of PAHs among the foundry workers was estimated as was $6.41x10^{-03}$ with Bap ($4.18 x10^{-03}$), DahA ($1.71 x10^{-03}$) contributing 92% of total risk and The total unit risk of PAHs in this occupational exposure group was $6.41x10^{-03}$ with Bap ($4.18 x10^{-03}$) & DahA ($1.71 x10^{-03}$) contributing 92% of total risk. According to the World Health Organization (WHO, 2000) Air Quality Guidelines for Europe, the unit risk was 10^{-5} (one extra cancer case in 100,000 exposed individuals in the general population) and USEPA guideline was 10^{-6} (Morrone, 2007; USEPA,1984).

The present study demonstrated that PAH exposure and its metabolites in Foundry workers may be risk to their health if proper and suitable precautionary methods such as using appropriate Personal Protective devises are not used. Though the concerned Industry management or proprietor provides the facilities to the workers an awareness should be created among the trade unions, middle level workers and individual worker for effective control measures. This will help in reducing the exposures and will create healthy work environment.

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Self-reported Symptoms of Heavy Metal Exposure among Electronic Waste Workers in Northeastern Thailand

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Occupational exposure more than the limit of quantitation: LOQ of urinary levels of lead (3 µg/L), cadmium (0.5 µg/L), and arsenic (5 µg/L) may cause symptoms and health effects in electronic waste (e-waste) workers. The goals of this study were to investigate symptoms of heavy metal exposure among e-waste workers, as well as factors associated with their self-reported symptoms. A cross-sectional study was conducted among 164 e-waste workers in Ubon Ratchathani province, Thailand. Data were collected using an interviewer-administered questionnaire and urinary analysis by Atomic Absorption Spectrometer. Univariate analysis of each variable was first done, and then variables with a p-value less than 0.2 were included in the multivariate.

The result found that the most common symptoms reported in the last month until the week preceding the interview were muscle pain (45.7%), followed by excessive sweating (29.3%), skin rash (24.4%), headache (23.8%), and numbness in hands/feet (19.5%). A multiple logistic regression analysis revealed that muscle pain was significantly associated with working more than 6 days per week (aOR=2.4; 95%CI=1.1-5.2), eating or drinking in the working area (aOR=2.6; 95%CI=1.3-5.2), wearing a glove (aOR=0.1; 95%CI=0.01-1.0), and exposure to lead (aOR=3.5; 95%CI=0.9-12.9). Excessive sweating was significantly associated with drinking alcohol (aOR=4.4; 95%CI=2.1-9.2) and working more than 6 days per week (aOR=1.8; 95%CI=0.8-4.1). Skin rash was significantly associated with taking a bath immediately after working (aOR=0.3; 95% CI=0.1-0.6) and working more than 8 hours per day (aOR=2.9; 95% CI=1.3-6.2), and exposure to lead (aOR=1.8; 95% CI=0.6-5.8). Headache was significantly associated with drinking alcohol (aOR=1.9; 95% CI=0.9-4.2), working more than 6 days per week (aOR=2.3; 95% CI=0.9-5.8), and wearing a glove (aOR=0.2; 95% CI=0.04-0.8), and exposure to lead (aOR=1.6; 95% CI=0.5-5.4). Numbness in the hands/feet was significantly associated with eating or drinking in the working area (aOR=3.1; 95% CI=1.2-8.0), wearing a mask (aOR=0.3; 95% CI=0.1-0.7), and wearing glasses (aOR=0.5; 95% CI=0.2-1.1).

Personal hygiene practices may reduce the health effects of heavy metal exposure, particularly lead, which is associated with the most symptoms in e-waste workers. Additionally, alcohol consumption behavior has the potential to induce symptoms.

Temporal Trend Changes in Blood Heavy Metal(Loid) Levels with the Risk of Childhood Anemia from a Typical E-waste Recycling Area in China from 2006 - 2023

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Lead is able to damage child health through different exposure manners and no safe threshold of lead for children has been identified. Even low levels of blood lead, such as less than 5 and 10 μg/dL, are confirmed to have toxic effects on children. It has been verified that lead exposure in children (measured by blood lead levels, BLLs) is associated with impairment of several systems including nervous, immune and hemopoietic system. Reduction level of hemoglobin (a special protein in erythrocytes essential for oxygen transportation) indicates a risk of anemia, which in children can have many adverse effects on their health, including poor physical, cognitive, and behavioral development.

Electronic waste, or e-waste, refers to discarded electronic appliances. According to e-waste monitoring predictions, China is expected to produce 28 million tons of e-waste annually by 2030. E-waste pollution remains one of the environmental challenges in China. Heavy metal(loid)s are the main components of e-waste, accounting for around 60%, primitive dismantling methods lead to serious heavy metal(loid) contaminations, in which lead is the largest and most representative. Guiyu is one of the largest e-waste dismantling areas in China, with a history of e-waste dismantling and recycling for 40 years.

Since 2003, our research group has estimated lead exposure for the child cohort through BLLs measured in children in Guiyu, a typical e-waste recycling area. The previous National Health and Nutrition Examination Survey analyses of BLL data have compared trends in U.S. general children by selected age groups, sociodemographic, and housing characteristics over a 40-y period. Hence, conducting a continuous and cross-sectional annual survey of child lead exposure in this characteristic area is rare but necessary. Although higher BLLs in children has been linked to significantly decreased hemoglobin levels, evidence has been limited to a single-year survey. This study was designed to take advantage of secular trends in lead pollution from informal e-waste dismantling activities by local residents to explore the anemia risk (estimation mainly through hemoglobin levels) among children recruited cross-sectionally within the same set of kindergarten over a period of lead pollution decline. A generally declined trend in BLLs of children in this e-waste recycling area was observed over time based on previous studies. However, the temporal trends in the BLLs among children from the same kindergarten in this area are not well established. Furthermore, potential attributable risk factors of blood heavy metal(loid) burden among children and association with hemoglobin levels and other blood-related parameters have not been evaluated. This study characterized trends in BLLs of children aged 2-7 years from 2006 to 2023 using recall data of child dietary habits, behavior and e-waste contact from the annual physical examination. This study further assessed the association of temporal trend changes in BLLs with hemoglobin levels in children from 2011 to 2017 and heavy metal(loid) exposure with blood-related parameters in children from 2021-2023. Such information can provide priorities and policies around control of lead pollution and improve the health quality of children in this special e-waste polluted place.

The study population of e-waste exposed area was drawn from a kindergarten in Guiyu from 2006 to 2023 (n = 3896). The reference population in 2006 and 2008 were recruited from a kindergarten in Chendian (n = 203), whereas participated children from 2011 to 2023 were from a kindergarten in Haojiang (n = 1559). Annually pre-designed questionnaires regarding the children’s diet and behavior habits, and e-waste exposure, as well as demographic information, were completed by the parents or guardians.

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We used data on participants ages 2-7 years with valid blood lead measurements and grouped them by e-waste exposure and survey periods: 2006-2012, 2013-2019, 2020-2023. Particularly, for the survey period, we set a time point at 2013 based on the local government starting out to establish a Circular Economy Industrial Park in Guiyu for comparison analysis, and another time point at 2020 is because of the Covid-19 restriction policy, which have impacted the local e-waste recycling activities. Prevalence of participants, geometric means (GM) with geometric standard deviation (GSD) of BLLs, and prevalence (%) of BLLs ≥ 5 μg/dL (CDC blood lead reference value since 2012) were calculated by overall, gender (boys and girls), age (2-3- years, 4-5- years, and 6-7 years), BMI level (less than 15.5, 15.5 - 17.0, and ≥17.0), maternal and paternal education level (primary school or below, middle or high school, college or above), passive smoke exposure (no/yes) and average household income per month (< 3000 Chinese yuan [CNY], 3000 - 6000 CNY, > 6000 CNY). Comparative analysis of the differences in BLLs and prevalence of BLLs ≥ 5 μg/dL between e-waste exposed children and reference were analyzed using t test and Pearson chi-square as appropriate, whereas for overall mean age and BMI were used independent-sample t test.

GM (GSD) for BLLs and the estimated prevalence (%) of BLLs ≥ 5 μg/dL were calculated by aforementioned characteristics and potential influencing factors for lead exposure among e-waste exposed children. Comparative analysis of the differences in the GM (GSD) for BLLs of participants categorized by the investigating factors in e-waste exposed children were analyzed with t-test or one way ANOVA. An overall trend or stratified by the selected characteristics of GM BLLs during the entire period was assessed with one way ANOVA . We also calculated the overall prevalence (%) of BLLs ≥ 10 μg/dL and ≥ 5 μg/dL for children aged 2-7 years in aggregate among e-waste exposed area, as well as presented GM of BLLs in children from e-waste exposed area and reference area by survey years. Changes of child BLLs and prevalence (%) of BLLs ≥ 10 ug/ dL and ≥ 5 ug/ dL over time were determined by comparing each of the estimates from earlier years with the estimate from 2006 to 2023, using t-test.

We set BLLs of children ≥ 5 ug/ dL as high BLL. The adjacent survey periods (2006-2012, 2013-2019, 2020-2023) in e-waste exposed area were respectively combined to estimate prevalence of achieving risk factor control goals. Factors associated with lead exposure were identified with logistic models, with all of the aforementioned categorical variables included as covariates. Multivariable linear regression analyses (adjusted for confounding factors including child age, gender, BMI, parental education, passive smoke exposure, and average household income per month, times of child eating iron canned products in a year) on exploring the association of child BLLs with hemoglobin levels were performed using combined data from 2011 to 2023 measured in the total samples of e-waste exposed children. Logistic models for binary outcome structure were conducted to investigate the effect estimates for the associations between child BLLs and the risk of anemia.

The significantly and generally decreasing trend in GM BLLs was observed among all population subgroups of both the exposed and reference children from 2006 to 2023 (range, 8.09 to 16.58 vs. 5.73 to 10.07 μg/dL; range, 3.36 to 4.67 vs. 2.40 to 3.82 μg/dL). Particularly in the exposed children, their GM BLLs appeared a precipitous fall in 2009, but had a steep rebound to a higher level (than before) in 2010 among all population subgroups. In contrast, the slightly decreasing trend in GM BLLs of the exposed children was observed from 2011 to 2014, but the slightly increasing trend was found from 2014 to 2016 and ultimately decreased to 2019. Also the general downward trends in the GM BLLs of both exposed children and reference children over time were be noticed. Nonetheless, in the exposed children, their GM BLLs had a precipitous decline in year of 2009 which interrupted an upward trend before. However, they had a steep rebound to a highest level in 2010 and then gradually decreased to a lower level in 2014. After two years transient elevating in 2015 and 2016, they slightly decreased again year by year. In contrast, the reference children in Chendian were in a relatively higher level of blood lead, whereas reference children in Haojiang had the general downward trends in the GM BLLs over time though varied slightly in 2015 and 2018. Nonetheless, in the e-waste exposed children, the upward trends in prevalence (%) of high BLL (≥ 10 μg/dL and ≥ 5 μg/dL) were observed from 2006 to 2010, except for a sudden drop in 2009. After year of 2010, there were the general downward trends in prevalence (%) of high BLL in the exposed children from 2011 to 2019, although with a slightly variation in 2015 and 2016. Also, it is clear to know the GM BLLs and prevalence (%) of high BLL were all significantly higher in the exposed children before year of 2013 than those values after year of 2013. Throughout the overall survey periods, among the e-waste exposed children, the highest GM BLLs were observed in children with diet of eating preserved eggs, drinking dairy products, and eating bean products 1-3 times a month in a year, whereas children eating iron canned products every day in a year had the highest GM BLLs. The exposed children always washing hands before eating food, never sucking fingers or biting nails, never biting pencils or erasers, never sucking or biting toys had the lowest GM BLLs. Similarly, the higher frequency of child touching e-waste, or child living place is a workplace, or having stacked e-waste or dismantling sites or pollutants within 50 meters of the child residence, or child parents work related to e-waste recycling, the higher GM BLLs in the exposed children. Moreover, significantly higher prevalence (%) of high BLL (≥ 5 μg/dL) and GM BLLs in children before year of 2013 (2006-2012) were observed than those results after year of 2013 (2013-2023) [87.0% vs. 53.2%.; 10.92 (± 2.40) vs. 5.31 (± 1.60), $P < 0.001$]. These findings were still persisted even though being stratified by each potential influencing factor including child diet, behavior and e-waste exposure related activities.

In multivariable logistic regression analyses, exposed children whose parents' work was related to e-waste recycling (father's adjusted odds ratio [AOR], 1.73 [95%CI, 1.44-2.07]; mother's AOR, 2.51 [95%CI, 1.79-3.59]), having stacked e-waste or dismantling sites or pollutants within 50 meters of the residence (AOR, 1.58 [95%CI, 1.33-1.88]), higher frequencies of pencil or eraser biting behaviors (AOR, 1.40 [95%CI, 1.17-1.68]), greater frequencies of eating canned products (AOR, 1.29 [95%CI, 1.11-1.49]), higher frequencies of toy sucking or biting behaviors (AOR, 1.25 [95%CI, 1.07-1.47]), as well as higher frequencies of playing and touching with e-waste (AOR,1.16 [95%CI,1.04-1.28]) had greater odds of having high BLL, whereas higher frequencies of hand washing before eating food was the main protective factor for the exposed children with high BLL (AOR = 0.83, [95%CI, 0.75-0.92]).

There was a significant negative association between BLLs and hemoglobin level among e-waste exposed children over 7 years (from 2011 to 2023, n = 2836), after adjustment of confounding factors including child gender, age, body mass index, parental education, passive smoke exposure and average household income per month, times of child eating iron canned products in a year (b = -0.28, 95%CI: -0.40 to -0.16, $P < 0.001$). Temporal trend changes in BLLs were also accompany with changes in child hemoglobin level. The logistic regression analysis by combining all the data from 2011 to 2023 was performed to explore the effects of BLLs on the risk of child anemia among e-waste exposed children. BLL was positively associated with child anemia risk even adjusted for gender, age, and BMI (AOR = 1.08, 95%CI: 1.02, 1.13, $P = 0.002$). Each 1 μg/dL increase of BLLs in the exposed children, their anemia risk would elevate 8%. This tended to be an elevation of 6% in anemia risk with each 1 μg/dL increase of BLLs in the exposed children after adjustment of all potential confounders including parental education, passive smoke exposure, average household income per month and even times of child eating iron canned products in a year (AOR = 1.06, 95% CI: 0.99, 1.12, $P = 0.071$).

Additionally, a significant negative association was observed between heavy metal(loid) exposure and blood-related parameters among e-waste-exposed children in 2021 (n = 272), after adjustment of confounding factors. Interaction analysis showed that the effect of blood heavy metal(loid) exposure on children's blood-related parameters was modified by gender, age, and BMI. The study implied the potential risk of anemia associated with metal Cu exposure. To more specific, multiple linear regression analysis revealed child blood Cu level was negatively correlated with blood-related parameters, with increasing levels of Cu in blood associated with decreases in hemoglobin ($\beta = -2.743$, 95% CI: -4.49, -0.995), mean corpuscular volume ($\beta = -1.024$, 95% CI: -1.767, -0.281), mean corpuscular hemoglobin ($\beta = -0.505$, 95% CI: -0.785, -0.226), mean corpuscular hemoglobin concentration ($\beta = -2.137$, 95% CI: -3.54, -0.734), and hematocrit ($\beta = -0.005$, 95% CI: -0.01, -0.001). Cluster analysis

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found that children with high levels of heavy metal Cu exposure had lower mean corpuscular hemoglobin and mean corpuscular volume compared to the low concentration group, indicating the sensitivity of Cu element to blood-related parameters and suggesting a potential risk of anemia. The Mann-Whitney U test was employed to analyze the significant differences in blood heavy metal(loid) levels of children grouped by family environment and behavioral factors, to identify potential influencing factors. Result indicated that housing characteristics were associated with children's blood heavy metal(loid) levels. Higher levels of metal V exposure were associated with exposed soil nearby, higher Cd concentrations associated with closer proximity to main roads, and increased Cr exposure associated with the use of paint as wall surface material. Several family behavioral factors related to children's blood heavy metal(loid) levels were also identified, with children from households using indoor shoe cabinets and frequently ventilating windows showing significantly higher heavy metal(loid) levels. Furthermore, healthy dietary habits were found to effectively reduce heavy metal(loid) exposure, while hand-to-mouth behaviour increased heavy metal(loid) exposure in children.

In this serial cross-sectional study of a typical e-waste recycling area, kindergarten data from 3896 Chinese children aged 2-7 years, their GM BLLs and prevalence of high (≥ 5 g/dL) BLLs decreased substantially (from 12.0 to 3.8 g/dL and from 100% to 19.8%). Child eating habits, behavior and activities relate to e-waste were the risk factors for having high BLL. BLLs was negatively associated with hemoglobin level in the e-waste exposed children. Heavy metal(loid) exposure related to disadvantageous changes with blood-related parameters. Elevation of blood heavy metal(loid) levels, especially BLLs, were associated with the risk of child anemia. Among children aged 2-7 year in a typical e-waste recycling area of China, the BLLs and prevalence of BLLs ≥ 5 g/dL in children reduced significantly from 2006 to 2023 and this contributed to lower the risk of child anemia.

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Adsorption of Heavy Metal from Surface Water Using Manganese-Oxide Acrylic Fiber in Eastern Economic Corridor (EEC) Area, Thailand

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Manganese oxide acrylic fiber was prepared by soaking the acrylic fiber (TORAY 3 denier) in 3 mol Sodium Hydroxide solution at a temperature of 80 degrees Celsius for one hour or until the fibers turn orange-red and soaking in a 0.5 mol Potassium Permanganate solution at a temperature of 80 degrees Celsius for one hour or until the fibers turn shiny black. The preparation makes the acrylic fibers effective at absorbing radioactive radium-226 with the highest percentage was 94.95±2.18 and a low blanking value of 0.15±0.13 dpm/g (0.0025±0.0022 Bq/g). Seawater samples added with standard substances radium-226 was filtered through 5 grams of the fiber packed in a cylindrical plastic tube. The result shows that the fibers were effective at absorbing radium-226 with the highest percentage was 94.94±2.18 when the filtration rate was 250 and 500 milliliters per minute. The manganese oxide acrylic fibers can be used in conjunction with chemical analysis methods to measure radium-226 from 4 liters of seawater (Jintasaeranee, 2008). This method has powerful enough for measurement radioactive matters in surface water that the USEPA (2012) defines the standard criteria of radioactive radium-226 in surface water for consumer water and drinking water of 0.111 Bq/L (6.66 dpm/L). However, natural radioactive matters as well as the heavy metals eg. cadmium, copper and lead can be determined using gamma spectrometer Probe type HPGe and ICP-OES respectively (Jeasai et al., 2009). This method is suitable for analyzing large samples and makes it easier to study small amounts of substances in water. Eastern Economic Corridor (EEC) area (the Bangpakong Watershed and East Coast of the Gulf of Thailand) will be the area of a future study.

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Insights into Heavy Metal Contamination in Indian Rivers and Government-led-Initiatives

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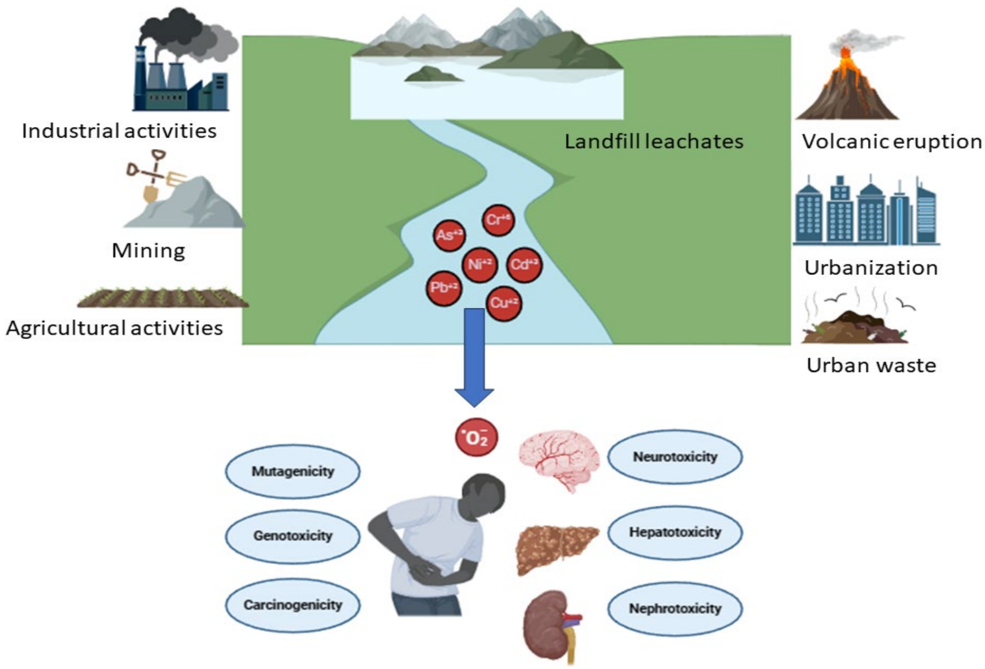
Graphical Abstract



Highlights:

1. The abstract draws attention to the pervasiveness of heavy metal contamination in Indian waters, which puts communities all over the country at serious risk to their health and the environment.
2. It focuses about the proactive steps, such as policy frameworks and regulatory activities, that the Indian government has done to address this important issue.
3. The abstract highlights the trace of heavy metals found in Indian rivers according to the different studies conducted by Indian government.

Introduction

In addition to being one of the most significant and fundamental natural resources on the planet, water is also one of the most crucial necessities for our daily existence. The lifeline of all living things is this natural resource. The two natural sources of clean water on earth are snow and rain. The first stage of water's trip on Earth consists of surface runoff, which manifests as rivers, lakes, and streams. There is always the same amount of water accessible in the world. Most people agree that there is enough water on Earth to satisfy all of humanity's needs. However, its variable quality and distribution throughout the world's geographical regions lead to issues with appropriateness and scarcity. Because water is a natural resource that is essential to the country's processes of social and economic growth, it is vital to check its quality in order to preserve its healthy state.

One of the main environmental issues in India is water pollution, which is the introduction of pollutants into natural waters that have a negative impact. The release of waste and contaminants into surface runoff flowing to surface water sources, involving urban runoff and agricultural runoff that might include chemical fertilisers and pesticides, eutrophication and littering, emissions of untreated or semi treated industrial effluents, mining operations, and the purposeful or unintentional spilling of commercial and industrial wastewater into surface waters are all considered forms of pollution. Numerous water sources have been contaminated, making them dangerous for humans and other living things. In addition to building up through the food chain, the harmful compounds dumped into water bodies have the potential to restrict the diversity of animals or create dense populations of microbes. Numerous factors have an impact on aquatic habitats, which considerably reduce biodiversity. Worldwide, river pollution is a problem for the environment. A number of aquatic habitats are dying as a result of human activity due to unheard-of development. Pollution occurs when different nutrients and other contaminants enter aquatic ecosystems through storm water runoff and sewage flowing into rivers. The aquatic ecosystem that contains a variety of creatures, including fish, may be adversely affected by heavy metal pollution, especially if it affects non-essential elements. Because heavy metals can bio accumulate and multiply in the food chain and become harmful to living beings at greater tropical levels in nature, they are especially significant in eco-toxicology.

Trace of heavy metals in drinking water sources

With the help of its expert groups, the WHO has identified about 100 pollutants and established permissible limits for them in order to provide safe drinking water. The Bureau of Indian Standards (BIS) is in charge of maintaining the water's documentary standard in India. The acceptable quantity of pollutants in water for human consumption is specified by standard IS 10500.

Significant concentrations of hexavalent and total chromium have been found in numerous wells that are adjacent to some of the enterprises in Tamil Nadu's industrial district of Ranipet. The sources are localised groups of tanneries and other enterprises. These wells had total chromium concentrations ranging from 3.1 to 246 mg/L and hexavalent chromium [Cr(VI)] concentrations ranging from 2.1 to 214 mg/L, all of which are significantly higher than the 0.05 mg/L allowed by the Indian Standards Specification for Drinking Water Quality. As a result, [Cr(VI)] is seriously contaminated the ground water in these places. [Cr(VI)] levels in groundwater in the Kanpur Dehat village of Khanpur, in the Rania area, were likewise found to be high, ranging from 1.05 to 35.34 parts per million (1).

According to data provided by Central Ground Water Board (CGWB), in the State of Punjab, specifically in the Malwa belt, three districts—Mansa, Faridkot, and Sangrur—have reported finding arsenic in ground water that exceeds permissible limits; three districts—Bathinda, Ferozepur, and Muktsar; four districts—Fatehgarh Sahib, Ludhiana, and Patiala; three districts—Chromium, Mansa, and Sangrur districts; and nine districts—Bathinda, Moga, Faridkot, Fatehgarh Sahib, Ferozepur, Ludhiana, Muktsar, Patiala, and Sangrur—have found uranium (2).

According to the study conducted in 2019 (3), by Central Water Commission (CWC) it was found that:

1. **Arsenic in Indian Rivers:** The BIS has established an acceptable threshold for arsenic concentration in drinking water of 0.01 mg/L (10 µg/L). Between August 2018 and December 2020, a total of 2834 water samples were collected and tested for arsenic levels in Indian rivers from 688 water quality monitoring stations. The range of the arsenic concentration is 0.00 to 13.33 µg/L. In December 2019, the Porakudi water quality monitoring station on the Rasalar river, a tributary of the Cauvery river, recorded the highest levels of arsenic (13.33 µg/L). Eight sites had arsenic concentrations above allowable limits based on data from all of the river's water quality stations.

2. **<u>Cadmium in Indian Rivers:</u>** The BIS has suggested that the permissible level of cadmium in drinking water is 0.003 mg/L (3 µg/L). During the period of August 2018 to December 2020, a total of 3113 water samples were collected and tested for cadmium levels in Indian rivers from 688 water quality monitoring stations. The range of the cadmium levels is 0.00 to 12.57 µg/L. In December 2020, the Todarpur water quality monitoring station on the Suketa river recorded the highest quantity of 12.57 µg/L of cadmium. Based on information provided by all river water quality stations, it was discovered that at 11 locations, the concentration of cadmium exceeded allowable levels.
3. **<u>Chromium in Indian Rivers:</u>** The BIS has established an acceptable limit of 0.05 mg/L (50 µg/L) for chromium in drinking water. Between August 2018 and December 2020, a total of 3106 water samples were collected and tested for the presence of chromium in Indian river from 688 water quality monitoring stations. The range of the content of chromium is 0.00 to 180.47 µg/L. The highest concentration of chromium (180.47 µg/L) was recorded in December 2019 at the Hasdeo river's M.B.P.L. water quality monitoring station. It was discovered that the permissible limits for chromium concentration were exceeded at 46 spots based on reported data from all river water quality stations.
4. **<u>Lead in Indian Rivers:</u>** The BIS has established a tolerable lead value of 0.01 mg/L (10 µg/L) in drinking water. Between August 2018 and December 2020, a total of 3111 water samples were collected and tested for lead levels in Indian rivers from 688 water quality monitoring stations. The range of the lead concentration is 0.00 to 67.55 µg/L. The highest concentration of lead (67.55 µg/L) was recorded in May 2020 at the Chopan water quality monitoring site on the Sone river. 34 sites have lead concentrations above allowable limits, according to data from all of the river water quality stations.
5. **<u>Copper in Indian Rivers:</u>** The BIS has established an acceptable threshold of 0.05 mg/L (50 µg/L) for copper in drinking water. Between August 2018 and December 2020, a total of 3107 water samples were collected and tested for copper concentration in Indian rivers from 688 water quality monitoring stations. The range of the copper concentration is 0.00 to 132.64 µg/L. In December 2019, the Ulhas river's Badlapur water quality monitoring station recorded the highest concentration of copper at 132.64 µg/L. Copper concentration was determined to be over allowable limits at 17 places based on reported data from all river water quality stations.
6. **<u>Nickel in Indian Rivers:</u>** BIS has established an acceptable nickel value of 0.02 mg/L (20 µg/L) in drinking water. Between August 2018 and December 2020, a total of 3111 water samples were collected and tested for nickel content in Indian rivers from 688 water quality monitoring stations. The range of the nickel concentration is 0.00 to 242.90 µg/L. In December 2020, the Elunuthimangalam water quality monitoring station on the Noyyal River recorded the highest levels of nickel (242.90 µg/L). Based on information provided by all river water quality stations, it was discovered that at 199 locations, the concentration of nickel was higher than permitted.

<u>Initiatives taken by Indian government for water management and quality</u>

Different initiatives have been done by the Central Government for aiding ground water quality improvement/ remediation of contamination in the drinking water in the country (2)

1. The Central Pollution Control Board (CPCB), in collaboration with State Pollution Control Boards/Pollution Control Committees (SPCBs/PCCs), is enforcing the regulations outlined in The Water (Prevention & Control) Act, 1974 and The Environment (Protection) Act, 1986 throughout the country. The objective is to prevent and manage water pollution.
2. The Government of India initiated the Jal Shakti Abhiyan (JSA) in 2019. This campaign aims to enhance water availability, particularly in areas with water scarcity. The JSA has a time-bound approach and employs a mission mode strategy to address issues related to groundwater conditions in 256 districts across India. For this purpose, groups of officials from the Central Government, along with technical officers from the Ministry of Jal Shakti,

were assigned to tour districts facing water scarcity. Their objective was to closely collaborate with local officials and implement appropriate measures. Also, the Ministry of Jal Shakti has initiated the "Jal Shakti Abhiyan: Catch the Rain" (JSA:CTR) with the objective of covering all blocks in both rural and urban areas of Punjab, as well as the entire country. This initiative was implemented from 22nd March 2021 to 30th November 2021, with the theme "Catch the Rain - Where It Falls When It Falls". The campaign was initiated by the Honourable Prime Minister on 22 March 2021. The implementation of artificial recharge structures and increased water collection is expected to greatly enhance groundwater recharge, leading to a substantial reduction in the concentration of pollutants in the aquifer waters.

3. The Government of India, in collaboration with the states, has been carrying out the Jal Jeevan Mission (JJM) from August 2019. The mission aims to ensure that every rural household in the country, has access to clean and safe tap water by 2024. Under the administration of JJM, when devising water supply projects to deliver tap water to households, emphasis is placed on prioritising habitations that are impacted by water quality issues. When distributing funding to States/ UTs in a specific financial year, 10% of the importance is placed on the population living in areas impacted by chemical contaminants such as Arsenic and Fluoride, as of March 31st of the previous financial year.
4. Subsequently, organising, execution and establishing of piped water supply strategies relying on a safe water source may take time, purely as a temporary measure, States/ UTs have been advised to install community water purification plants (CWPPs) in such habitations, to provide potable water to every household at the rate of 8–10 litre per capita per day (lpcd) to meet their drinking and cooking necessities.
5. Department of Drinking Water & Sanitation had launched a National Water Quality Sub-Mission (NWQSM) on 22nd March, 2017 as a part of National Rural Drinking Water Programme (NRDWP), which has now been subsumed under JJM, to provide safe drinking water to 27,544 arsenic/ fluoride affected rural habitations in the country.
6. Under Atal Mission for Rejuvenation and Urban Transformation (AMRUT) which was inaugurated on 25th June, 2015 in selected 500 cities of the country with focus on improvement of urban infrastructure in various sectors including water supply. States/UTs have the ability to take projects on specific water supply arrangements for difficult terrain, hill and coastal towns, including those suffering water quality difficulties.
7. Under the National Aquifer Mapping Programme (NAQUIM) of CGWB, significant emphasis is being given to the aspect of ground water quality including pollution by harmful compounds such as arsenic in ground water.
8. CGWB has developed various exploratory and observation wells in the Country tapping the arsenic safe deeper aquifer zones determined by exploration aided comprehensive aquifer mapping under NAQUIM. Successful wells have been handed up to the State Governments for their deliberate exploitation. Further, CGWB is giving technical help to the states by sharing the cement sealing technology for tapping contamination free aquifers in Gangetic flood plains.
9. This Ministry has released regulations for control and regulation of groundwater extraction with Pan-India applicability notified on 24 September 2020. The guidelines include suitable provisions on steps to be adopted to control groundwater pollution.
10. River restoration and cleaning is a continuous process. The States/UTs and local bodies bear the obligation of guaranteeing that sewage and industrial effluents are treated in accordance with defined standards prior to being released into rivers, other water bodies, coastal waters, or land, with the aim of preventing and controlling pollution in these areas. The Ministry has been supporting the States' and Union Territories' efforts to conserve the nation's rivers by offering financial and technical support for the reduction of pollution in specific river segments under the Central Sector Scheme of Namami Gange for rivers in the Ganga basin and the Centrally Sponsored Scheme of National River Conservation Plan (NRCP) for other rivers. With a project sanctioned cost of Rs. 5961.75 crore, the NRCP has so far covered filthy sections on 34 rivers in 77 towns distributed across 16 states in the nation. Among other things, a sewage treatment capacity of 2677.03 MLD (million litres per day) has been built. A total of 353 projects, including 157 for the treatment of 4952 MLD of wastewater and 5212 km of sewer network, have been approved under the Namami Gange plan (4).

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Health effects due to heavy metals

There are several ways that heavy metals impact human health. The kind and concentration of heavy metal, the length of exposure, and the method of exposure all affect which organ is impacted as well as how severe the health conditions are (5).

Arsenic

There have been reports of arsenic contamination in public tube well water in the Nadia district of West Bengal. Out of all those who were exposed, 15.44% of cases (15 skin lesions) had arsenicosis, whereas 84.56% of controls (no skin lesions) had the disease. The average exposure to arsenic from groundwater was 64.98 μg/l in controls and 87.56 μg/l in exposed population cases. The results showed-

- Chronic lung diseases: 12.8% in cases and 0.78% in controls
- arsenicosis:15.4%
- Peripheral neuropathy:4.15% of controls and 15.9% of cases.

Hexavalent chromium

In Kanpur, India, a research on individuals exposed to and not exposed to chromium-contaminated groundwater was carried out. The main effects on health of those who are exposed:

- Gastrointestinal distress: 39.3% of the exposed population and 19.1% of the controls
- Skin anomalies: 6.5% in the population under exposure and 24.7% in the control group
- Symptoms related to the eyes: 18.2% of exposed populations and 7.8% of controls

Lead

The discharge of treated and untreated industrial wastewaters from various sources has contaminated the Yamuna river water with heavy metals. In order to determine the lead levels in blood samples from mothers and kids who were representative of the local residents in the area, a study was conducted. Mothers' blood was found to contain high levels of lead, and 23% of children's blood lead levels were higher than 10 μg/dl.

Cadmium

Urinary cadmium levels were 10 times greater in workers exposed to cadmium in a research conducted in Kolkata, West Bengal, on workers in jewellery workshops utilising the metal and reference jewellery sales staff. Approximately 75% of the exposed workers and 33% of the controls, respectively, reported respiratory tract problems. Compared to controls, the exposed workers reported a deficiency in lung function.

Copper

- The health effects of copper exposure are thought to be gastrointestinal in nature.
- The possible health implications of copper exposure include hepatic damage.

Nickel

Allergy is the most frequent adverse health impact of nickel in people. Ten to twenty percent of people are nickel sensitive. When jewellery or other things containing nickel come into close, continuous contact with the skin, a person may develop a nickel sensitivity (6).

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Exploration of Nephrotoxic Heavy Metal Contaminants in Edible Fish and Reservoir Sediments Linking with CKDu Prevalence of Sri Lanka

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Abstract

Inland fish is one of the main protein sources of the regular diets of remote communities in Sri Lanka where the incidences of Chronic Kidney Disease of unknown etiology (CKDu) have significantly increased. Nevertheless, the presence of nephrotoxic heavy metals in reservoir sediments poses a potential threat to the local ecosystem, particularly impacting the aquatic food web and fish populations. To study the problem, concentrations of heavy metals (Cd, Pb, As, Cr, Cu, Zn, and Mn) in two common edible wild and commercial inland fish species and associated reservoir sediments were investigated in selected CKDu endemic and non-endemic areas in Sri Lanka. The concentrations of heavy metals were 1,000 times higher in sediments than in dorsal fish muscles. Based on SQGs, Sediment-bound As, Cu, Zn, and Cd contents which exceeded the Effect range-low and median levels, implicated the harmful biological impacts to the living organisms inhabiting the Ulhitiya reservoir in the CKDu hotspot, including fish. Significant strong correlations in Cd, Pb, and Zn between the reservoir sediments and dorsal muscles of *E. suratensis* and *O. niloticus* confirmed that presume. Calculated Hazard Indices (HIs) were higher in E. suratensis (wild species) than *O. niloticus* (commercial species) irrespective of the location, and nephrotoxic heavy metals, including Pb, Cd, and As in fish muscles, contributed about 80% to the HI. Whether the estimated Target hazard quotients (THQs) for fish consumption were very much less than the threshold of 1, a relative possibility of the occurrence of chronic kidney failure of CKDu can exist due to exposure to the nephrotoxic heavy metals such as Pb, Cd, and As via fish consumption in the selected CKDu prevalence area. While a pollution event into an inland reservoir is often transitory, the pollutants' effects may be long-lived due to their tendency to be absorbed in the sediments and then released into the food chain. Even though detected heavy metal contents have complied with acceptable limits for human consumption, long-term consumption as the main animal protein source can directly impact the prevalence of CKDu among the residents in CKDu endemic areas in Sri Lanka.

Keywords: Inland fish, reservoir sediments, nephrotoxic heavy metals, CKDu, human risk assessment

Introduction and Theoretical Framework

Chronic Kidney Disease of Unknown Etiology (CKDu) has emerged as a significant health concern in Sri Lanka, drawing attention from both the Ministry of Health in Sri Lanka and the World Health Organization (WHO,2016). According to records from these authorities, CKDu prevalence has been on the rise, particularly in rural agricultural regions. CKDu is characterized by a gradual loss of kidney function, leading to chronic kidney failure, without clear underlying causes. Its prevalence poses significant challenges to healthcare systems and communities, with limited treatment options available. Efforts to combat CKDu include public health initiatives focused on raising awareness, improving access to healthcare services, and implementing preventive measures. However, the complex interplay of factors contributing to CKDu underscores the need for comprehensive research and collaborative efforts to address this growing public health issue in Sri Lanka according to the investigations of the Ministry of Health and Nutrition, Sri Lanka.

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In Sri Lanka, the contamination of food, particularly inland fish, with heavy metals has emerged as a critical concern in light of the rising prevalence of CKDu. Inland fish, a staple protein source for many Sri Lankan remote communities, face contamination from heavy metals such as cadmium, lead, arsenic, and chromium, primarily due to agricultural runoff and geographical localization of heavy-metal-bound minerals in soils. These heavy metals accumulate in the aquatic ecosystem, eventually reaching inland fish populations. Prolonged consumption of contaminated fish can lead to the bioaccumulation and biomagnification of these toxins in human tissues, potentially exacerbating the incidence of CKDu. The correlation between heavy metal contamination in inland fish and the prevalence of CKDu underscores the urgent need for comprehensive research, monitoring, and regulatory measures to safeguard public health and mitigate the impacts of food contamination in Sri Lanka.

Humans' destructive influence on the aquatic systems is one form of sub-lethal pollutions, which generates adverse effects on aquatic life with chronic environmental stress conditions. In aquatic ecosystems, heavy metals have received considerable attention as a risk factor due to their toxicity and accumulation in biota. They act as metabolic poisons to living organisms. Heavy metal toxicity primarily occurs due to their subsequent inhibition of enzyme systems (e.g., sulfhydryl (SH) enzyme systems) and oxidative stress, which can devastate the inherent antioxidant defenses of cells resulting in the production of reactive oxygen species. In the typical scenario, some beneficial heavy metals, indeed dietary essentials, such as Copper (Cu), Zinc (Zn), and Manganese (Mn) may become toxic when occurrence in excess by exhibiting toxic effects on aquatic organisms. Several heavy metals are recognized, which are associated with renal damage, and Cadmium (Cd), Lead (Pb), Arsenic (As), and Chromium (Cr) are among the environmentally relevant most hazardous heavy metals and can be categorized as biologically non-essential elements and also potentially nephrotoxic heavy metals. Toxicological studies in animals and humans primarily demonstrated a clear association between exposure to these metals, the pathophysiology, and the occurrence of chronic renal damage.

Methodology

The rapid spread of CKDu was observed from the north-central province to remote communities in the Uva province of Sri Lanka, with a minimum of 15% of CKDu affected people in the age group 15-70 years over the last decade. Hence, Girandurukotte Grama Niladhari Division (GND) [81.020176E, 7.465041N], Badulla district, Uva province, Sri Lanka, was identified for the sampling as the CKDu endemic area according to the data of the Ministry of Health and Nutrition, Sri Lanka and Dambethalawa GND [81.51630E, 7.309013N], Ampara district was selected as the reference site where no CKDu cases were reported but having similar climate conditions which are present in the selected CKDu prevalence area. Therefore, Ulhitiya reservoir in Girandurukotte GND and Namaloya reservoir in Dambethalawa GND were selected for the collection of fish and sediment samples as those reservoirs fulfill not only the inland fish requirement of the residents in the selected GN divisions but also the irrigatory water requirement for the paddy cultivation.

A semi-quantitative food frequency questionnaire was conducted among residents in both sampling areas, and it was found that inland fish as their only animal protein source while *Etroplus suratensis*; an edible wild fish species, and *Oreochromis niloticus*; an edible commercial fish species were the common inland fish which are constituted the most frequently found component of the meals in local populations. Therefore, the inland fish samples were collected from fishers' catch, and the type of fish selected for the study was found throughout the reservoirs. Twenty similar-sized samples of each species were sorted out to analyze the heavy metal levels in the muscles of fish from each species from each reservoir. Ten composite sediment samples from each reservoir were randomly collected from the bank to the center of the water body by a cleaned bottom grab sampler. Concentrations of each heavy metal element, including Cd, Pb, As, Cr, Zn, Cu, and Mn in digested inland fish and sediments samples, were determined using Inductively Coupled Plasma Mass Spectrometry (ICP-MS-7800-Agilent, Germany) followed by microwave digestion. Human health risk assessment for consumption of heavy metal-containing fish was done by non-carcinogenic risk evaluation (Target hazard quotients and Hazard Index) and spatial distribution of sediment metal toxicities was interpolated and autocorrelated using ArcMap 10.8 Software. The relationships between heavy metals present in both inland fish species and the heavy metals in the reservoir sediments were determined by applying Pearson product-moment coefficients at 0.01 and 0.05 significant levels.

Results and Discussion

In Ulhitiya reservoir, which is situated within the CKDu hotspot, Mn, Cu, and Zn contents in *O. niloticus* were 8.30, 1.45, and 25.58 in mg/kg, respectively, while in *E. suratensis*, recorded Mn, Cu, and Zn contents were 7.45, 1.62, and 22.33 in mg/kg. In the Namaloya reservoir, 6.54, 1.06, and 18.46 mg/kg of Mn, Cu, and Zn were found in *O. niloticus* and 6.11, 1.05 20.36 mg/kg in *E. suratensis*. Considering both reservoirs, Cu and Zn contents in dorsal muscles in both fish varieties have complied with the FAO and TFC standards (FAO/WHO, 2003; TFC, 2002), and Mn contents in both fish species were exceeded the permissible levels given by WHO/FAO,1989. However, Higher Zn levels were observed in dorsal muscle tissue according to higher total content, and Zn was the most available heavy metal for both fish species in both reservoirs. The contents of Cd, Pb, As, and Cr in Oreochromis niloticus samples were found as 184.06, 215.85, 43.20, and 27.63 µg/kg. In Etroplus suratensis, those metals were 84.31, 45.20, 206.85, and 115.62 µg/kg, respectively, in the Ulhitiya reservoir. Interestingly, Cadmium and Arsenic contents were lower than the detection limits (<LOD) in wild fish species in the reference reservoir. In the commercial fish species, significantly lower Cd levels (0.65 µg/kg) were found, and As contents were also recorded as lower than the LOD (<LOD). Cr and Pb levels in both fish species were also comparatively more deficient in the Namaloya reservoir than in the Ulhitiya reservoir.

Comparing mean concentrations of all analyzed heavy metals in fish tissues, the results showed the following accumulation ranking: Zn > Mn > Cu > Pb > Cd > Cr > As in *E. suratensis* (wild edible fish) while *O. niloticus* (commercial edible fish)had the following one: Zn > Mn > Cu > Pb > Cd > As > Cr in Ulhitiya reservoir in the CKDu hotspot. According to the ranking orders, differences were observed only in As and Cr between edible parts of fish species. Zn had the highest concentrations in both fish species because Zn shows high mobility in Aquatic systems. It is probably due to Zn's precipitation as a coating onto amorphous or poorly crystallized sediments' components. It increases Zn's release quickly to the adjacent water column and the aquatic organism like fish. Even though Pb represents heavy metals primarily embedded in the crystal lattice of sediments, the input of Pb into the reservoirs was increased due to the intensive paddy cultivation in these sampling areas. Therefore, among the toxic heavy metals, Pb had the highest availability in edible fish muscles.

The mean concentrations of Cd, Pb, As, Cr, Cu, Zn, and Mn in the sediments of Ulhitiya reservoir (nearby source for the CKDu hotspot) were 1.97 ± 0.52, 21.84 ± 2.75, 47.42 ± 6.79, 31.47 ± 6.11, 72.92 ± 2.28, 1367.92 ± 2.79 and 19.20 ± 2.47 in mg/kg respectively. The mean concentrations of the selected heavy metals in the Ulhitiya bed sediments followed the order: Zn > Cu > As > Cr > Pb > Mn > Cd. When considering the reference, The mean concentrations of Cd, Pb, As, Cr, Cu, Zn, and Mn in the sediments of Namaloya reservoir were 0.87 ± 0.26, 8.40 ± 2.77, 11.95 ±7.22, 11.90 ± 3.98, 51.07 ± 2.80, 879.74 ± 2.94 and 12.57 ± 2.40 in mg/kg respectively. Those mean concentrations of the selected heavy metals in the reference site followed the order: Zn > Cu > Mn > As> Cr > Cd.

When comparing the mean heavy metal contents in Ulhitiya reservoir (in the CKDu hotspot) with the sediment quality standards/guidelines implemented by different organizations/literature, Cd exceeded the LEL, CB- TEC, ERM, and SEPA given limits. As and Zn in sediments exceeded all the concerned standard levels. Sediment Cu exceeded LEL, CB-TEC, ERL, and SEPA limits, while Cr only exceeded the LEL standard limit. Pb in sediments has not exceeded any of the considered standard limits. Instead of Pb (standard limits are not available for the Mn), all the other selected heavy metals exceeded the lowest effect level (LEL) indicating that living organisms in the reservoir, including fish, can affect the sediment-bound heavy metals.

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The results of the Inverse Distance Weighted (IDW) interpolation tool showed that concentrations of sediment Cd, Pb, As, and Cr spatially changed in the ranges of 1.25 - 2.86, 13.50 - 32.80, 22.00 - 74.38, and 11.00 - 62.63 in mg/kg respectively. When comparing the spatial patterns with the areal satellite footages, A strong association can be observed where the areas with heavy metal clustering and the regions with intensive agriculture in Girandurukotte GND (the CKDu hotspot).

Knowing about correlations between dietary essential and nephrotoxic heavy metal concentrations in fish and those in the reservoir sediments is a major concern in understanding the contamination pathways. It is generally expected that bio-accumulation of heavy metals in fish will correlate positively with the metal levels in associated sediments. Still, the actual situation under natural environmental conditions is not so simple. Many Physicochemical factors other than the metal levels can be affected by such accumulation, including inland fish characteristics such as fish physiology and regulatory/detoxification mechanisms for heavy metals and different external physicochemical environmental factors and climatic conditions. The results suggest a strong association of the Cd, Pb, and Zn between the reservoir sediments and the selected two fish types. Cadmium in the dorsal muscles of both *E. suratensis* and *O. niloticus* have expressed a significant negative correlation (at 0.01 level of significance) with the Cd present in the reservoir sediments. This may be attributed to the fact that Cadmium is a highly mobile and potentially bioavailable metal and was primarily scavenged by non-detrital carbonate minerals, organic matter, and iron-manganese oxide minerals.

A strong positive correlation was observed between Zinc in *E. suratensis* (at 0.05 significant level) and in *O. niloticus* (at 0.01 significant level) between the inland fish tissues and the reservoir sediments while Lead in the commercial inland species sampled; *O. niloticus* showed a significant positive correlation with Pb in sediments at 0.05 significant level. The correlation coefficient, calculated for other selected heavy metals, including As, Cr, Cu, and Mn, between sediment and inland fish samples was not significant.

Fish is generally considered one of the healthiest and cheapest sources of protein. Still, despite its valuable nutritional constituents, its ability to bioaccumulate toxic and non-biodegradable heavy metals in its edible body parts calls for serious concerns. This part of the study attempts to estimate the potential non-carcinogenic human health risk associated with the consumption of selected wild and commercial fish from the sampling areas using THQs and HI indices because CKDu is a non-carcinogenic disease caused by chronic nephropathy which there is gradual loss of kidney function over a long period.

According to the evaluation results for the CKDu hotspot, Pb, As and Cd showed the highest THQ values in both fish species. The THQs of *E. suratensis* of Pb, As, and Cd were 0.16006, 0.04663, and 0.03579, respectively, with a HI of 0.29975 and THQ for O. niloticus of Pb, As, and Cd were 0.10250, 0.02743, and 0.03506 respectively with 0.20049 of HI value. HI of *E. suratensis* was 0.16068 and HI of O. niloticus was 0.06666 in the reference area. Furthermore, all the calculated Hazard Index values (i.e., the sum of THQs) were less than 1 (HI < 1) and indicated no adverse non-carcinogenic health effects to consumers. However, considerably higher HI values can be seen in the CKDu prevalence area than in the reference, and residents of the Girandurukotte GND (the CKDu hotspot) should be advised to consume inland fish moderately. In the calculation of THQ, the ingested dose and the absorbed pollutant dose have been assumed to be the same. Still, the food handling, preparation, and preservation methods can positively or negatively influence the magnitude of levels of toxicants. Calculated HIs are higher in *E. suratensis* (wild species) than *O. niloticus* (commercial species) irrespective of the location, and it can be resulted due to their difference in nitches, feeding habits, and metabolic functions. This implies that the continuous consumption of these *E. suratensis* (wild species) will pose a potential health risk to consumers over a long time.

the relative contributions of THQs of selected heavy metals to the estimated HI as a percentage in *E. suratensis* and *O. niloticus* fish species in Ulhitiya reservoir, Girandurukotte GND (the CKDu endemic area). It accounted that 53.40% of Pb, 15.56% of As, 11.94% of Cd (80.9% out of 100%) in *E. suratensis* and 51.13% of Pb, 17.49% of Cd, and 13.68% of As

(82.30% out of 100%) in *O. niloticus* were responsible for the occurrence of the actual health risk in the selected CKDu hotspot. Therefore, three concerned nephrotoxic heavy metals (Pb, Cd, and As instead of Cr) contributed about 80% to the HI.

Whether the estimated THQ for the general fish consumption is very much less than the threshold of 1, a relative possibility of the occurrence of adverse effects (such as chronic kidney failure) can exist due to exposure to nephrotoxic heavy metals such as Pb, Cd, and As via fish consumption in the selected CKDu prevalence area. Furthermore, the biomagnification of these heavy metals in fish and long-term bioaccumulation within human tissues could potentially lead to adverse health effects. Since human health risks associated with inland fish consumption from these sampling areas were beyond negligible amounts, suitable strategies should be implemented to control and mitigate the sources of nephrotoxic heavy metals associated with inland reservoirs in Sri Lanka.

Conclusion

The heavy metal contents in selected edible wild and commercial fish species and associated reservoir sediments in CKDu prevailed remote areas, and non-carcinogenic human health risks of combined heavy metals via oral ingestion were evaluated. Based on SQGs, Sediment-bound As, Cu, Zn, and Cd were higher than NOOA-ERL, and ERM levels, implicating harmful biological impacts of these metals on living organisms inhabiting the Ulhitiya reservoir in the CKDu hotspot. Instead of Pb, all the other selected heavy metals exceeded the lowest effect level (LEL), indicating that living organisms in the reservoir, including fish, can be affected by contaminants. Significant strong correlations in Cd, Pb, and Zn between the reservoir sediments and dorsal muscles of *E. suratensis* and *O. niloticus* confirmed that presume.

Non-carcinogenic health risks cannot be expected from the consumption of both fish species analyzed (THQs <1). Calculated HIs are higher in *E. suratensis* (wild species) than O. niloticus (commercial species) irrespective of the location, and this implies that the continuous consumption of these *E. suratensis* (wild species) will pose a potential health risk to consumers over a long time. Nephrotoxic heavy metals, including Pb, Cd, and As in fish muscles, contributed about 80% to the HI. Whether the estimated THQ for the general fish consumption is very much less than the threshold of 1, a relative possibility of the occurrence of chronic kidney failure of CKDu can exist due to exposure to nephrotoxic heavy metals such as Pb, Cd, and As via fish consumption in the selected CKDu prevalence area.

The present study suggests essential implications for reservoir health management and maintaining sustainable diets among the residents in remote areas in Sri Lanka to mitigate the CKDu prevalence. Immediate actions should be taken by the responsible parties to control the heavy metal pollution of reservoirs and to improve the dietary status of rural communities. Moving into integrated agricultural practices and implementing constructed wetlands to runoff outlets can be recommended to minimize the input of toxic heavy metals into the reservoirs.

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Preliminary Findings on Levels and Health Risk Assessment of Mercury Contamination in Dried Fish Consumed in Bhutan

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Introduction

Dried fish is the most affordable and abundantly available source of proteins to the Bhutanese population. It is considered a delicacy and are consumed by all ages including children in Bhutan. Annually, 372 metric ton of dry fish are imported from the neighboring country India and there has been a steep increase in the consumption of dry fish (1).

However, the concentration of heavy metals above the permitted level is a global public health concern (2). Lead, cadmium and mercury is the most commonly found contaminants in the dry fish (3). These heavy metals, also referred as toxic elements occur naturally in the environment from various sources and are often at higher levels from past industrial uses and pollution (4).These metals do not have any physiological role in the human system and even a trace amount is detrimental to the human health (5).

Of note, methylmercury is one of the toxic contaminants that is of greatest concern due to its acute and chronic toxicity to the CNS, CVD, respiratory system, hepatic, renal and musculoskeletal system (6). Several species of environmental mercury are commonly found, including elemental mercury (Hg), inorganic mercurial salts (Hg + and Hg 2+), and methylated mercury (MeHg) (7).

More specifically, excessive levels of methylated mercury are associated with various negative effects on human health, mostly the neurological damage, reproductive and developmental abnormalities (8). Methylated mercury, the most common inorganic form of mercury, exists in the water and quickly enters the aquatic food chain (9). In most adult fish, 90-100% of the mercury is methylated mercury (10). Globally, heavy metals contamination in aquatic organisms is an emerging phenomenon (11).

Currently, there is no available data in the country in regard to the maximum residue level (MRLs) of toxic element mercury in dried fish. This is further aggravated with the Bhutanese dietary habit of high consumption of dried fish, as it is a delicacy and served in almost all important occasions due to its easy availability and a cheap high source of protein. In contrary, there is no regular monitoring programs for food safety in terms of regulating MRL of mercury in dried fish samples. Therefore, this study aims to determine the toxic metals (mercury) content in different dried fish available in the country and to assess the potential health risk in the Bhutanese population.

Methods

Sample collection

Bhutan imports all the dry fish from neighboring country India. Different species of dried fish that are widely available and consumed in the country were included in the study. Samples were randomly collected from grocery and supermarket shelves. The collected samples were stored at room temperature until analysis. Only edible portions were used for the analysis

Sample preparation

Samples were prepared for analysis according to the AOAC standard official methods (12). Briefly, the edible portion of the samples were grinded and homogenized in a clean metal free sample processing container. A 0.5 grams of samples were weighed in a mercury free sample boat and inserted directly for analysis. For further confirmation with other techniques for method validation, samples were digested in ultra-pure nitric acid. For this, 5 grams of dry fish tissue samples was weighed and transferred to the digestion vessel and 5 ml of ultra-pure nitric acid and 2 ml of hydrogen peroxide was added. Blank digest was also carried out to validate the digestion procedure. The samples were initially pre-digested for 30 minutes followed by micro-wave assisted digestion using the following temperature-controlled program including the blank (5, 10, 25, 50 ppb) to constructed a calibration curve. Samples will be diluted if the concentration of metals in the samples are beyond the limit of quantification. Calibration curve with the correlation coefficient (R2) of 0.9999 will be used to quantify the level of each heavy metals in the samples. The following figure demonstrates the calibration curve for mercury.

Health risk estimation

The estimated daily intake (EDI), Target hazard quotient (THQ), hazard index (HI) and target cancer risk (TCR) was calculated as per the US EPA guidance for assessing mercury contaminant data and WHO chemical risk assessment guidelines (13).

Data analysis

The levels of toxic element mercury are expressed in mean ± standard deviation. One-way analysis of variance (ANOVA) and turkey's method was used to compare the differences in contents of heavy metals among the groups of sample collection area of dried fish. A p-value of less than 0.05 was considered significant wherever applicable.

Results

There was a total of 35 samples collected for determination of mercury in dried fish samples. Of the total of 35 samples, 100.0 % of the samples were detected with mercury in the range of 8.33-122.79 µg kg-1 with the mean concentration of 49.7±32.9 µg kg-1. The concentration at 95^{th} percentile was 116.8 µg kg-1. From the mercury concentration in dried fish, it is correlated with the frequency of fish consumption by Bhutanese, the estimated daily intake of dry fish for an adult consuming four pieces of dry fish (28.0 grams x 4 pieces = 112.2 grams) for four times a week (52.1 x 4 = 208.5 days) was ~0.2 mg/day/kg body weight. An average body weight of 65 kg with a lifetime exposure of 67 years was considered for the current assessment. The results showed that the Hazard quotient is 1 which poses a risk for the consumers.

Discussion

Mercury is a well-established cumulative neurotoxic agent that can have serious adverse effects on the development and functioning of the human central nervous system, especially when exposure occurs prenatally. In the study, mercury was found to vary in concentrations in the studied fish samples. Based on the risk assessment of fish mercury concentrations, we reckonfish diets are high-risk to health.

The source of dried fish samples collected were either imported from India or Bangladesh. Contamination of heavy metals in dried fish was studied in Bangladesh with Mercury at the third highest concentration among heavy metals. The probable source of contamination has been suggested to arise from leaching from the drying pans into fish, atmospheric deposition and the river/marine waters in which fish were harvested (14).

In Mumbai, mercury levels in fish were 0.03-0.82mg total Hg/Kg dry weight compared to the permissible limit of 0.5mg/kg. The North Koel river showed mercury concentrations almost 600-700 times above the limits (15). Currently, in Bhutan, there is no restriction on the import of dried fish from any country. However, in a study from India, the highest sediment concentration of Methyl mercury (202.0ng/g) was obtained during monsoon season (10). In this regard, import of dried fish during different seasons of the year should also be considered and monitored.

Along with mercury, many other heavy metals such as lead, cadmium, Arsenic, Copper and Zinc can also be found in the dried fish. Additionally, residues of organochlorine pesticides were found in a study conducted at Bangladesh and Kerela, India (15,16). Further studies on the contamination of other heavy metals such as lead, cadmium and arsenic are also required for assessment of human health risk. Our preliminary study has the limitation with a smaller number of samples collected, and the unknown types of fish. Further, an increased sample size and categorization of fish species is essential.

Conclusion

The results from this preliminary finding suggest that the dried fish sampled were contaminated with mercury posing significant health risk to the consumers. Moreover, consumption of various delicacies prepared with dried fish in a long run may lead to bioaccumulation of mercury in tissues that may pose greater impacts. Therefore, continuous monitoring of heavy metals through surveillance programs is pertinent in the dried fish imported from India and other neighbor countries.

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Enhancing National Food Safety in Myanmar

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Myanmar's agricultural exports, including fisheries products, are crucial to its economy. However, as a developing nation, ensuring the safety of these exports (cereals, beans, fruits, vegetables, meat, fish) has traditionally been a higher priority than local food safety. This is changing as the national food safety policy gains traction.

A recent workshop brought together representatives from the Ministry of Health, the Ministry of Agriculture, Livestock and Irrigation (MoALI), Ministry of Home, and Ministry of Commerce. This landmark collaboration aimed to clarify the roles and responsibilities of each stakeholder in ensuring national food safety. The workshop successfully defined clear lines of communication, established protocols for data sharing and joint inspections.

The MoALI plays a key role in implementing this policy. The Plant Protection Division (PPD) within MoALI is responsible for ensuring the safety of agricultural products for both domestic consumption and export. Multiple laws govern food safety, including the Pesticide Law, Plant Pest Quarantine Law, Food Safety Law and Fishery Laws. The PPD, designated as Myanmar's Competent Authority by the International Plant Protection Convention (IPPC), focuses on the safety of agricultural products, farm workers, and the environment. The PPD issues phytosanitary and import certificates for agricultural products.

Combating environmental pollution from pesticide misuse involves collaboration between various government ministries. Local authorities and food safety specialists from NGOs conduct regular inspections to monitor heavy metal contamination in drinking water and agricultural products.

Recognizing the importance of meeting international safety standards, Myanmar is prioritizing improvements in inspection bodies and laboratory systems. The recent ISO 17025 accreditation of the Agricultural Products Analytical Laboratory (APAL) for pesticide residue, mycotoxin, and heavy metal analysis is a significant step. This achievement motivates other laboratories to pursue accreditation. Additionally, laboratory heads have formed a network for knowledge sharing and collaboration on food safety issues.

However, challenges remain. Many agricultural commodity standards haven't been implemented. Training programs and international technical assistance are urgently needed to address these gaps. Additionally, enhancing the competency of managerial personnel through exposure to international conferences on environmental pollutants, toxicants, pesticides, and food safety is crucial. Myanmar's commitment to ensuring safe food for its citizens necessitates international collaboration in technology and regulatory frameworks for mutual benefit.

Human Health, Environmental Challenges, and Sustainable Development Nexus: Concerns from Sri Lanka

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Human and environmental health are intimately intertwined. The extent to which people can enjoy their basic rights to life, health, food, shelter, livelihood, and culture depends on the existence of clean air, clean water, a stable climate, flourishing wildlife, and well-managed natural resources. People have been aware of the crucial relationship between human and environmental health for thousands of years. However, still, there is a tendency to separate the human health and environmental issues and people deal with them independently. This attitude should be changed to protect the environment, promote human health, and practice sustainable development. Although there is a surge in international, regional, national, and local recognition of the link between the environment and human health in developed countries, the burden of disease due to environmental health issues in developing countries is increasing. Among the developing countries, Sri Lanka is an island in South Asia, a lower-middle-income country with nine provinces and 25 administrative districts. The total land area is approximately 65,000 square kilometers. Over 20 million of the population, 15% live in urban areas, 80% reside in rural areas, and 5% live in rural estates where plantation crops are grown and harvested. The north-central zones of the country are rich with agricultural lands. Although the life expectancy is 74 years and rising, disease patterns have shifted away from infectious, maternal, and childhood diseases towards non-communicable diseases, which account for approximately 90% of the overall disease burden. It is imperative to tackle the environmental health concerns in Sri Lanka in order to protect public health, conserve biodiversity, and promote sustainable development. The Ministry of Environment has identified air pollution, inland water pollution, land degradation due to soil erosion, depletion of coastal resources, waste disposal climate change, and loss of biodiversity, as key environmental issues in Sri Lanka. The health of the population is directly impacted by these issues, which are leading to health problems such as respiratory diseases, waterborne illnesses, and malnutrition. Furthermore, environmental deterioration threatens ecosystems and natural resources that are vital to the livelihoods and economic development of Sri Lanka. The country can protect human health, uphold ecological balance, and foster sustainable development for present and future generations.

Air pollution is a crucial environmental health issue affecting people in Sri Lanka. Among many air pollutants, the most important are particle pollution which is known as particulate matter (PM), ground-level ozone (O_3), carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), lead (Pb), environmental tobacco smoke (ETS), formaldehyde and polycyclic organic matter. Air pollution co-exists with other major public health problems in Sri Lanka, such as communicable diseases, vector-borne diseases, malnutrition, and poor sanitation and these have been taken higher priority in circumstances as the economic resources are limited. Based on the evidence, the major source of ambient air pollution arises from vehicle emissions, and it contributes to more than 60% of total emissions in Colombo. The National Policy on Urban Air Quality Management was established in 2000 to reduce outdoor air pollution due to vehicle emissions. Some significant measures that have been taken to reduce urban outdoor air pollution in Sri Lanka include the phase-out of leaded gasoline in June 2002, the introduction of low-sulfur diesel in January 2003, the prohibition on the importation of two-stroke three-wheelers in 2008, and the initiation of vehicle emission testing programs in the year 2008. The maximum permissible ambient air quality standards were enacted under the National Environmental (Ambient Air Quality) Regulations of 1994 for the first time. Furthermore, in August 2008, the air quality standards for Sri Lanka including standards for PM_{10} and $PM_{2.5}$ were amended with the publication of the World Health Organization (WHO) air quality guidelines in 2005. There has been only one station located at Colombo Fort to expand air quality monitoring in Sri Lanka, since 1997. Based on the data collected from this station, the average annual ambient PM_{10} levels in Colombo for more than ten years have remained stable ranging from 72 to 82 μg/m^3. However, the WHO guidelines recommend that the average annual ambient PM_{10} level be less than 20 μg/m^3. In addition, a comparison of several cities around the world emphasized that the PM_{10} and SO_2 levels in Colombo which is based on the Colombo Fort monitoring station are unhealthier than cities including Hong Kong, Singapore, Bangkok Taipei, and Tokyo. Further, based on the data emphasized by the Central Environmental Authority (2007), hourly averages of SO_2 have exceeded the maximum allowable limits based on the Sri Lankan standards on 177 occasions from May 2003 to December 2006. Although the NO_2 levels in Colombo city did not exceed the Sri Lankan standards over the past few years, it has shown an increasing trend. The CO and O_3 levels were recorded relatively low in Colombo compared to other air pollutants. In 2001, a passive air quality monitoring network was established by the National Building Research Organization (NBRO) of Sri Lanka covering 15 locations in Colombo city to monitor NO_2 and SO_2. According to the data provided by the Central Environmental Authority (CEA), the land transport density, population, and building density are associated with the air quality of Colombo city.

Indoor exposures are due to the complex interactions between the structure of the building and building systems, the strength of the indoor source, removal and deposition rate inside the structure, indoor mixing and chemical reactions, furnishings, the outdoor environment, and the practices and behaviors of the inhabitants. As Sri Lanka is a tropical country, it is expected to have good ventilation. However, the data unveiled that the indoor air is more polluted than the outdoor air. One of the main sources of indoor air pollution in Sri Lanka is cooking fuel and some other sources include tobacco smoke and smoke from other outdoor sources. Based on the data shared by the Demographic and Health Surveys of Sri Lanka of 2000 and 2007, firewood is the major type of cooking fuel in 78.3% and 78.5% of the households in Sri Lanka, respectively. The incomplete combustion of the firewood coupled with poor ventilation produces very high levels of indoor air pollution. Women and young children who typically stay close to their mothers during cooking activities are more potentially at the highest risk of indoor air pollution exposure due to cooking fuel. Further, the regular usage of mosquito coils by around 12% of households in Sri Lanka may be another source of indoor air pollution especially in poorly ventilated houses. Due to health issues, smoking in healthcare institutions, educational institutions, government facilities, universities, indoor offices, and other indoor workplaces has been banned by the National Authority on Tobacco and Alcohol (NATA) Act. However, as reported by the Global Youth Tobacco Survey (GYTS), there is no significant reduction in exposure to second-hand smoke in public places following the enforcement of the NATA Act. Further, the school children are also exposed to the high amounts of pollutants exaggerated by overcrowding of schools in cities such as Colombo. As emphasized by various studies throughout the country, air pollutant levels including NO_2, SO_2, and TSP have been significantly higher in the schools located in urban areas compared to the rural schools. PM_{10} levels in ‘outside the city schools’ have shown lower values (84 mg/m^3) compared to the ‘city schools’ (121 mg/m^3). Episodes of bronchitis, emphysema, and other chronic obstructive pulmonary diseases had a strong association with PM_{10} levels according to the data of the Colombo Fort monitoring station. Based on the health impact assessment software developed by WHO, it can be suggested that nearly 20% of the asthma patients who visited the Lady Ridgeway Hospital for children in Colombo in 2005 were exposed to PM_{10} in Colombo. Therefore, the evidence acquired from various studies and environmental authorities emphasized the requirement for the implementation of early mitigation strategies. As per the data collected from Mount Lavinia which is a metropolitan area bordering Colombo regarding the air pollutants, bus drivers have been exposed to more NO_2 and SO_2 compared to trishaw drivers, shopkeepers, and outdoor vendors. It emphasized that the highest prevalence of respiratory symptoms among bus drivers compared to other occupations. In addition, abdominal discomfort, tremors, and hypertension are human health issues due to air pollution in the country, and these health issues mainly can be seen in traffic policemen as compared to non-traffic policemen.

Implementing baseline data related to both indoor and outdoor air pollutants and human health is important to address this issue at the national, community, and individual levels which can be used as the basis for advocacy, formulating mitigation strategies, and reducing the exposure. The establishment of a modern ambient air quality monitoring network covering at least busy cities in the country is an early requirement because the availability of stringent standards is of no use if the air quality that citizens are exposed to is unknown to identify for intervention. Furthermore, various activities are implemented to mitigate outdoor air pollution, but there is a lack of specific interventions implemented at the national level to reduce indoor air pollution or to decrease the exposure of vulnerable groups including younger communities to indoor air pollutants. As well, there is a lack of trustworthy indoor air quality data and determinants of indoor air quality in Sri Lanka, which is important in estimating the burden of diseases associated with indoor air pollution. Therefore, implementing new legislation and reinforcing the existing laws will necessary reliable baseline data on both indoor and outdoor air quality, as well as their effects on health. Adjusting existing regulatory practices according to the insights gained from robust research studies, ensuring rigorous compliance with regulations at both community and household levels, and identifying new mitigation strategies can significantly reduce the health consequences of air pollution. These findings from Sri Lankan studies emphasized that both ambient and indoor air pollution is a major public health issue in Sri Lanka.

Water pollution is internationally recognized as a crisis for human health as well as the environment. In Sri Lanka, water pollution is broadly due to both natural and anthropogenic activities including industries and agriculture. The high amounts of chemicals that are used in the agriculture sector and industries, the discharges from hospitals, organic water and sewage, wastewater discharge from textile, painting, tanning, fertilizer and food industries, and landfill discharges are the main pollutants that are added into the water bodies directly. In addition, the excessive usage of pesticides and fertilizers contaminates the groundwater sources which leads to a high incidence of cancers in people in agricultural areas. As shown by various studies, high amounts of nitrate contents have been reported from the Jaffna, Batticaloa, and the Kalpitiya aquifer. Furthermore, the coastal groundwater sources are threatened due to the contamination by various sources including sewage from population increase, sea level rise, industrial effluent and landfill leachate, and overuse of agro-chemicals. Fluoride is one of the major groundwater pollutants reported in the dry zone in Sri Lanka which exceeds the permissible level recommended by the WHO standards for drinking water. Excessive levels of irons and high hardness are other issues reported in deep groundwater wells in the dry zone of Sri Lanka. The occurrence of Chronic Kidney Disease with unknown etiology (CKDu) and dental fluorosis in the people in the dry zone of Sri Lanka are also caused by an array of anomalies in groundwater and foods. Water pollution in the country has increased due to the growing number of industries that release substantial amounts of environmental contaminants. It is crucial to address water pollution as only 25% of households in Sri Lanka have access to clean water. As per the findings of the Central Environmental Authority (CEA), the Beira Lake, Bolgoda Lake, Boralesgamuwa Lake, Kesbewa Lake, Kandy Lake, River Kelani, River, Manik Ganga, Mahaveli River, and Walawa River are some of the most polluted surface water bodies in Sri Lanka due to the heavy pollution including outbreaks of algal blooms caused by eutrophication and frequent fluctuations in the chemical and physical qualities of the water. The water quality tests conducted by the CEA near the industrial zones have shown that the critical safe water quality limits are constantly exceeded. In addition, the improper discharge of industrial effluents and the generating and disposing of hazardous waste are some other significant concerns of water pollution in Sri Lanka, that contribute to environmental challenges. The Sri Lankan government has implemented various measures to address the issues related to water resources effectively. Although there are more than 50 legislative measures, and 20 government entities responsible for overseeing and managing water resources, there is a notable lack of coordination among these agencies. The Central Environment Authority (CEA), and the National Water Supply and Drainage Board (NWSDB) are two government bodies responsible for mitigating water body contamination and monitoring drinking water quality, respectively. Furthermore, new regulations such as Environmental Impact Assessment (EIA) and Environmental Protection Licenses (EPL) have been introduced to manage industrial effluents. However, it is essential to identify all forms of water pollution including surface water, groundwater, and marine water to contribute to mitigating the extensive ecological degradation.

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Climate change is another significant and growing environmental health issue that poses a range of risks and challenges to natural resources, ecosystems, and the stability of nations and communities. As extreme weather events disrupt the infrastructure, increase economic risks, raise temperatures, shift precipitation patterns, and challenge emergency response capabilities, climate change might end up becoming a danger multiplier that causes environmental security. Environment security is one of the major parts of a country and it is the ecological framework required for sustainable development. In Sri Lanka, climate change exhibits a complex and multifaceted challenge with considerable implications for the country's environment, economy, and society due to its geographical position and the dependence on climate-sensitive factors such as agriculture, fisheries, and tourism. As stated by the Asian Development Bank in their study titled 'Climate Risk Country Profile: Sri Lanka' in 2020, the increasing frequency and intensity of extreme weather events such as heavy rainfall, floods, and landslides are the most pressing concerns in Sri Lanka which have been more common in recent years. The climate change impacts including deforestation, habitat degradation, and water pollution are exacerbating existing environmental issues in Sri Lanka. Deforestation and degradation of the habitats disrupt the balance of the ecosystems while reducing their resilience to climate impacts as well as contributing to resource conflicts. Moreover, Water pollution compounds affect both terrestrial and aquatic ecosystems which harm biodiversity while exacerbating climate change through methane emissions and increased energy consumption for water treatment. Hence, the environmental health concerns emphasize the urgent need for thorough climate adaptation and mitigation strategies in Sri Lanka in order to safeguard the well-being of its population and preserve its natural resources and ecosystems. The rise of the sea level and coastal erosion is another threat to the coastal communities in Sri Lanka and vital infrastructure along the coastline. Due to coastal erosion, the coastal ecosystems including mangroves and coral reefs that provide essential habitats and protect against erosion are at risk. Therefore, adaptation mechanisms and necessitating sustainable coastal management strategies are required. As climate change is considered an environmental health concern under the soft notion of national security in a state, many organizations play a significant role in protecting the environment In Sri Lanka, the Ministry of Defence participates actively in addressing the security and strategic implications of climate change. As highlighted in the Extraordinary Gazette No. 2289/43 dated 12th July 2022 under table No. 01, Column 1 para 18, 19, 20, 21, 22, and 23, the Ministry of Defence is responsible for "Provision of weather and climate-related services", "Meteorological surveys and research", "Landslide disaster management and related research and development", "Forecasting natural disasters and sensitizing relevant sectors regarding them", "Coordination of awareness programs on natural and man-made disasters" and "Conduct rescue operations during natural and man-made disasters". The Department of Meteorology, National Disaster Management Council, Disaster Management Centre, and National Disaster Relief Services Centre are the departments and institutions that have been established by the Ministry of Defence to address and prevent disaster risks. Sri Lanka needs a complex and comprehensive response regarding climate change that involves environmental protection hazards mitigation, adaptation, and long-term development initiatives. From the start, Sri Lanka should prioritize initiatives to decrease greenhouse gas emissions, adopt regulations that encourage sustainable land use and transportation, invest in increasing climate resilience across sectors in terms of adaptation, improve early warning systems and disaster preparedness, Investing in climate education and awareness initiatives. Therefore, comprehensive policies are required to ensure environmental protection in the face of climate change in Sri Lanka and it is crucial to increase climate policy, laws, and international collaboration that eventually protect Sri Lanka's environment and people's livelihoods in the face of climate change.

Land degradation, deforestation, degradation of biodiversity, waste and waste disposal, and mining impacts are some other critical environmental concerns in Sri Lanka. As stated by the Ministry of Environment and Renewable Energy (MERE) in Sri Lanka, decreased agricultural productivity, loss of irrigation and hydropower generation capacity due to siltation of reservoirs, and intensification of natural hazards are some of the main manifestations of land degradation. During the last century, the forest cover has been depleted due to the forest clearing for irrigation, agriculture, settlements, hydropower generation, timber extraction, and shifting cultivation. Further, as described by the MERE, the extensive use of fertilizers and pesticides has affected the degradation of biodiversity by affecting the forests and wetland flora and fauna. Considering the management of Municipal Solid Wate, the daily generation of MSW in the western and central provinces is 1660 and 230 tonnes/day respectively (MERE). The local authorities are responsible for maintaining the open dumpsites while the western province itself has more than 60 open dumpsites. Some of the institutions in Sri Lanka practice composting, anaerobic digestion, incineration, and recycling to produce compost, biogas, electricity, and the recovery of valuable materials. However, a comprehensive action plan and infrastructure is crucial for disposing of Municipal Solid Waste as it is creating a series of environmental hazards in Sri Lanka. Soil erosion and sedimentation in Rathnapura district are major environmental impacts of gem mining in Sri Lanka. Furthermore, tunnel mining causes land subsidence and accumulates water in open mines that act as sites for breeding mosquitoes.

In conclusion, environmental health is a critical matter that spans multiple sectors, which necessitates coordination and collaboration among the various sectors to enhance the quality of life for millions of individuals. As Sri Lanka is now going through a transition to emerge as an industrial economy with a growing service sector, it is important to change the environmental concerns from poverty-related concerns to production and consumption-related issues. In addition, there is a crucial need to incorporate an economic advancement in environment and health by enhancing the identification of the quantitative links between environment, health, and economic advancement, or the introduction of liability and compensation frameworks. These measures should consider the irreversible impact on health and the environment, as well as principles of intergenerational equity. Therefore, there is a great necessity to improve environmental health knowledge among both healthcare professionals and the general public. Comprehensive environmental education integrated into educational curricula at all levels can be used to empower individuals to safeguard themselves from environmental hazards and reduce the health consequences of environmental factors.

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Invasion-Promoting Potential of Bisphenol A in Liver Cancer Depends on Cancer Cell Differentiation State

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Bisphenol A (BPA) is a monomer and plasticizer used in production of polycarbonate plastics and epoxy resins-coated food and beverage cans. BPA is released from polycarbonate water bottles and food cans. It widely spreads in environment, and finally reaches to human body. BPA has been detected in blood and urine of people around the world. Liver cancer (hepatocellular carcinoma) is one of the most cancer found in Thailand. Cancer invasion is a critical step of metastasis - the spread of cancer cells in the body. Invasion-promoting effect of low concentrations of BPA has been evident in several cancer cell types, but the effect in liver cancer has not been reported. Differentiation state of cancer cells reflect their loss of tissue-origin characteristics and functions, and related to invasion capability of the cancer cells. Until now, there are no report of the differential effect of BPA across liver cancer cell lines with different degrees of differentiation. To explore this issue, three human liver cancer cell lines (HepG2, HCC-S102, and SK-Hep-1) were used as a model to evaluate effects of BPA. To determine differentiation state of the cell lines, qRT-PCR method was used to detect expression level of liver-specific and epithelial-specific genes (albumin, glucose-6-phosphatase, E-cadherin, and c-Met). Cell growth and invasion were determined by using MTT and Transwell assay, respectively. HepG2 cells displayed a well-differentiated state by expressing all four target genes, whereas HCC-S102 and SK-Hep-1 cells showed lesser degrees of differentiation by losing expression of two and three genes, respectively. BPA at low concentration range (1 to 100 nM) did not affect growth of all the three cell lines. Invasion-promoting effect of BPA was the most prominent in HepG2 cells (well-differentiation) and lesser in HCC-S102 cells (intermediate differentiation), while was not observed in SK-Hep-1 cells (poorly differentiation). Effect of BPA on activation of invasion-related signaling proteins in HepG2 cells was investigated. Immunoblot analysis revealed that BPA treatment selectively increased Akt phosphorylation in HepG2 cells. Finally, BPA-promoted invasion in HepG2 cells was abolished by treatment with a PI3K-specific inhibitor. This study suggested that exposure to low concentration of BPA might accelerate metastatic progression of well-differentiated liver cancer through activating PI3K/Akt signaling pathway.

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Baby Diapers Containing Toxic Chemicals and Its Risk to Human Health and the Environment in Ethiopia; A Call to Action

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Baby Diapers Containing Toxic Chemicals

Baby diaper is a sanitary consumer product particularly used for infants aged up to 30 months that are not able to do toilet training by themselves. It is believed to be invented in the middle of the 19th century in Sweden. During the time diapers were considered as a luxury product and mainly used for special occasions like going on a long car trip ad flying across the country[1]. Through time it became one of the dominant ways to prevent leakages around the legs and waist and stay the baby dry for up to 12 hours.

Different studies have found that baby diapers contain various types of toxic chemicals including polychlorodibenzo-p-dioxins (PCDDs), xylene and toluene, ethylenebenzene, and polyacrylates or phthalates that can pose a higher risk to children health and the environment when dumping out[2].

- **Polychlorodibenzo-p-dioxins (PCDDs)**: are substances which are part of the bigger groups of the 75 various dioxins. It can be exposed through inhalation, ingestion, and dermal contact Babies can be exposed when using PCDDs containing diapers and those with skin infections are highly exposed.
- **Ethylenebenzene:** is an organic chemical substance with potential carcinogen characteristics and acute toxicity for sensitive groups like infants and children.
- **Xylene and toluene:** are toxic chemicals that contain harmful substances with potential exposure through inhalation, ingestion and dermal contact.
- **Polyacrylates/Phthalates:** are additive harmful chemicals used as plasticizers added to plastics in diapers to strengthen their durability, flexibility and longevity.

Baby Diapers in Ethiopia

In Ethiopia, baby diapers have become one of the essentials for infants. The baby diaper product in Ethiopia is both imported directly and manufactured by some local industrial parks. Ethiopia imported an estimated 4.9 million kg of baby diapers from Egypt, China and Turkey[3]. The local industrial parks manufacture diapers by importing raw materials from abroad. The market of baby diapers in Ethiopia is expected to grow by $391 million during 2021 – 2027, growing at an annual growth rate of 13.6%. Rising rates of labor force participation, middle-class consumer growth, and increased urbanization are the key market growth drivers[4].

The diaper lifecycle in Ethiopia starts from importation/manufacturing to end users and finally to dumping sites. Currently, the potential environmental and health risks of chemicals in diapers are not well acknowledged and not given proper attention nationwide. It is not considered toxic and harmful even by health organizations under the national government. There is no risk management strategy in place to manage toxic chemicals found in baby diapers. Importers, manufacturers, distributors, retailers and end users have limited concern about the impacts of baby diapers containing toxic chemicals. There is also a gap in managing baby diaper waste starting from its source to its disposal stage. There is no proper segregation of diaper waste and it is collected and transported together with other wastes.

A sustainable consumption and production approach is designed to ensure the use of products and services that responds to needs and improve the quality of life of citizens while reducing the use of toxic chemicals in products and reduction of potentially hazardous wastes throughout the lifecycle of the product or service[5]. Therefore, the production and importation of baby diapers containing toxic chemicals need to consider the potential health risks that pose to babies and the risks associated with the generation of hazardous waste that is to be disposed of in the environment.

Risk Reduction and Sustainable Financing

In Ethiopia, baby Diapers containing toxic chemicals have been imported, manufactured locally, and placed on the market widely as well. Appropriate risk reduction measures are required to minimize and control potential risks through sustainable financing. Sustainable financing will help the sound management of chemicals and wastes in the country by identifying the roles and responsibilities of traders and industries involved in the transaction of products containing chemicals and the regulatory body under the government structure. An integrated approach to financing could be taken in place through mainstreaming in the national budget, involvement of the business community and donors from external financing[6].

Risk Reduction Tool

The risk reduction tool that I have chosen to minimize and control the risks emanating from the use of baby diapers containing toxic chemicals is through economic instruments. Economic tools can be used to speed up the process of innovation and substitution as well as to support safer alternatives by facilitating their entry into the market or growing their market share[7]. Economic instruments are important to reduce the use of chemical-intensive products and encourage the utilization of chemicals-free and environment-friendly products through taxes, fees and subsidies.

The main interventions to be used while adopting the economic instruments for the management of baby diapers containing toxic chemicals are as follows.

- Imposing higher taxes on importers and manufacturers that import and manufacture baby diapers containing toxic chemicals,
- Higher subsidy to importers and manufacturers that import and manufacture chemical-safer and environment-friendly baby diapers,
- Imposing Extended Producer's Responsibility (EPR) on importers with strict follow-up and law enforcement.
- Subsidizing chemical-safer baby diaper products for consumers.

Table 1 Stakeholders and their roles in implementing economic instruments for risk reduction

List of stakeholders	Roles and Responsibilities	Areas of sustainable financing
The Parliament	Ratifying laws and legislation on the adoption of economic instruments	Budget for subsidies and fees
Environmental Protection Authority	Initiating laws and regulations, enforcement.	Awareness, monitoring and inspection
Ministry of Health	Monitoring public health issues, impacts on women and children	Research and study
Ministry of Trade	Monitoring imports and exports	Awareness, monitoring and inspection
Ministry of Industry	Monitoring Manufacturers	Awareness, monitoring and inspection
Customs Commission	Monitoring of imported and exported consumer products	Awareness and inspection
Business Communities	Importation and production	Importation and production of safer alternatives
Ministry of Women and Social Affairs	Ensure the incorporation of gender issues in all implementations of the tool	Awareness and research

Options for Financing National Administration

1. A wide range of societal awareness through different risk communication tools: which is very feasible and can address the problem very well since one of the factors is lack of awareness.
2. Capacitating the government regulatory and research body on sound management of baby diapers containing toxic chemicals throughout the lifecycle: this is also very feasible and one of the areas that need sustainable finance both from the national budget and external sources.
3. Promotion of innovation and technology for safer product alternatives: a critical activity and feasible since business communities have weak infrastructure and old technologies for their operation.
4. International cooperation on the phase-out of chemical-intensive products is very important since transboundary trade and the movement of chemical-intensive products is a global problem that requires bilateral and multilateral cooperation and action.

Conclusion

Baby diaper is a sanitary consumer product particularly used for infants aged up to 30 months that are not able to do toilet training by themselves. Different studies have found that baby diapers contain various types of toxic chemicals including polychlorodibenzo-p-dioxins (PCDDs), xylene and toluene, ethylenebenzene, and polyacrylates or phthalates that can pose a higher risk to children health and the environment when dumping out. In Ethiopia, baby diapers have become one of the essentials for infants. The demand and supply of baby diapers have been increasing significantly over the past some years. Sound management of baby diapers containing toxic chemicals is required to minimize and control the risk associated with it. Sustainable financing is critical through the management process. Economic instruments are the best tools to minimize risk through the participation of all key stakeholders. The adoption of economic instruments requires sustainable financing to strengthen the administration system to manage baby diapers. The government of Ethiopia must take risk-reduction measures as soon as possible to protect human health and the environment from the adverse effects of toxic chemicals in baby diapers.

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Exposure to Low Concentration of Perfluorooctanesulfonic Acid (PFOS) Increases Metastatic Potential of Thyroid Carcinoma Cells

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Perfluorooctanesulfonic acid (PFOS) is a man-made fluorosurfactant widely used in various consumer products and has been considered as a persistent environmental contaminant. Cancer invasion is the primary step of the cancer spread process to distant regions in the body that termed metastasis. The agent's potential to accelerate invasion and metastasis has been considered a new risk assessment of environmental contaminant substances. A wide concentration range of PFOS (0.3 to 869.8 nM) was detected in serum of U.S. general population (3,966 cases). Thyroid carcinoma is cancer cells that developed in the thyroid gland. PFOS has been detected in surgical thyroid tissue specimens. However, the information about effect of PFOS on thyroid cancer metastasis is limited. This study aims to investigate effect of PFOS on cell invasion capability of FTC-133 thyroid carcinoma cells. MTT and Transwell invasion assays were used to determine cell growth and cell invasion, respectively. Effect of PFOS on invasion-related cell signaling pathways was assessed by western blot analysis. PFOS treatment at 1 nM for 72 h did not affect cell growth but markedly increased cell invasion. Phosphorylation of Akt, ERK, and EphA2 signaling proteins in FTC-133 cells was increased by PFOS treatment. In summary, exposure to low concentration of PFOS might accelerate metastasis of thyroid cancer.

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Microplastic Pollution in Paradise: Assessing Environmental Health Concerns in Sri Lanka

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Introduction

Over the past several decades, there has been a significant increase in both the production and utilization of plastics on a global scale. This surge in production encompasses a wide array of plastic products, ranging from single-use plastic ware to disposable materials such as single-use water bottles, disposable personal protective equipment, straws, food containers, plastic bags, and wrappers. Unfortunately, this proliferation of plastics has led to a concerning accumulation of plastic waste in the environment, driven by a combination of low recovery rates and high disposal rates. It is estimated that millions of tons of virgin plastic items are manufactured annually, with commercially produced plastics including polyethylene, polyethylene terephthalate, polypropylene, polystyrene, polyvinyl chloride, acrylates, nylon, melamine, and polyesters [1].

According to the "National Action Plan on Plastic Waste Management 2021-2030" report issued in 2021 by the Ministry of Environment in Sri Lanka, the country imports approximately 300,000 metric tons per annum of virgin plastic raw materials for various applications. Alarmingly, the report highlights that a staggering 10,768 metric tons of solid waste, predominantly consisting of plastic, is generated daily, yet only a fraction, approximately 3458 metric tons, is collected by authorities. The remaining waste is often disposed of improperly, either by being released directly into water bodies and soil or through incineration. One contributing factor to this issue is that many plastic items manufactured by Sri Lankan industries are not recycled after use, as the recycling process is perceived as more costly and time-consuming compared to importing raw plastic materials [2].

As a small island nation, Sri Lanka faces significant environmental challenges due to the accumulation of plastic waste on land and its disposal into marine environments and rivers. Plastic waste in Sri Lanka originates from various sources, including electrical and electronic waste, healthcare and clinical waste, construction site debris, plastic waste from food and agriculture sectors, the textile industry, and packaging materials [1].

Plastic waste released into the environment undergoes physical degradation through processes such as crushing, as well as biological, enzymatic, and chemical degradation, leading to the formation of secondary microplastics measuring less than 5 mm in length, as well as nanoplastics measuring less than 1mm. Additionally, primary microplastics are intentionally produced as small particles for use in cosmetics like cleansers, scrubs, toothpaste, and synthetic textiles. Alongside micro and nanoplastics, larger categories of plastic waste include meso-plastics (5-25 mm), macro-plastics (26-100 mm), and mega-plastics (>100 mm). However, particular concern surrounds microplastics and nanoplastics due to their potential environmental and health impacts [2].

Microplastic Pollution in Sri Lanka

Once microplastics are generated, the particles accumulate in soil and leach into underground water sources. Through rivers, these particles ultimately end up in the marine environment. The presence of microplastics poses significant threats to marine organisms' digestive systems, potentially causing reproductive and developmental disorders, as well as inflammation of vital organs such as the liver and kidneys. The ingestion of microplastics can occur directly or indirectly; for instance, zooplankton ingest microplastics when the particles are covered by biofilms, and subsequently, these zooplankton are consumed by higher marine animals. Ultimately, this food chain leads to humans, who occupy the apex of the food chain. Microplastics not only contain toxic chemicals themselves but also serve as carriers for other harmful pollutants. While some studies have explored the health impacts of microplastics on animals like mice, data regarding the hazardous effects of microplastics on human health remain scarce [1].

The MV X-Press Pearl ship disaster stands out as one of the most alarming maritime accidents to have occurred in the Indian Ocean, near the western coastline of Sri Lanka in May 2021. This vessel was carrying approximately 1500 containers laden with various metallic, chemical, and plastic substances. According to the cargo list published by the UN advisory committee, more than 1700 tons of plastic nurdles and 11000 tons of polymer products were released during this calamity, marking it as the worst maritime nurdle spill in history [3, 4]. A study conducted by Sewwandi M. et al. found that Sarakkuwa Beach in Sri Lanka, located just one nautical mile from the disaster site, is heavily polluted with 2-5mm nurdles and pyrolyzed microplastics [5].

Marine-derived products consumed by humans, such as seafood, algae, and sea salt, serve as major avenues for exposure to microplastics. Food-grade salt, predominantly obtained from seawater, saline lakes, and saline rocks, is often contaminated with microplastics due to their accumulation in oceans. A study by Kapukotuwa R.W.M.G.K. et al. in 2022 on microplastic contamination of sea salt concluded that commercial sea salt from Hambantota, Sri Lanka, was the most heavily contaminated, followed by Puttalam Sea salt and Elephant Pass sea salt. Furthermore, the study identified microplastics primarily in fiber form, with 23 polymer types identified, among which low-density polyethylene was the most abundant [6].

Seafood, being a primary source of sustenance for many, is significantly contaminated with microplastics, given the ocean's role as the ultimate repository of microplastic accumulation [7]. Prawns, in particular, serve as carriers of microplastics to humans, as they are extensively consumed, especially those inhabiting lagoon areas. A study conducted in the Negombo area of Sri Lanka revealed that two commercially available prawn species, *Penaeus monodon* and *Penaeus indicus*, were contaminated with blue-colored microplastic fibers exceeding 1 mm in length. Microplastics were isolated from the gastrointestinal tracts and gills of the prawns, with the observed microplastics in the Negombo lagoon water identified as polystyrene, polyamide, polyester, polypropylene, and rayons, suggesting fishing nets and tools as major sources of microplastics in the region [8].

Another study aimed at detecting microplastic contamination in ten selected coral reefs in Sri Lanka revealed an average detection of more than 500 microplastic items per kilogram of coral. The most abundant polymer type identified was low-density polyethylene. Coral reefs serve as crucial environments for marine organisms, including fish, and act as habitats for various marine life forms. Plankton contaminated with microplastics are easily ingested by fish and other animals, leading to the accumulation of microplastics in higher trophic levels of the food chain [9].

Bottled water presents another significant concern regarding microplastics in Sri Lanka. While commercially available bottled water in plastic bottles in some countries has been found to contain various types of microplastics, limited studies have been conducted in Sri Lanka to determine the levels of microplastics in bottled water. These plastic bottles are often reused multiple times by consumers, sometimes being stored in a manner that exposes them directly to sunlight. Additionally, some individuals refill these bottles with warm water, potentially leading to the leaching of microplastics into the water. In a study by Kapukotuwa G. et al., thirty-five brands of bottled drinking water samples were tested, and all samples were found to contain microplastics. Most of the microplastics were in fiber form, followed by films and fragments. Twelve types of polymers were identified, with polyvinyl alcohol, polyacrylamide, polyethylene, and polyethylene terephthalate being the dominant polymer types. It was reported that the water sources for these bottles were mainly springs, dug wells, and tube wells [10]. Rivers in Sri Lanka are the primary source of tap water, and they are often contaminated with household and industrial waste, contributing to microplastic pollution. Although treatment plants can remove a considerable amount of microplastics from raw water, these pollutants are still detected in treated water samples [11].

Toxicity of Microplastics

The toxicity of microplastics poses a concerning issue for human health, as individuals can potentially encounter these tiny particles through inhalation or consumption via food and beverages. Despite the widespread exposure, our understanding of the specific impact of microplastics on human health remains incomplete, with a lack of available data pertaining directly to humans. Nonetheless, numerous research efforts have been undertaken to investigate the effects of microplastics on animal models. Through these studies, a range of adverse effects have been uncovered, including toxicity within the gastrointestinal tract, cardiovascular system, neurological function, behavioral patterns, oxidative stress responses, inflammatory reactions, hematopoietic disorders, immune system dysregulation, reproductive impairments, disruptions to endocrine functions, and metabolic irregularities across various animal models [12].

Action Plan of Sri Lankan Government to Reduce Plastic Pollution

The Ministry of Environment of Sri Lanka, in its forward-thinking approach, has diligently implemented an extensive action plan spanning until 2030, aimed at mitigating the dire issue of plastic pollution plaguing the nation. This comprehensive action plan predominantly centers on the effective management of plastic waste, steadfastly adhering to the esteemed 3R principle: reduce, reuse, and recycle, all with the overarching objective of fostering sustainable consumption practices for plastics while minimizing their detrimental impact on the environment. Within the ambit of this visionary action plan, concerted efforts are directed towards curbing the rampant proliferation of single-use plastics, augmenting the collection and recycling infrastructure for plastic waste, and curtailing the pervasive use of plastic as packaging materials. Moreover, the plan espouses and promotes the adoption of cleaner production strategies by industries, fostering in-house recycling initiatives, and rigorously ensuring the quality standards of recycled materials [2].

By steadfastly adhering to the tenets of a circular economy, the action plan unequivocally aspires towards the attainment of zero landfill status, thereby charting a sustainable course towards a cleaner and greener future for Sri Lanka.

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Assessment of Exposure to Pesticides and the Knowledge, Attitude and Practice among Farmers of Western Bhutan.

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Abstract

An estimated 69% of the population of Bhutan is engaged in agriculture. Farmers are exposed to a wide variety of pesticides during the preparation, transport, storage, mixing and application of pesticides posing a significant health risk. A controlled cross-sectional study of farmers in selected sites of Bhutan was conducted to characterize the level of exposure to pesticides and assess their knowledge attitude and practice on the safe handling of pesticides. A total of 399 participants were enrolled in the study comprising of 295 exposed farmers and 104 healthy and unexposed controls. A structured investigator administered questionaries was used to assess their Knowledge, Attitude and practice, and their blood samples were taken for measuring Acetyl Cholinesterase enzyme activity level. There was a significant difference between the Acetyl Cholinesterase enzyme inhibition of exposed and non-exposed control groups observed in the study ($P < 0.001$). Of the total of 295 farmers, 62 (21.01%) had severe enzyme inhibition of >30% as compared to the unexposed group. Safety practices of handling pesticides were low. The most common symptoms self reported were headache (OR 1.08, 0.60–1.93) and neurological problems like forgetfulness, lack of concentration (OR 1.12, 0.50–2.48) and increased tiredness (OR 1.075, 0.52–2.19) that were significantly associated with the enzyme inhibition. In addition, we record a very low level of knowledge (17.0%), a fair attitude (63.0%) and poor practice (35.0%) on the safe handling and management of pesticides. This pilot study provides indication of exposure to pesticides in the selected sites of the country. Furthermore, it provides evidence for public health interventions by identifying the exposure patterns and pathways of individuals most at risk in the farming communities of the country. Surveillance and bio-monitoring programs are deemed necessary.

Introduction

Pesticides are substances that destroy, repel or attack pests and include: herbicides, insecticides, fungicides and rodenticides. Exposure to pesticides, short and long term/dose dependent effects is associated with various unintended adverse effects on humans and the environment [1]. More specifically, exposure is associated with development of wide spectrum of diseases such as cancer, endocrine disturbances, asthma, hypertension, diabetes, allergies and also developmental toxicities like miscarriage and infertility [2–4]. These OP and carbamate pesticides affect the nervous system by inhibition of the acetylcholinesterase enzyme (AChE) causing poisoning to agriculture workers and children [7]. In Bhutan, an estimated 69% of the population is engaged in agriculture [8]. A range of insecticides, fungicides and herbicides are imported and widely used in the country. And Bhutanese farmers are likely to be exposed to a wide variety of pesticides during the preparation, transport, storage, mixing and application of pesticides [9]. Moreover, there are unsubstantiated reports indicating the use of pesticides without the recommended safety measures by farmers. Currently, very little is known about the extent of pesticide exposure among farmers and the awareness levels about the potential toxicity of inappropriate handling of pesticide and use of personal protective equipment (PPEs) while handling pesticides. Although the government emphasizes organic agriculture, the use of pesticides has been increasing due to frequent outbreaks of pests and diseases such as fall armyworm, rice blasts and chili blight [10]. Notably, there is a steep rise in diseases such as cancer, hypertension and diabetes that are of increasing public health concern among the Bhutanese population [11] which maybe attributed to chemicals. Monitoring programs are undertaken to detect early physiological changes before resulting in reversible or irreversible diseases and illness. The globally accepted monitoring programs include the measurement of peripheral cholinesterase enzymes; the erythrocyte and serum cholinesterase [14]. These are the approved surrogate biomarkers for exposure of OP and carbamate pesticides [7]. The inhibition of the AChE enzyme is the early event of poisoning by OPs and carbamates before the onset of severe neurological conditions [15]. Such surveillance and bio-monitoring programs are unavailable in the country. Therefore, this study aims to determine level of pesticide exposure, identify the associated risk factors and assess the knowledge, attitude and practice on proper handling and safe management of pesticides.

Methodology

Study type and settings

The study employed the prospective observational approach to assess exposure via the comparative inhibition of AChE enzymes in farmers that handled pesticides and the control group for comparison (i.e. individuals not directly exposed to pesticides). A total of nine villages from four districts that use the maximum pesticides in the country were sampled for the study.

Sample size

The sample size was determined at confidence interval level of 95% with a desired margin of error of ± 5% with population proportion of 50% using epi info statcalc version 7.2.4.0 [17]. The target population of famers (i.e. pesticide handlers and control) from sample villages of four dzongkhags were randomly selected from the list of households provided by the government officials. A total of 295 farmers handling pesticides were involved in the study.

Study tool

An investigator-administered questionnaire was used to collect demographic information, risks, KAP on risks, proper handling, and safe management of pesticides. Sample farmers were asked about safe handling of practices, and symptoms associated with pesticide exposure. For the control group, only the demographic variable, occupation, comorbidities and whether they handled pesticides or not were asked to select samples for the study. Finally, blood samples were collected from all the consenting and qualifying participants to test for AChE inhibition assay.

Blood sample collection and testing

From each sample participant, 5 ml of blood samples was collected in vacutainer. The test for AChE inhibition was performed with Ellman method [18] as per the manufacturer's instruction in the leaflet.

Determination of cut-offs for AChE inhibition

The reference value for blood cholinesterase levels has been not established in the country yet. Also, the baseline value of the study population was not measured in the study. Therefore, the AChE levels were compared with the normal unexposed population range. The benchmarks for cholinesterase in whole blood were determined from the enzymatic activity of the enzymes in the control group stratified by gender. To classify, the inhibition in the case/exposed groups to OP pesticides, an inhibition value of 30% was used accordingly to the US EPA

Questionnaire

The study questionnaire was adopted and modified from studies elsewhere [20–22].

Data analysis

The data was entered in forms created with Epi info version 7 and extracted and analyzed using both Epi info version 7 and IBM SPSS Version 22.

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Ethics approval

Ethical approval was sought from the Research Ethics Board of Health in Bhutan Ref. No. REBH/Approval/2022/015. Written informed consent was obtained by getting both the signature on the approved consent form from the eligible farmers prior to interview and that of the person obtaining consent.

Results

Socio-demographic characteristics

A total of 399 participants were enrolled for the study, of which 295 (73.9%) were exposed and 104 (26.0%) were unexposed control group. There were 214 (53.63%) males and 185 (46.36%) of the females. Among the exposed farmers group, 55.2% (n = 163) were males and 44.7%(n = 132) were female.

The mean age of male was 45.78 ± 13.28 and female was 42.89 ± 12.43. Between the different age categories of respondents, the majority of the respondents (n = 120) were in the age group of 35–49 years and the least was observed in the age category of 18–24 years (n = 11). It was found that 48.5% (n = 145) of the respondents were literate while 51.5% (n = 154) were illiterate.

During the study period, the majority of farmers had been farming between 21–30 years (22.71%) while the least was between 1–5 years (10.51%). Among the types of crops grown, the majority (87.2%) grew potatoes, whereas the least grown was rice (0.3%). It was found that almost all the farmers included in the study use pesticides in their farms. The most common pesticides used were cypermethrin (58.19% (n = 174)) followed by mancozeb (22.07% (n = 66)) of famers used cypermethrin, whereas only 0.33% (n = 1) used malathion.

Prevalence of blood AChE inhibition

The overall mean of AChE levels of the study participants was 673.9 ± 144.4 mU/ml. A significant difference between the AChE enzymatic activity of exposed and non-exposed control groups (652.01 vs 733.68) was observed in the study ($p < 0.001$). Male exposed farmers had a slightly lower AChE level (642.7 ± 153.0 mU/ml) than exposed female farmers (663.7 ± 141.6 mU/ml), however this difference was not significant ($p < 0.216$). Furthermore, the benchmarks for the total AChE inhibition in whole blood were obtained from the mean values of the control group (n = 105) for comparison. The overall activity of the AChE enzyme in the control group corresponded to 733.68 mU/ml, and 703.87 mU/ml in males and 755.96 mU/ml in females. Therefore, a 30% inhibition of AChE cut-offs was adopted as 513.0 mU/mL in all participants, 492.71 mU/ml in males and 529.18 mU/ml in females respectively. Of the total of 295 farmers, 62 (21.01%) had severe AChE inhibition of > 30% as compared to the unexposed group. The prevalence among the exposed farmer population was 20.60% in males and 20.76% in females. Similarly, farming experience in years also did not influence AChE levels in the exposed groups ($p > 0.721$), although farming groups in the 1–10 and 10–20 years showed a slight inhibition in AChE levels compared to those in 20 to 30 and 30 years and above farming experience.

Pesticide usage and poisoning risk factors

The main risk factors of poisoning identified in the study were farmers spraying and finishing whatever pesticides mixtures that they have made (82.6%) and disposing the empty containers along with the household garbage (40.0%). In addition, 34.0% of the farmers were routinely spraying pesticides regardless of whether they observe pests or not.

Prevalence of clinical symptoms associated with pesticide usage

The most common symptoms reported in our study by the farmers was headache (61.0%), forgetfulness/lack of concentration (61%) followed by burning/watery eyes (43.0%) and increased tiredness (36.9%) respectively (Table 6). A comparative analysis using chi square test was conducted in an attempt to determine the relationship between blood AChE level and subsequent clinical symptoms. Headache and forgetfulness/lack of concentration were significantly associated with the inhibition of the AChE enzyme (p-value 0.0146 and <0.0001).

Knowledge, attitude and practice of farmers

The questionnaire used for the assessment in the current study was pre-tested and adapted from previous studies conducted elsewhere [23, 24]. There were 7 knowledge assessment questions, four attitude questions and eight practice assessment questions (S2–S4 Tables). Previously published methods were used for calculating knowledge, attitudes and practices scores [24]. The present study shows that only 17% (n = 52) of the interviewed farmers had a high level of knowledge and majority (59%, n = 177) had low knowledge on the usage of pesticides The attitude assessment consists of four questions that could be answered by 'strongly agree to strongly agree' or being neutral. The study shows that, 63% (n = 188) of the respondents had concerned attitude and 37% (n = 112) of them are least concerned with right attitude while handling pesticides safely while working in the field.

Discussion

This is the first ever study to assess the exposure to pesticides and the knowledge, attitude and practice regarding the safe handling and management of pesticides among the farmers in four Dzongkhags (regions) of Bhutan. The study exhibited a significant depression of AChE enzyme level among farmers as compared to the control. Neurological problems like headache, forgetfulness, lack of concentration and increased tiredness were associated with AChE inhibition. Moreover, the observation on safety practices of handling pesticides were low. A statistically significant level of inhibition of AChE activity in farmers were reported low as compared to the control unexposed group ($p < 0.001$) giving a prevalence of 21.01%. This indicates that farmer's depression of AChE enzyme is attributed to the pesticide exposure raising a concern to their health. Exposure to pesticides in farmers occurs due to unsafe working practice such as not using proper personal protective equipment, having a limited knowledge on the safe handling and management of pesticides [29]. Therefore, advocacy on the proper use of pesticides, the risk associated to it and bio-monitoring programs are necessary.

Conclusions

The findings from this study indicate that the sampled population of farmers had significant inhibition of AChE activity as compared to the unexposed group. This provides strong evidence of exposure to pesticides raising concerns on the health risk it poses. Farmers had a low level of knowledge and the practice was low. Poisoning risk factors identified; included random use and dosage of pesticides, poor management of pesticide waste, illicit import of pesticide across the border and inadequate knowledge on the purpose of pesticide application that may lead to high exposure and pesticide poisoning events in the future. Most of the farmers included in the study reported two or more clinical symptoms which were associated significantly with the depression of AChE enzyme activity. Pesticide usage in the country therefore needs to be controlled via regular monitoring of exposure, assessment of PPE usage and compliance, provide public awareness and advocacy on its health impacts.

P-23

Application of Protists Isolated from RSPG Areas in Assessing Toxicity of Pollutants in Laboratory: A Case Study of Insecticides

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To reduce yield loss due to agricultural destruction by insect pests, increasing use of chemical insecticides nowadays may have led to loss of ecological balance. Such chemicals not only destroy the target pests, but also other organisms inhabiting the same environments. Utilization of natural compounds has provided an alternative approach and is believed to be less harmful to humans and environments in general. This research was aimed at assessing and comparing the toxic effect of four insecticides — three chemically synthetic ones, namely organophosphorus profenofos, pyrethroid betacyfluthrin, and neonicotinoid thiamethoxam, and a naturally derived *Derris elliptica* (Wall.) Benth. extract — on a freshwater ciliate strain, Paramecium species, isolated from a man-made canal in Chulalongkorn University. Toxicity evaluation of each insecticide was based on the concentrations of the chemical that produce mortality in 50% of the treated cells (LC_{50}) after 24-hr exposure. The results indicated that betacyfluthrin was the most toxic insecticide to Paramecium sp. with the LC_{50} of 3.30 µg/ml, followed by profenofos (12.36 µg/ml) and thiamethoxam (83.46 µg/ml), respectively. On the contrary, *D. elliptica* extract showed the least harmful effect on *Paramecium* sp. as indicated by an averaged high viability percentage of 89.79% after treating the cells with a 500-time concentration of recommended dose for 24 hr. On the treated cells of Paramecium, the chemical insecticides also induced the formation of cytoplasmic blebbing, detachment of cilia, and morphological deformity, ultimately leading to cellular lysis. This study not only demonstrates the cytotoxic impact of chemical insecticides on a freshwater ciliate *Paramecium* sp., but also supports the use of insecticides derived from natural extracts, which are more eco-friendly than the chemically synthetic ones.

N-Phenylpyrazole Insecticide Fipronil Causes Endoplasmic Reticulum Stress and Unfolded Protein Responses in SH-SY5Y Cells

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Numerous people experience neurodegenerative illnesses, symptoms found in neurodegenerative diseases which are mainly described as age-related diseases. However, exposure to environmental toxicants is also considered to be a risk factor for developing neurodegenerative diseases. The increasing use of fipronil, a broad-spectrum *N*-phenylpyrazole insecticide, in various sectors poses a human health risk. This study aims to use proteomics for exploring neurodegenerative mechanism of fipronil in SH-SY5Y human neuroblastoma cells. In this study, upon fipronil treatment at sub-cytotoxic and cytotoxic concentrations (43 and 78 μM) induced superoxide production from 3 to 48 hours. Moreover, decreasing levels of glutathione were found at 48 hours, suggesting oxidative imbalance induced by fipronil. Neurite outgrowth was found to be damaged by fipronil at both concentrations. However, cell death via apoptosis and necrosis modes were induced by fipronil only at cytotoxic concentration. Pretreatment of N-acetyl cysteine (NAC), an antioxidant, effectively ameliorated neurite outgrowth damage and cell viability impairment induced by fipronil. Proteomic analysis showed that expression of proteins involving endoplasmic reticulum (ER) stress and unfolded protein responses were predominantly affected by fipronil. Immunoblotting confirmed the increased expression of ER stress markers, GRP78/BiP (HSPA5) and PDI (PDIA3), in fipronil-treated cells. These findings indicate that fipronil is an environmental risk factor for neurodegenerative diseases and its use should be carefully managed in order to reduce human health risks.

P-25

The Impact of Paraquat on Antibiotic Resistance in Bacteria: A Study of *ferritin-like* (*frl*) Gene in *Stenotrophomonas maltophilia*

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Paraquat, a widely used herbicide in agriculture, has been shown to induce genetic changes in bacteria that can affect antibiotic susceptibility by triggering a stress response and altering gene expression related to antibiotic resistance. Our laboratory has selected paraquat-induced mutants that showed increased resistance to ciprofloxacin in *Stenotrophomonas maltophilia* K279a. Whole genome sequence analysis revealed that some of the mutants had mutations in the *ferritin-like* (*frl*) gene. Ferritins are involved in managing intracellular iron levels, protecting cells from iron toxicity, and safeguarding against oxidative stress and DNA damage.

To confirm the function of the *frl* gene on antibiotic resistance phenotype, the *frl* knock-out strain was constructed and the mutant showed increased resistance to various antibiotics, including β-lactams, aminoglycosides, and fluoroquinolones, and enhanced tolerance to paraquat and other oxidative stress generating substances and iron-related compounds. However, the *frl* knock-out strains were more sensitive to ferric chloride than the wild-type and complemented strains. These results suggest that the *ferritin-like* gene plays a complex and multifaceted role in modulating bacterial antibiotic resistance and oxidative stress response and that its knock-out confers a fitness advantage under certain environmental conditions.

Interestingly, compared to K279a wild-type the *frl* knock-out strain showed higher plating efficiency and bacterial growth rate under low temperatures (20 and 25°C). We noticed that the *frl* gene exists at a higher frequency in the clinical strains than the environmental strains of *S. maltophilia* implying that the lack of this gene can make the environmental strains survive under low environmental temperatures.

In conclusion, our study suggests the roles of the *ferritin-like* gene in the evolution of antimicrobial resistance, tolerance to oxidative stress, and iron homeostasis in *S. maltophilia*.

Keywords: Paraquat, Antibiotic susceptibility, Stress response, Iron homeostasis, *ferritin-like* gene, and *Stenotrophomonas maltophilia*.

Role of Glyphosate in Antibiotic Resistance in *Stenotrophomonas maltophilia*

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Glyphosate is an herbicide that is widely used for controlling weeds and grasses. Contamination of glyphosate in agricultural areas could have several effects on plant, animal, and human health, and environmental bacteria. *Stenotrophomonas maltophilia* is a gram-negative, aerobic bacterium found in diverse environments, including soil, water, and hospitals. It is also known as an opportunistic pathogen that causes nosocomial infection and inherits antibiotic resistance genes. Currently, the impact of herbicide exposure on antibiotic resistance in bacteria is little known. Therefore, the role of glyphosate in antibiotic resistance is characterized in this study. When *S. maltophilia* was exposed to sub-lethal concentrations of glyphosate)6 mM(, cells exhibited a decreased susceptibility to aminoglycosides. Genes related to aminoglycoside resistance such as *arg1*, *arg2*, *arg3*, *arg4*, *arg5*, *arg6*, *arg7*, and *arg8*, were then measured their expression level in *S. maltophilia* under tested conditions while the expression level of other *arg* genes was in a similar magnitude with the untreated conditions. The results showed that the *arg1* expression was high in the presence of glyphosate. In addition, the *arg1* gene was located in a head-to-head fashion with the *arg* transcription regulator)*argR1*(. Thus, the regulatory function of ArgR1 on controlling *arg1* was investigated. The result showed that *arg1* expression was regulated by ArgR1. However, there are other unidentified regulators that might be involved regulation of *arg1*.

Keywords: Glyphosate, Antibiotic resistance, and *Stenotrophomonas maltophilia*

P-27

Biological Wastewater Treatment and Plant Nutrient Recovery: A Case Study for the Slaughterhouse Industry

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The wastewater discharged from slaughterhouses contains high levels of organic matter and plant nutrients (nitrogen and phosphorus). Therefore, it requires proper treatment to minimize its negative impacts on receiving water bodies. Additionally, given concerns about phosphorus resource depletion, recovering phosphorus from waste-activated sludge for agricultural applications is a promising solution. In this work, we present a local case study on the pilot-scale implementation of three processes for removing and recovering plant nutrients from swine slaughterhouse wastewater. These processes include an AnA^2/O^2 SBR system, an anaerobic sludge digester (ASD) system, and phosphorus crystallization through the struvite precipitation process. The results of the wastewater treatment showed that the AnA^2/O^2 SBR system greatly reduced the concentration of organic matter and plant nutrients, aligning with Thailand's industrial effluent standards. The average removal efficiencies for COD, TKN, and TP were 96.2%, 88.7%, and 86.1%, respectively. It was found that not only did the concentration of phosphorus in the effluent decrease, but there was also significant accumulation of phosphorus in the excess sludge. Phosphorus accumulation in the excess sludge from the pilot plant reactors ranged from 37.8 to 66.1 mg-P/g-sludge. The results of sludge treatment indicated that the ASD system was effective in treating excess sludge from the main wastewater treatment systems (AnA^2/O^2 SBR) and releasing appropriate amounts of plant nutrients into the supernatant. After sludge treatment in the reaction tank with a solid retention time (SRT) of 10 days, the results demonstrated a decrease in the concentration of plant nutrients in the waste sludge (5.92% and 12.64% for N and P removal, respectively), while the digested effluent exhibited higher concentrations of these nutrients. Conversely, in the reaction tank with an SRT of 30 days, there was a significant reduction in the concentration of plant nutrients accumulated in the waste sludge and in the digested effluent. The phosphorus crystallization process proved effective in removing and recovering plant nutrients from the digested effluent. The pH of the solution was a critical factor influencing the quantity and structure of the crystals formed. The struvite precipitation process yielded 0.251 kg/m^3 of struvite, with a phosphorus content of 10.109% in the solids. However, the presence of various foreign ions disrupted the process, leading to the formation of alternative crystal forms, which impacted the environmental and economic benefits anticipated from pure struvite crystals. Despite this, the process remained capable of removing and recovering nutrients from the effluent, indicating the need for further studies to optimize the process and mitigate the effects of foreign ions.

Methodology for Polyhydroxyalkanoate Biosynthesize Material Production by Indigenous Isolated Strains

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Nowadays, the accumulation of nondegradable plastic waste has become an increasingly environmental issue in the modern world. In order to mitigate this approach, biodegradable materials especially polyhydroxyalkanoate (PHA) are becoming recognized for their biodegradability, biocompatibility, and renewability properties that can produced by microorganisms and are significant alternatives to replace synthetic polymers. The framework of this study was applied a quantitative image analysis procedure aiming to identify PHA-producing strains and measure of PHA inclusion by using a visualized bright-field and fluorescence microscope at excitation wavelength 546 nm for PHA granule detection due to Nile red dying and Nile blue A staining technique, respectively. The result shows two positive strains demonstrated significant synthesis of PHA granules inside the cell under growing in nutrient-limited conditions. Quantification of PHA products from these positive strains exhibited a maximum quantity of biopolymer as 14 mg/L and 0.72 mg/L when cultivated in nitrogen limitation with dry cassava pulp waste at 50 g/L as a carbon source. Classification of the biosynthesized polymer was extracted by cell lytic pretreatment and chemical extraction adapted technique prior to characterized by Fourier-transform infrared spectroscopy (FT-IR) indicated this biosynthesized polymer was polyhydroxybuterate (PHB) which is a short-chain polyester family of PHA.

Keywords: Polyhydroxyalkanoate (PHA); Biosynthesize polymer; Biodegradability; Indigenous microorganisms; Nile red dying; Nile blue A; Cassava pulp waste

P-29

Evolution of Water Quality from Bangpakong Headwater to Coastal Area of Chonburi Province in Thailand by Using Water Quality Index Method

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The Bangpakong River is an important river in the eastern region of Thailand and is pointed out the importance of this natural wetland ecosystem from the area of upstream, midstream, and downstream. The river has biological diversity of natural resources and the environment that are important to the lives of communities in the eastern region (The Secretariat of the Cabinet, 2000). The published water quality data of 1) Pollution Control Department, Ministry of Natural Resources and Environment 2) Bureau of Aquatic Safety and Environment, Marine Department, Ministry of Transport and 3) Research Division for Marine Science, Institute of Marine Science, Burapha University from Bangpakong headwater to Coastal Area of Chonburi Province between year 2020 and year 2023 were evaluated by using Surface Water Quality Index (WQI) and Marine Water Quality Index (MWQI) methods and displayed dynamics plots. The results of WQI and MWQI showed that the headwater had good and excellent water quality in every season. The upper part of the Bangpakong River that received water from the community had poor to moderate level for use in the summer and moderate to excellent in the rainy and winter. The lower part of the river in agricultural and farming areas had poor to moderate for use in every season while the water quality in the river mouth had moderate in the summer and poor to moderate in the rainy and winter. As for the water quality in the coastal aquaculture area of Chonburi Bay, it was fair to good in summer, moderate to good in the rainy and excellent in winter. The water quality in the Bangsaen Beach was in the range of fair to very good in the summer, moderate to excellent in the rainy season and moderate to good in winter, respectively. This water quality assessment shows that activities in the community water catchment area and agricultural and farming areas affect the quality of water draining through the Bangpakong Estuary to the coastal areas of Chonburi Province.

P-30

Development of High Performance Immunochromatographic Methods for the Detection of Anti-IFN-gamma Autoantibodies in Adult-onset Immunodeficiency Disease

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Adult-onset immunodeficiency (AOID) is a debilitating autoimmune disease characterized by the production of anti-IFN-γ autoantibodies (anti-IFN-γ AAb), resulting in susceptibility to opportunistic infections, primarily nontuberculous mycobacteria (NTM). The disease is often misdiagnosed as other systemic disorders, leading to delays in appropriate treatment while also wasting resources. The diagnosis of AOID primarily relies on detecting anti-IFN-γ AAb through methods such as ELISA, flow cytometry analysis, or western blotting. In this study, we created an AOID diagnostic test kit using two formats of immunochromatographic test (ICT). For the first format, IFN-γ gold-conjugate was used as detection probe and protein A/G was immobilized at the test zone as the capture probe. For the other format, protein A/G gold-conjugate was used as detection probe and IFN-γ was used as the capture probe. The recombinant rabbit monoclonal anti-human IFN-γ antibody (rb anti-IFN-γ) was used as the positive sample. Both ICT formats provide a similar limit of detection (LOD) at 0.625 ng/mL of rb anti-IFN-γ. When 1/500 diluted human plasma protein was mixed into the sample, the LOD was at 5 ng/mL for both formats. The test kit also demonstrated no cross-reactivity with human anti-myeloblastin antibody and human anti-myeloperoxidase antibody at a dilution of 1/100. Although more studies are needed to validate the efficiency of the ICT in clinical samples, these findings suggest a promising diagnostic test for AOID screening. This test kit has the potential to enable broader population outreach, enhance patient awareness, facilitate prompt medical intervention, and ultimately improve patient outcomes.

P-31

Production of Low-Cost Recombinant Proteins for Immunoassay to Support Local Biologic Drug Development

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Horseradish peroxidase (HRP) is an important enzyme in life science used as an enzyme-based signal amplification for various applications. Herein, we report the design, construction, and expression of recombinant HRP-conjugated streptavidin using the ExpiHEK293 cell expression system. HRP was purified through the Ni-NTA column. The molecular weight of HRP-streptavidin was analyzed using SDS-PAGE and Western immunoblotting. Hemin incubation was performed to activate apo-HRP. The enzymatic activity testing of hemin-activated HRP-streptavidin was tested. The activity of activated HRP-streptavidin with 2 equivalents of hemin showed the highest activity. The results provided convincing result that the production of functional HRP-streptavidin in ExpiHEK293 cells is applicable, which can be further used as a detection molecule in immunoassay to reduce the cost of commercial HRP-streptavidin in the future.

P-32

The Effects of Dibutyl Phthalate (DBP) Degrading enzyme, *EstB*, against β-lactam Susceptibility in *Pseudomonas aeruginosa*

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A dual function Esterase B (EstB) from *Sphingobium* sp. SM42 had been characterized. The studies showed its ability in degrading dibutyl phthalate (DBP), the endocrine disruptor; and cleaving the side chain of antibiotic in cephalosporin family via de-arenethiolase activity. In *Sphingobium* sp. SM42, expressing EstB in periplasmic space had increased antibiotic susceptibility. Here, we used the National Center for Biotechnology Information (NCBI) public database to study the distribution of *estB* and *estB*-like genes in other organisms. Two *estB*-like genes were identified in an inserted sequence of DBP degrading *Pseudomonas aeruginosa* PS1. The two EstB-like protein are called UCM26615 and UCM26628 which are 98% and 90% identical to EstB, respectively. The finding suggested possible horizontal transfer events between microorganisms dwelling in DBP contaminated soil. To mimic multi-copies of *estB*-like genes found in PS1, we introduced plasmid encoding EstB to our surrogate *P. aeruginosa* PAO1. The effect of de-arenethiolase activity in cytoplasm and periplasmic space were studied using antibiotic susceptibility assay. Expressing EstB in the periplasmic space of PAO1 showed an increased in susceptibility to β-lactam antibiotics including carbapenems and cephalosporins suggesting that de-arenethiolase activity of EstB is not specific to *Sphingomonadaceae*. The advantages of horizontally transferred EstB-like proteins in *P. aeruginosa* PS1 is needed to be explored further.

Keywords: EstB, DBP degrading enzyme, De-arenethiolase, β-lactam, *Pseudomonas aeruginosa*

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Identification and Characterization of Small Multidrug Resistance Family Efflux Pump in *Stenotrophomonas maltophilia*

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Quaternary Ammonium Compounds (QACs) have been used in disinfectants, sanitizers, surfactants, and preservatives. The usages had been accelerated by the COVID-19 pandemic leading to the increased exposure of QACs in microorganisms. Gram-negative bacteria acquired *qac* resistance genes via horizontal transfer mechanisms. Here, *qac* resistance gene, named *smr*, encoding Small Multidrug Resistance (SMR) efflux pump was found on genome of a QACs-resistant *Stenotrophomonas maltophilia* strain SMR. A horizontal transfer event was mimic by plasmid carrying *smr* which transferred to *S. maltophilia* strain K279a. This generating K279a/pSMR where function of *smr* against QACs resistance/tolerance was characterized. Growth kinetic of K279a/pSMR against benzalkonium chloride, benzethonium chloride, and cetylpyridinium chloride revealed that pSMR increased QACs tolerance in *S. maltophilia*.

Keywords: SMR efflux pump, QACs, disinfectant, *Stenotrophomonas maltophilia*

Change in Air Pollutant Concentration, Their Associated Meteorological Parameters, and Potential Sources in Samut Prakan Province

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Samut Prakan province has a high air pollution in Thailand regarding many industrial factories, transportation, and open burning. This study investigated a change in air pollutant concentration associated with meteorological parameters and potential sources of air pollutant at Samut Prakan City Hall station (18t). Pollutant data (PM_{10}, $PM_{2.5}$, NO_2, O_3, SO_2, and CO) were analyzed between 2017-2021 with meteorological data (temperature, wind speed, wind direction, and relative humidity) by using time series and bivariate polar plot (BVP). The result demonstrated that high concentration of $PM_{2.5}$ related in east direction which Motorway road no. 9 or Kanchanaphisek road, National highway no. 3344-Srinakarin road, Highway no. 3 Sukhumvit-Samrong road and Phraeksa road are located. For seasonality, high pollutant concentration was found between November to February associated with low wind speed, high air pressure, poor circulation, and ventilation. For factor of land and sea breeze, the result demonstrated that wind speed at daytime (sea breeze) was higher than wind speed at nighttime (land breeze).Therefore, air pollutants concentration in daytime can be diluted rather than that in nighttime. The BVP confirmed that potential sources of PM_{10}, $PM_{2.5}$, NO_2, O_3, SO_2, and CO associated transportation and industrial area. Moreover, Samut Prakan has ecotourism areas (Bang Nam Phueng floating market, Bang Krachao, etc.) that caused VOCs emission to the air and played a role in background O_3 concentration. This study provided important potential sources of pollutants and high concentration duration that can be used by policy maker to set mitigation policy and improve environmental quality.

P-35

Effects of Short-term Exposure to $PM_{2.5}$ on Outpatient Department Visits for Anxiety and Atress-related Sisorders in Mae Hong Son, Thailand

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Mae Hong Son is a province situated in the northern region of Thailand, which suffers from air pollution originated mainly from forest fires, biomass open burning, and transboundary haze. However, the scientific evidence showing health effects associated with air pollution is limited. Therefore, this study aims to examine the effect of short-term exposure to $PM_{2.5}$ on outpatient department (OPD) visits for anxiety and stress-related disorders. Daily concentration of air pollution was obtained from air quality monitoring stations and daily meteorological data were obtained from weather monitoring stations between January 2017 and December 2022. Daily number of OPD visits for anxiety and stress-related disorders (ICD-10 code: F40– F48) during the same period was obtained from the database of the National Health Security Office (NHSO) according to the Universal Health Coverage (UHC) system. A time-stratified case-crossover design with the conditional quasi-Poisson regression model was applied to estimate the effects of $PM_{2.5}$ on OPD visits for anxiety and stress-related disorders, adjusting for temperature and relative humidity. We found that the relative risk (RR) of OPD visits for anxiety and stress-related disorders was 1.0257 (95% Confidence Interval (CI): 1.0042, 1.0476) per each 10 $\mu g/m^3$ increase in $PM_{2.5}$ at lag 0-1 days. Findings of this study can be used as scientific evidence for improving air pollution control policies to reduce the concentration of $PM_{2.5}$ and for protecting population health in Mae Hong Son, Thailand.

Estimation of Surface $PM_{2.5}$ Concentration in Thailand Using Satellite Remote Sensing and Machine Learning Algorithm

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Particulate matter with aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$) is one of the most serious air pollutants, causing detrimental effects on human health in Thailand to date. The monitoring network operated by the Pollution Control Department (PCD) has been used to measure real-time concentration of $PM_{2.5}$ and other criteria air pollutants throughout Thailand, but the number of monitoring stations remains limited, where $PM_{2.5}$ concentration in unmonitored areas could not be reported. Therefore, satellite remote sensing data might be applied to monitor the concentration of $PM_{2.5}$ in such locations. This study aimed to estimate ground-level $PM_{2.5}$ concentration across Thailand using the Multi-Angle Implementation of Atmospheric Correction Aerosol Optical Depth (MAIAC AOD) and other meteorological and land-use data with the 2-stage random forest model using the data from January to December 2022. In the first stage model, the missing MAIAC AOD was imputed by 500 decision trees of random forest model, and the imputed MAIAC AOD was then applied with other predictor variables to estimate ground-level concentration of $PM_{2.5}$ in the second stage model via 500 decision trees of random forest model. The model was then validated using holdout approach by splitting 80% of the data for training and the remaining 20% was used for testing. Results indicated that the coefficient of determination (R-square: R^2) and the root mean square error (RMSE) in estimating MAIAC AOD in the first stage model in training dataset were 0.94 and 0.03, respectively, and those in validating dataset were respectively 0.42 and 0.06. Moreover, R^2 and RMSE in estimating surface $PM_{2.5}$ concentration in the second stage model in training dataset were 0.94 and 4.03, respectively, and those in validating dataset were 0.51 and 9.43, respectively. Finding of this study can be used as a tool to monitor daily $PM_{2.5}$ concentration throughout Thailand, even in the areas without monitoring station.

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In Utero Exposure to Polycyclic Aromatic Hydrocarbons (PAHs): DNA Damage in Maternal Urine and Placental Tissue

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Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous carcinogenic pollutants produced from natural and anthropogenic sources, i.e., traffic emissions from fuel combustion. Exposure to particulate PAHs is associated with respiratory diseases and lung cancer in humans. Cytochrome P450 enzymes metabolize PAHs into benzo[a]pyrene diol epoxide (BPDE) resulting in the formation of BPDE-DNA adducts. In addition, PAH metabolism induces oxidative stress, leading to oxidative DNA damage and lipid peroxidation. Pregnant women are particularly susceptible to PAH exposure because they can easily penetrate the placental barrier and potentially cause developmental abnormalities in the fetus. This study aimed to assess the effects of PAH exposure during pregnancy on DNA damage in pregnant women and newborns.

The study was conducted in high- and low-traffic congested areas as the exposed and control sites. A total of 100 pregnant women were recruited from the study sites consisting of 50 exposed and 50 control subjects. Analysis of particulate PAHs by gas chromatography-tandem mass spectrometry (GC-MS/MS) showed that the traffic-congested area had a significantly higher ($p<0.01$) concentration of PAHs bound to $PM_{2.5}$ (PAHs-$PM_{2.5}$) and ultrafine particles (PAHs-UFPs) than those in the low-traffic area by 1.9- and 1.3-fold, respectively. PAH exposure in pregnant women assessed by urinary 1-hydroxypyrene (1-OHP), a metabolite of PAHs, was significantly higher ($p<0.05$) in exposed subjects than in control subjects. Liquid chromatography-tandem mass spectrometry (LC-MS/MS) analysis of DNA damage and lipid peroxidation in urine revealed that exposed pregnant subjects had higher levels of BPDE-DNA adducts (2.1-fold), 8-hydroxydeoxyguanosine (8-OHdG; 1.1-fold) and malondialdehyde (MDA; 1.9-fold). In agreement with maternal exposure to PAHs, BPDE-DNA adducts and 8-OHdG were detected in placental tissues indicating DNA damage in newborns, potentially influenced by exposure to particulate PAHs during pregnancy.

In conclusion, this study demonstrates that exposure to traffic-related particulate PAHs *in utero* can result in transplacental transfer, leading to fetal exposure to PAHs. Exposure to PAHs during pregnancy has the potential to increase DNA damage in pregnant women and placental tissue which may affect fetal development. Therefore, this study highlights the importance of being aware of *in utero* exposure to particulate PAHs which may lead to an increased health risk of disease development in newborns.

Potential Source Areas of Air Pollution in Bangkok, Thailand: A Case Study in North Thonburi Zone

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Air pollution is a major issue in Southeast Asia, especially in Bangkok. The primary sources of air pollution are road traffic, industrial plants, and open burning. This study aims to identify potential source areas and air pollution situation in Bangkok. Air pollutant data (PM_{10}, $PM_{2.5}$, O_3, NO_2, CO, and SO_2) and meteorological data (wind direction and speed) were collected from air quality monitoring stations in Bangkok between January 2017 and December 2021. Time series analysis and the Bivariate Polar Plot technique were used for analysis. Results showed PM_{10}, $PM_{2.5}$, NO_2, CO, and SO_2 pollutants are found in the highest concentrations in the morning (08.00-09.00 a.m.) and at night (08.00-10.00 p.m.). Additionally, the highest concentrations of O_3 were observed in the afternoon (02.00-03.00 p.m.), which can be attributed to photochemical reactions. Bivariate polar plots were used to identify the potential source areas at Station 02T. These areas serve as potential sources of air pollution due to traffic activities, leading to increased concentration values in the surrounding areas. Additionally, the potential source areas contributing to the increase in PM_{10} concentration in the afternoon is attributed to construction activities along Charoen Nakhon Road and Charoen Krung Road. This result can support the policymaker in the area for the management and reduction of air pollutants.

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Assessment of In *Utero* Exposure to Micro-nanoplastics and Potential Health Effects in Mother and Newborns

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Microplastics (MPs) have become a major emerging threat to the environment worldwide, due to the widespread use of plastics. Airborne microplastics are contributors to microplastic pollution which can be directly inhaled and pose health risks to humans due to their potential adverse effects. Growing evidence suggests that maternal exposure to toxic substances during pregnancy can have profound impacts on fetal development and childhood disorders. This study aimed to assess the prenatal exposure of airborne MPs and their potential health effects in pregnant women and newborns.

This study was conducted in high- and low- traffic density locations. The study included 50 exposed pregnant subjects living in high traffic and 50 control pregnant subjects recruited from low-traffic areas. MPs in ambient air samples and urine samples were analyzed and identified using Pyrolysis GC-MS/MS. Various polymers of MPs were detected in ambient air including polyvinyl chloride (PVC), polyethylene (PE), polyethylene terephthalate (PET), nylon (N66), styrene-butadiene rubber (SBR), polymethyl methacrylate (PMMA) and polystyrene (PS). The total concentrations of MPs in ambient air from high-traffic location were approximately 1.5-fold significantly higher than those of low-traffic location (4.32 vs 2.88 μg/m^3, $p<0.05$). Total MPs in maternal urine were also higher in the exposed group than the control group with the detected MPs including N6, N66, PE, PS, PVC and SBR. Urinary biomarker of oxidative DNA damage (8-hydroxydeoxyguanosine, 8-OHdG) and lipid peroxidation (8-iso-prostaglandin F2α; 8-isoPGF2 and malondialdehyde; MDA) were analyzed using LC-MS/MS. The concentrations of 8-OHdG, 8-isoPGF2 and MDA were higher in the exposed-group with a significant 2-fold increase in MDA (7.17 vs 3.59 μg/ml, $p<0.05$). Consistent with the presence of MPs in maternal urine, MPs were detected in placental tissue suggesting transplacental transferred and fetal exposure. In addition, mutagenic DNA adducts including 8-OHdG and ethenodeoxy adenosine (1N^6εdA), a lipid peroxidation-derived DNA adduct, were detected in placental tissue.

Taken together, the results obtained suggest that traffic emissions contribute to air pollution of MPs. Exposure to MPs during pregnancy can increase DNA damage in pregnant women. The detection of MPs and mutagenic DNA damage in placental tissue indicates fetal exposure to MPs which may increase the health risk of adverse birth outcomes and disease development in newborns

Human Exposure of Microplastic by Consumption of Canned Sardines in Tomato Sauce

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Study of small-sized microplastics (1-20 µm) in canned sardines produced from four different countries. Microplastics were found in canned sardines from Thailand (415.98±45.66 µg/can), Malaysia (415.98±45.66 µg/can), Vietnam (415.98±45.66 µg/can), and the Philippines (415.98±45.66 µg/can), with the majority coming from sardine meat. The risk assessment of consumers' exposure and accumulation of microplastics in the body from consuming canned sardines per day (Thailand - FDA = 0.73 mg_{MPs}/day, IFOSY = 0.01 mg_{MPs}/day, and Maximum case = 1.25 mg_{MPs}/day) suggests that excessive accumulation of microplastics in the body may pose health risks to consumers. This underscores the importance of establishing food standards for microplastic contamination (ISO22004).

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Risk Assessment of Exposure to Small Microplastics (1-60 μm) from Green Mussel Consumption

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The purpose of this work was to investigate the accumulation and risk assessment of microplastics in an urban populated area (Sriracha) and a rural pristine area (Chang Island). The microplastics in mussels accumulated in the digestive tract were 322.68 ± 195.67 and 193.12. ± 85.90 ng/g (wet weight), and accumulated in tissues were 212.40 ± 105.55 and 49.66 ± 15.38 ng/g (wet weight), respectively. The accumulation of microplastics in mussels may be caused by exposure to different humans. In addition, the microplastics found in mussels can be identified using μ-FTIR techniques and are 72% similar to PP plastics. Risk assessment calculations show that humans consume more microplastics from mussels in urban than rural areas. Therefore, it may be beneficial to develop practical solutions to environmental problems.

Toxicity of Polyethylene Microplastics on Human THP-1 Monocyte-derived Macrophage Cells

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Polyethylene microplastics (PE-MPs) are one of the most commonly found microplastics in the environment. Due to their small size, they can widely distribute in various ecosystems and could get exposed by humans which may result in adverse effects. Macrophages play a key role in innate immunity and regulate the inflammatory response. However, the possible mechanism underlying the toxicity of PE-MPs to macrophage cells has remained rather unclear. This study aimed to assess the PE-MPs' effects on cytotoxicity, reactive oxygen species (ROS production), inflammatory response, and macrophage cell surface expression by using human THP-1 monocyte-derived macrophage cells. MTT assay showed a significant decrease in cell viability at high PE-MPs concentrations (500-2000 µg/mL) after 48-hour exposure, while lower PE-MPs concentrations (0.1-250 µg/mL) did not exhibit cytotoxicity compared to control. Flow cytometry assay demonstrated a significant increase ($p < 0.05$) in ROS production in THP-1 macrophages following 24 hours treatment of PE-MPs (25 µg/mL) by 1.19-fold compared to control but no change was seen after 48 hours. Macrophage functions were assessed by determining the level of pro-inflammatory cytokine production and CD86 which is a pro-inflammatory (M1) phenotype marker via ELISA and flow cytometry assays, respectively. The result showed that 50 pg/mL LPS and IFN-γ 20 ng/mL treatment increased the IL-6 level indicated macrophage activation, whereas PE-MPs themselves did not affect the level of IL-6. Notably, PE-MPs (25 µg/mL) significantly increased ($p < 0.05$) IL-6 production in the LPS and IFN-γ-activated macrophage cells. Moreover, the activated macrophages exposed to PE-MPs (0.1-25 µg/mL) exhibited slightly increased in $CD86^+$ M1 macrophage cells after 48 hours treatment when compared to the LPS and IFN-γ treatment alone. These findings suggest that PE-MPs exerted effects on macrophages partly through induced ROS production, up-regulation of pro-inflammatory phenotype marker and increased pro-inflammatory cytokines production.

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Arsenic Reduced Insulin Expression in Differentiated Neuroblastoma SH-SY5Y Cells

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Arsenic contamination in ground water is a well-known issue. Previously, we reported that prolonged arsenic exposure caused insulin signaling impairment in neurons. As neurons have been reported to be able to synthesize insulin similar to pancreatic β cells, thus we questioned whether arsenic altered insulin expression in neurons. Here, we examined the levels of insulin in differentiated human neuroblastoma SH-SY5Y cells by ELISA, immunofluorescent staining, and immunodot blot analysis. We found that arsenic dramatically decreased intracellular insulin levels. Additionally, level of insulin in the medium was reduced by arsenic treatment. In conclusion, arsenic may reduce production and secretion of insulin in neurons.

Effect of Arsenic on Stem Cell Aging and Its Impact on the Differentiation to Hematopoietic Stem Cells

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Arsenic contamination in groundwater poses a significant public health concern, with over 300 million individuals exposed to levels exceeding the WHO recommendations of 10 µg/L. Arsenic can readily cross the placental barrier resulting in not only the adverse pregnancy outcomes, but also increasing the risk of disease development in both childhood)higher risk of acute respiratory infections in children(and adult life)higher risk of developing cardiovascular and metabolic diseases(in populations exposed to arsenic since *in utero*. Apart from induction of oxidative stress as a main mechanism involved in arsenic toxicity, accumulating evidences revealed that arsenic exposure can promote cellular senescence in various cell types including stem cells with potential disrupting stem cell function and organ development. Furthermore, several studies underscore the impact of early–life insults on the development of fetal immune system, which can permanently alter the immune function of the offsprings leading to long–term unfavorable health outcomes. This study aimed to explore whether chronic exposure to arsenic induces cellular senescence and its effects on the development of human hematopoiesis using an *in vitro* differentiation model. Treatment with 1 µM $NaAsO_2$ resulted in an increased activity of β-galactosidase, a commonly used biomarker of cellular senescence, in human iPSCs and an impairment of their hematopoietic differentiation potential as evidenced by decreasing the number of hematopoietic stem cells)HSCs(. In summary, this study provides more understanding on the potential detrimental effects of arsenic exposure on stem cell function, which may permanently alter the immune function of the offsprings.

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Effects of a Novel Estrogenic Endocrine Disruptor on Breast Cancer Promotion and Progression: The Mechanistic Insights from *In Vitro* Studies

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Breast cancer is a malignant tumor and the second leading cause of cancer death among women globally. The estrogen receptor)ER(has been shown to regulate the promotion and development of ER+ breast cancer. Several lines of evidence indicated that exposure to estrogenic environmental chemicals is strongly associated with breast cancer incidence. Herein, we investigated the effects of an environmentally ubiquitous estrogenic flame-retardant 2-ethylhexyl diphenyl phosphate)EHDPP(on breast cancer promotion and development using two human breast cancer cell lines namely MCF-7)ER+(and MDA-MB-231)ER–(. Cells were exposed to EHDPP at biologically relevant concentrations found in humans ranging from 0.1-10 µM. Interestingly, EHDPP significantly increased the cell viability and clonogenicity of MCF-7)ER+(in a dose- and time-dependent manner, while a slight reduction in cell viability and clonogenicity was observed in the MDA-MB-231)ER–(cells. Furthermore, a co-treatment with ICI 182, 780, a competitive ER inhibitor, significantly suppressed the EHDPP-induced breast cancer promotion, suggesting the effects of EHDPP were mediated through the activation of the ER signaling pathway. Additionally, the protein expression of ERs and anti-apoptotic protein)Bcl-2(were significantly increased. The mRNA expression of genes related to estrogenic activity)*ESR1*, *PGR*, *BRCA1*, and *pS2*(and proliferation)*KI67* and *MYC*(further supported that EHDPP is an estrogenic compound and promotes ER+ breast cancer development. Our result indicates that EHDPP may pose a significant human health risk associated with estrogenic endocrine disruption such as the development of ER+ breast cancer.

Food Handlers' Practices and Coliform Bacteria Contamination in Food Stalls: A Case Study of Flea Markets in Prachuap Khiri Khan Province, Thailand

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This analytical survey study aimed to determine the association between the compliance with food sanitation principles of the food handle in food stalls and coliform bacteria contamination at flea markets in Prachuap Khiri Khan province area. The total sample of 265 food stalls from 8 flea markets were collected by randomized method. Each food stall, the food sanitation inspection forms were used to observe the food handlers' practices and the market hygiene and the SI-2 test kits were used to determine the coliform bacteria contamination in three samples of ready to eat food, kitchen utensil, and a hand of the food handler. The linear mixed model was used to investigate the association between the food handlers' practices and coliform bacteria contamination. The results showed that most of food handlers passed food sanitation practices in their food stalls (69.8%). The coliform bacteria contamination was found around half of food stalls' samples (50.2%), the majority of contamination was found on a hand of food handlers, following by contamination in ready to eat food and on kitchen utensil, respectively. There was no association between food sanitation practices and coliform bacteria contamination. However, there was an association between market hygiene and coliform bacteria contamination ($p<0.001$). Therefore, the flea market should be recommended strictly follow the laws and regulations related to market hygiene and promoted food sanitation practices in food handlers, which can help to minimize the risk from foodborne disease.

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Huperzine A Reduces Amyloid-Beta-Induced Neuroinflammation In Human Neuroblastoma Cells

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Alzheimer's disease (AD) is the most common neurodegenerative disease). The main hallmarks of AD are the presence of amyloid-beta (Aβ) plaques and the formation of abnormal tau tangles. Several studies have revealed that inflammation increased in people with AD. Huperzine A (Hup A) is a purified alkaloid compound extracted from *Huperzia Serrata*, has been established to exhibit anti-inflammatory and antioxidative properties. Our objective is to investigate the potential of Hup A in mitigating neuroinflammation in a model of Alzheimer's disease induced by amyloid beta. Human neuroblastoma SH-SY5Y cells were pretreated with Hup A (1 μM and 10 μM) for 1 h. Subsequently, the cells were treated with Aβ42 for 24 h before being collected. The cells were collected and different proteins (TNF-α, IL-1β, and NLRP3) were identified using western blot analysis. The result showed that 1 μM Aβ significantly enhanced the expressions of TNF-α, IL-1β, and NLRP3 while the induction of these proteins was significantly abolished by 10 μM Hup A. These results indicated that Hup A attenuated Aβ-induced NLRP3 pathway activation by inhibiting proteins associated with the NLRP3 pathway and thereby suppressing the expression of IL-1β and TNF-α. The current study aims to enhance understanding of the beneficial effects of Hup A, which has the potential to be a breakthrough therapy for preventing the onset or slowing the progression of AD in individuals at a high risk of developing the disease.

Keywords: Alzheimer's disease, Huperzine A, neuroinflammation, amyloid beta.

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A Model of Shwachman-Diamond Syndrome, the *SDO1* Deletion Mutant, Exhibits Phenotypic Differences from Mutations in *RPS19A* or *RPS19B* Implicated in Diamond-Blackfan Anaemia

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Ribosomopathies are a group of diseases characterised by the presence of structural as well as functional abnormalities in the proteins that constitute the ribosome as well as defects in genes that participate in ribosome biogenesis. Due to the highly specific nature of protein assembly, ribosome integrity is maintained in a highly accurate and regulated manner in order to maintain error free protein synthesis. Mutations to genes involved in the production of mature ribosomes are implicated in several ribosome related diseases such as Shwachman-Diamond Syndrome (SDS) and Diamond-Blackfan Anaemia (DBA). In this study, we compare two yeast models of ribosomopathies, an *SDO1* knockout strain for SDS and the *RPS19A* and *RPS19B* knockout starins for DBA, in order to ascertain if phenotypic variances occur between mutations involved in these two ribosomopathies.

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Tetracycline Induces Minocycline Resistance in *Stenotrophomonas maltophilia*

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The misuses and overuses of tetracycline antibiotic in veterinary and agriculture purpose rises the concerns of emergence and spreading of antimicrobial resistance) AMR(microorganisms in environment. *Stenotrophomonas maltophilia*, a gram-negative obligate aerobe bacterium, is one of the most important opportunistic pathogens worldwide. In this study we focused on the effect of tetracycline on induction of minocycline resistance in *S. maltophilia* SMBT strain, isolated from clinical sample. Tetracycline resistance strains of *S. maltophilia* SMBT strain were isolated using sequential passage method in the presence of increasing concentrations of tetracycline ranging from 2 to 32 µg/ mL. Thirty- five colonies that grew on medium containing 32 µg/ mL were purified and tested for antimicrobial susceptibility against minocycline, a drug of choice for *S. maltophilia* treatment. The five candidate clones with different levels of minocycline resistance were further analysis of the mutated genes using whole genome sequencing. All of the tested clones showed mutations on *smlt*4073 *(smeT)* gene encoding transcriptional repressor of the RND efflux pump SmeDEF. To our knowledge, the contribution of *smeT* gene mutation to minocycline resistance of *S. maltophilia* has never been reported. Further analysis is required to elucidate the role of *smeT* on minocycline resistance of *S. maltophilia*.

Economic Benefits of Nutrients Removal and Recovery Processes from Slaughterhouse Wastewater Treatment using ANA^2/O^2 SBR Incorporation with ASD and P Precipitation

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This study aimed to evaluated the economic benefits of nutrients removal and recovery processes from slaughterhouse wastewater treatment using AnA^2/O^2 SBR, ASD, and MAP process. The previous studies have been shown that each process could reduce pollutant contamination and prevent environmental harm while also contributing to resource conservation, thus demonstrating the environmental friendliness of these processes. In the economic analysis, the results indicated that each process had the potential to reduce operating costs and reduce electricity consumption. Also, it could generate revenue during operations. Therefore, all three processes were appropriate and had the possibility of being applied further.

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Exploration of Reactivities of 4-Haloisocoumarins as Building Blocks in Preparing Other Heterocycles

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3-Benzoyl-2-phenylisoindolin-1-one (isoindolinones) could be synthesized from 4-chloroisocoumarin via sequential nucleophilic addition and intramolecular cyclization. In this work, the reaction optimization studies of the reactivity of the nucleophilic addition were examined and investigated using an aniline and 2-aminopyridine as the nucleophiles. It was proposed that aniline could add to 4-chloroisocoumarin that then opened the isocoumarin ring which re-cyclized to provide the desired isoindolinones. The protocol is being developed with the emphasis on the ability to produce the desired isoindolinones products under mild, environmentally friendly and sustainable conditions.

Geospatial Analysis of Total Coliform Bacteria Distribution: A Case Study at Bang Pakong River Mouth Area

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Biological parameters should be considered when monitoring water quality to ensure compliance with standards. Therefore, this study investigated the presence of total coliform bacteria (TCB) and searched for a suitable spatial interpolation method to create TCB spatial distribution mapping in the Bang Pakong river mouth area using a Geographic Information System (GIS). The research processed TCB data and applied GIS with four spatial interpolated method approaches, including inverse distance weighted (IDW), Spline with Barrier (SB), Ordinary Kriging (OK), and Universal Kriging (UK). Data showed that sampling during the dry season yields TCB concentrations within the range of 1.80 to 70.00 MPN/100 mL, with an average of 9.46 MPN/100 mL, demonstrating compliance with established standards. The spatial distribution of TCB is mapped utilizing GIS techniques, and the accuracy of these maps is validated by comparing the sampling values with the estimated values. The study identifies the IDW GIS as a suitable method for this river mouth area, with the coefficient of determination (R^2) of linear regression correlation at 0.8916.

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The Efficacy of *Canna indica* in Textile Wastewater Treatment

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The textile industry remains a significant source of environmental problems due to the discharge of textile wastewater, which is harmful to ecosystems and human health. Textile manufacturing processes had high levels of toxic, mutagenic, and carcinogenic substances in the textile wastewater. Among all dyes used in manufacturing processes, Methylene Blue (MB) is one of the most concerning. Currently, wetland plant species are studied to determine the efficacy of textile wastewater treatment in the vertical flow constructed wetland. In this study, *Canna indica* was examined for it efficacy in hydroponic conditions with synthetic wastewater concentrations of 0, 5, 10, and 20 mg/L of MB. We found that *C. indica* showed the highest decolorization at 97.66% after 14 days. Additionally, water treatment ability at different concentrations showed great removal percentages of COD, nitrogen, and phosphate, as well as a higher final BOD and pH than the initial period. Also, the response to MB toxicity was determined by plant growth indicators, including shoot height, root length, tiller number, and plant biomass. The results of plant morphology showed a difference in growth rates at different concentrations. Therefore, these results exhibited the potential of *C. indica* for further promoting the vertical flow constructed wetland, which could be used as a biological technology for increasing efficiency in textile wastewater treatment.

Assessing Risk Perception and Protective Behaviors Against Pesticide Exposure Among Pregnant Women in Malaysia

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Background: Occupational exposure to pesticides is a critical public health issue, particularly for pregnant women. This study aims to evaluate the knowledge, attitudes, and protective behaviors (KAP) of pregnant women in agricultural and related industries concerning pesticide exposure and its potential health implications. Pesticides, while essential in agriculture, pose risks of developmental toxicity that can affect both maternal health and fetal development.

Objective: The primary objective is to assess the KAP of pregnant women working in environments with potential pesticide exposure. The study focuses on understanding how these women perceive the risks associated with pesticide use and the extent of their engagement in protective behaviors to safeguard their health and that of their unborn children.

Methods: A cross-sectional survey using a structured questionnaire will be conducted among pregnant women working in agricultural settings and other industries where pesticide use is prevalent. The questionnaire will cover aspects of awareness regarding the dangers of pesticide exposure, knowledge of safe handling practices, and the adoption of personal protective equipment.

Results: Analysis revealed that only 40% of participants demonstrated a high level of awareness regarding pesticide risks. Knowledge on safe handling practices was moderately understood by 50% of the respondents, while 30% reported consistent use of personal protective equipment. Statistical analysis using a Chi-square test indicated significant gaps in safety practices among the respondents ($\chi^2 = 15.24$, $p < 0.05$). Moreover, logistic regression analysis showed that higher knowledge levels were positively correlated with the adoption of protective behaviors (OR = 2.35, 95% CI: 1.15-4.78).

Conclusion: The findings underscore considerable deficiencies in the KAP related to pesticide exposure among pregnant workers, highlighting an urgent need for targeted educational programs and interventions. The study reveals significant findings regarding the gaps in awareness and safety practices among pregnant workers exposed to pesticides.

Keywords: Pesticide exposure, workplace safety, KAP, pregnant women, developmental toxicity

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