Tropical Aquatic and Soil Pollution

Review
Volume 4(2), 2024, 100–110
https://doi.org/10.53623/tasp.v4i2.489

Endocrine-Disrupting Compounds in Urban Soils of Malaysia: Occurrence, Contamination, and Impacts on Health and the Environment

Michael Lie[1], Joseph Kasongo[2], Elias Mtui[3], Rubiyatno[4]*, Jovale Vincent Tongco[5]

[1]Envirotech Engineering, Kuala Lumpur, 59200 Malaysia
[2]Faculty of Science, University of Kinshasa, B.P. 190, Kinshasa, XI, Democratic Republic Congo.
[3]College of Engineerning and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania.
[4]Graduate Faculty of Interdisciplinary Research, University of Yamanashi, 4-3-11 Takeda, Kofu, Yamanashi 400-8511, Japan
[5]Department of Forest, Rangeland and Fire Sciences, University of Idaho, Moscow, ID, USA

*Correspondence: yrubi@yamanashi.ac.jp

SUBMITTED: 4 September 2024; REVISED: 4 October 2024; ACCEPTED: 7 October 2024

ABSTRACT: Endocrine-disrupting compounds (EDCs) have garnered increasing concern in recent years due to their association with severe health issues and significant environmental impacts. EDCs, which can interfere with endogenous hormone systems, are diverse in structure and are often characterized by low molecular mass and halogen substitutions. Their presence in the environment, originating from both natural and synthetic sources, has been well-documented in water bodies, but studies on their occurrence in soils remain limited. This review provides a comprehensive overview of the occurrence, contamination, and impacts of EDCs in the urban soils of Malaysia. The paper discusses the primary sources of EDCs, including pharmaceuticals, pesticides, industrial chemicals, and combustion byproducts, and examines the pathways through which these compounds enter the soil. Health risks associated with exposure to EDCs, as well as their ecological consequences, are also explored. The review highlights the current status of EDCs contamination in Malaysian soils, identifies gaps in research, and outlines the challenges in monitoring and mitigating these contaminants. Understanding the dynamics of EDCs in soil is crucial for developing effective strategies to protect human health and the environment in urban settings.

KEYWORDS: Endocrine-disrupting compounds (EDCs); urban soils; Malaysia; environmental impacts

1. Introduction

In recent years, concern over endocrine-disrupting compounds (EDCs) has been rising due to the increasing occurrence of severe and wide-ranging diseases, such as abnormal endocrine function and adverse environmental impacts linked to EDCs [1]. EDCs are defined as exogenous compounds that interfere with endogenous hormones, affecting their production, release, transport, metabolism, binding, action, or elimination. EDCs are often difficult to predict or detect as they do not share similar structures and typically have low molecular masses, though they frequently contain halogen groups, such as chlorine or bromine. The number of suspected EDCs has been increasing over time, from 881 in 2011 to 1,419 in 2017, due to advances in research aimed at identifying potential EDCs [2]. EDCs in the environment can be of natural or synthetic origin, and humans can be exposed to them through ingestion, inhalation, or direct skin contact. Fauna can also be affected through the consumption of contaminated food and water. EDCs are commonly found in pharmaceuticals, pesticides, industrial chemicals, combustion byproducts, phytoestrogens, and hormones excreted by humans and animals, and they can escape into the environment through chemical leakage or spillage, wastewater discharge, pesticide and herbicide use, and waste burning [3, 4]. Natural EDCs include 17β-estradiol and estrone, while synthetic EDCs include nonylphenol, bisphenol-A, diethylstilbestrol, and others. Although extensive research has been conducted on the effects and removal of EDCs, most studies focus on water bodies, with limited attention paid to soil [5, 6]. Thus, the focus of this paper is to provide an overview of EDCs in the urban soils of Malaysia, including their health and environmental impacts, occurrence and contamination, current status, and associated challenges.

2. Sources of EDCs' Exposure and their Health Impacts

The main health impact of EDCs is through disruption of the endocrine and reproductive systems by altering natural hormonal and homeostatic mechanisms, leading to inappropriate system functioning or development. The specific effects depend on the type of compound [4]. EDCs are present in many everyday products, such as plastics, lubricants, personal care products (PCPs), pesticides, herbicides, solvents, and paints. Although safety exposure limits for various EDCs have been established, the effects can vary among individuals. Therefore, the health impacts of EDCs remain a significant challenge for authorities when setting threshold limits in consumer products [7].

2.1. Bisphenol A.

Bisphenol A (BPA) is a widely used industrial chemical synthesized from acetone and phenol. It serves as an additive in the production of polycarbonates (PCs), epoxy resins, and other polymeric plastic materials. In 2015, 64% of the total BPA demand was driven by PCs production, with a projected increase of 3% over the next five years. BPA is found in many common products, including plastic bottles, food storage containers, food can linings, dental fillings, car dashboards, and lenses [8]. During plastics production, chemicals such as antioxidants, thermal stabilizers, plasticizers, and clarifiers are often added, but they are not chemically bound to the polymerized monomer backbone, allowing unpolymerized BPA to leach from the final product [9]. Humans can be exposed to BPA through water, food, air, and dust, with ingestion being the primary source. The rate of leaching from containers can be amplified by heating, exposure to low or high pH substances, improper handling, overuse, and microwave exposure [10, 11]. BPA can interact with estrogen receptors, leading to disorders such as infertility, precocious puberty, hormone-dependent cancers, and metabolic disorders. Case studies have linked elevated BPA levels in urine to obesity, reduced sperm quality in men, and impaired oocyte yield, maturation, and fertilization in women [8, 12].

2.2 Phthalates.

Phthalates are esters of 1,2-benzenedicarboxylic acid, produced by reacting alcohols with phthalic anhydride in the presence of a catalyst. High molecular weight phthalates like diethylhexyl phthalate (DEHP), diisononyl phthalate (DINP), and dioctyl phthalate (DNOP) are used as plasticizers in flexible vinyl manufacturing, commonly found in consumer products such as flooring, food packaging, medical devices, and toys [13]. Low molecular weight phthalates, such as diethyl phthalate (DEP) and dibutyl phthalate (DBP), are used in personal care products, pharmaceuticals, varnishes, and as solvents and additives. Phthalates do not form strong chemical bonds with the main polymer backbones, allowing them to easily leach into the environment through evaporation, abrasion, and leaching. Phthalates have been detected in various environmental matrices, including soil, air, water, and dust. They can enter the human body via ingestion, skin absorption, and inhalation, with children and toddlers being more vulnerable than adults. Phthalates can damage the liver, kidneys, and reproductive system and act as weak EDCs. Studies have linked phthalate exposure to childhood obesity, diabetes, allergies, asthma, and autism spectrum disorders [14, 15]. In women, phthalates can impair reproductive health by affecting oocyte yield and increasing the risk of pregnancy loss, while in men, they can cause DNA damage in sperm [15, 17].

3. Environmental Impacts

Aside from human health, it is also known that EDCs can affect the environment and impact the health of wildlife. The global chemical industry exceeded 5 trillion USD in 2017, and the size was projected to double by 2030 due to rapid increases in consumption and production trends [18]. Consequently, pollutant discharge could increase, associated with the rise in hazardous chemical usage, leading to environmental pollution and causing toxicity to accumulate in the food chain. The routes through which EDCs enter the environment are mainly through improper waste management, industrial discharge, construction and agricultural activities, transportation, and other sources (details will be discussed in the next section). Similar to humans, some EDCs cause health damage to wildlife by disrupting behavior patterns and affecting species survivability. Several impacts on wildlife, such as sex changes, thinning of eggshells, thyroid function disorders, and disruptions to mental, physical, reproductive, and immune systems, have been observed due to EDC exposure [19].

3.1. Wildlife's reproductive system.

In terms of female reproductive health, organochlorines such as polychlorinated biphenyls (PCBs) were found to cause uterine fibroids in marine mammals such as seals, sea lions, and whales. There was a 60% reduction in pregnancy in female ringed seals exposed to PCB contamination. Additionally, the thinning of eggshells in several predator species was identified in the 1950s due to organochlorine pesticide exposure, though this condition recovered after the banning of dichloro-diphenyl-trichloroethane (DDT) pesticide in North America and Europe [20]. In a study by Kamarudin et al. [21], Javanese medaka (O. javanicus) collected from Sungai Pelek, located in Sepang, Selangor, showed that higher Diuron exposure decreased gonadal staging and germ cell maturity in female medaka during oogenesis. For male wildlife, feminizing disorders were discovered, likely due to EDC exposure. Cryptorchidism was reported across species of domestic and farmed mammals such as horses, sheep, cattle, and dogs. Studies also found that around 42% of sludge-exposed rams showed major spermatogenic abnormalities. Male amphibians and fish species were also vulnerable to EDC exposure, with cases such as intersex and feminization reported at polluted sites. Intersex incidents in cricket frogs were highest during industrialization and heavy use of organochlorines, while feminization of male fish has been frequently found near sewage treatment plant outfalls [4, 20, 22].

3.2. Hormonal cancers.

EDCs, which also carry carcinogenic properties, can cause hormone-related cancers in both humans and wildlife. Although the rates of endocrine cancers in domestic and wild animals were much lower compared to humans, reports have increased in some populations. A case study reported that beluga whales in the St. Lawrence estuary had a higher cancer rate, including hormonal cancers, among cetacean species. Endocrine cancers such as leiomyomas, adrenal, and thyroid cancers were observed. While no direct evidence has proven that EDCs caused the cancer in belugas, carcinogenic polycyclic aromatic hydrocarbons (PAHs) were detected in the environment, likely ingested by the animals. Most studies suggested that cancers in belugas could be a joint effect of multiple factors, including PAH exposure [20]. Additionally, epidemics of liver cancer were found in 16 species of fish from 25 polluted spots, including both freshwater and saltwater environments, with the same tumor also reported in bottom-feeding fish species from heavily industrialized and urbanized areas along the Canadian Atlantic and Pacific coasts [20, 23]. Research by Ylitalo et al. [24] found that wild California sea lions diagnosed with carcinoma had higher mean concentrations of PCBs (>85%) and DDTs (30%) compared to those without cancer. Tumors and intraductal hyperplasias were also found in rodents such as rats exposed to high doses of BPA (Soto & Sonnenschein, 2010). In addition to the diseases mentioned, other harmful effects of EDCs on wildlife include metabolic disorders such as obesity and diabetes, bone disorders, and thyroid-related disorders [25, 26]..

4. Occurrence and Contamination in Soil

As mentioned earlier, EDC pollution in soil has not been extensively studied compared to pollution in water. However, runoff from soils is a major factor contributing to EDC pollutants in water bodies. The main causes of land and soil pollution include poor agricultural practices, inefficient irrigation, improper solid waste management, and industrial activities. EDCs used in fertilizers and pesticides at agricultural sites, as well as those present in sludge disposed of on land from wastewater treatment plants due to poor removal by conventional treatment methods, can be transported to nearby water bodies (rivers, seas, aquifers, etc.) via stormwater runoff [22, 23, 27].

4.1. Dumpsite.

In 2010, Malaysia had 290 dumpsites, with 114 closed and 176 still in operation. About 50% of these landfills practiced open dumping with minimal environmental protection measures, such as leachate management, gas collection, and surface runoff management [28, 29]. The numbers do not include illegal dumping grounds and small open dumpsites, so the actual number of landfills may be higher. The number of illegal and open dumping grounds is believed to have increased as developed countries began exporting waste to Southeast Asia after China banned waste imports in January 2018. Around half a million tons of plastic waste were imported to Malaysia from January to July 2018, most of which was not processed properly. Possible sources of EDCs in waste include plastic (13.2%), diapers (12.1%), metal (2.7%), rubber waste (1.8%), Tetra Pak (1.6%), and hazardous waste (1.3%), accounting for 32.7% of total waste [31]. Estrogens such as BPA, bisphenol S (BPS), and octylphenol are the major EDC compounds in plastic waste, while phthalates and parabens are common in diapers and sanitary products. Metals like zinc (Zn), arsenic (As), cadmium (Cd), and lead (Pb) are present in some waste, and benzothiazole derivatives can be found in rubber [4, 31]. Greenpeace conducted research on soils from several unregulated dumpsites and nearby water bodies. Samples were taken from 10 locations, including six at Pulau Indah, Klang, one in Kapar, Klang, one in Kampung Sri Cheeding, Kuala Langat, and two in Sungai Muda, Kedah. Heavy metals and metalloids (antimony, Cd, Pb, etc.) were found at all points, with PAHs present in soil and sediment, and organic compounds and volatile organic compounds found in the water bodies of Pulau Indah, Klang. These findings suggest that PAHs and heavy metals near illegal dumping grounds pose a threat to nearby residents, workers, and wildlife [32, 33].

4.2. Agriculture activities.

In the early development of Malaysia, the agricultural sector played a crucial role. In 1970, agriculture contributed 30.8% to the nation’s Gross Domestic Product (GDP), the highest in history (Alam et al., 2012). However, its contribution has been declining since 1975, accounting for only 7.3% in 2018 [34, 35]. Although the sector’s economic contribution is now overshadowed by industrialization, it still plays an important role in food security, sustainable development, and wealth creation. Among the sector, oil palm holds the highest share (37.9%), followed by other agricultural activities (25.1%), livestock farming (14.9%), fisheries (12.5%), forestry and logging (6.9%), and rubber production (2.8%) [35]. Although most agricultural activities occur in rural areas, urban populations can still be exposed to EDCs through agricultural runoff and agrotourism, while workers are directly exposed in the field. In Malaysia, Diuron is a commonly used herbicide for weed control in the agricultural sector, inhibiting photosynthesis by blocking electron transfer and oxygen production (Antoniou et al., 2014). Other common pesticides with endocrine-disrupting effects include organophosphates, pyrethroids, glyphosate, and 2,4-D-dimethylammonium. Beyond pesticides, large amounts of estrogens are present in livestock manure from cows, swine, chickens, and ducks, potentially polluting nearby land and water bodies if not managed properly [36, 37].

In Malaysia, Diuron was widely used in oil palm plantations to control weeds and grasses, and its persistence in soil depends on the physico-chemical properties of the soil. Studies have shown that the coastal waters of Johor, Klang, and Kemaman had significantly high concentrations of Diuron, with the main sources of leaching and runoff likely coming from nearby agricultural lands. A study conducted at an oil palm plantation in Sepang found that Diuron remained in the soil for up to 90 days after application, increasing the exposure risk for plantation workers [36, 38]. Previous study also detected organochlorine pesticide residues in the Bertam and Terla Rivers in Cameron Highlands, despite the prohibition of these pesticides in Malaysia. Some residues were even found in tap water in the town of Brinchang, posing a threat to the local community. As Cameron Highlands is a highly developed agricultural area, these residues likely originated from nearby farmlands, with the continued use of banned pesticides attributed to their low cost, effectiveness, and easy availability. Due to the area's popularity for agrotourism, people other than farm workers may also be exposed to EDCs through direct contact with plants and soil during visits [39].

4.3. Industrialization & urbanisation.

Industrial development in Malaysia began in earnest after independence, when the government adopted the Import Substitution Industrialization (ISI) strategy. Later, the Export Oriented Industrialization (EOI) strategy was implemented due to its significant contribution to the economy. The rapid industrialization spurred urbanization, as labor demands in industrial areas attracted large populations, resulting in urban development [40, 41]. However, this rapid development also led to severe pollution of land, air, and water due to the discharge of pollutants, including EDCs, from various sources. Compared to rural areas, urban and industrialized regions have higher concentrations and varieties of EDCs, with human populations in cities facing greater exposure [42].

In urban areas, EDC pollution originates from multiple sources, including road and impermeable paved surfaces (PAHs, chromium), building materials (heavy metals, PCBs, nonylphenols (NPs), Diuron), transportation (PAHs, heavy metals, phthalates), and industrial and construction activities [31]. Ruiz et al. (2018) found that nitrogen dioxide (NO_2) exposure in large metropolitan areas is higher compared to smaller urban areas in the United States due to increased traffic [43].

In Malaysia, the soils of Klang district were found to contain clusters of heavy metals such as chromium (Cr), cobalt (Co), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), iron (Fe), and aluminum (Al). Among them, neurotoxins such as Pb, Cd, and Zn were present, with Pb and Cd concentrations exceeding standard guidelines [44, 45]. These heavy metals are primarily of anthropogenic origin, sourced from port and shipping activities, as well as rapid urbanization and industrial processes. The discharge from factories contributed to high levels of heavy metals in the Klang River and surrounding soils. Zinc, in particular, was emitted from vehicle tires, and the heavy traffic in the Klang area resulted in contamination along major roads and highways [44].

In another study focusing on PAH runoff, Zakaria et al. (2002) found that sediments from rivers passing through heavily industrialized areas or major cities like Port Klang, Penang, Malacca, and Johor Bahru contained high concentrations of PAHs. This was largely attributed to the use of crankcase oil in motor vehicles. Urban areas with higher densities of vehicles led to increased use of crankcase oil, which then contributed to runoff into soils and rivers. The main sources of contamination were improper disposal and poor management of crankcase oil by garages and service centers, as well as oil leaks from poorly maintained vehicles that mixed with street dust and stormwater runoff [46].

5. Challenge Faced in Controlling EDCs

The general pollution hierarchy consists of several stages: reduction, replacement, reuse, recycling, recovery, treatment, and finally, disposal. Controlling EDC pollution can generally follow this trend, with source reduction being the top priority for pollution prevention. Legislation enforcement can be an effective way to reduce the use of EDCs in various industries. In Malaysia, certain EDCs have been banned due to health and environmental concerns. For example, the use of BPA in baby feeding bottles was prohibited in 2012 under the Malaysian Food Regulations of 1985 [1, 3], and organochlorine pesticides like DDT, aldrin, and heptachlor were banned under the Pesticides Act of 1974.

However, it is unlikely that the use of EDCs can be entirely eliminated due to various restrictions. One of the major challenges in regulating EDCs is the lack of convincing data and comprehensive knowledge regarding their impacts on human health and the environment. The threshold limits for different populations and wildlife species may also vary. Research on the potential impacts of EDCs is ongoing to provide more specific information [47]. Although the Department of Environment (DOE) Malaysia has listed EDCs as a monitoring parameter under the Environmental Quality (Industrial Effluent) Regulations of 2009, no specific list of EDCs is provided for reference. This lack of specific legislation makes controlling EDCs at the source difficult. Additionally, weak enforcement may lead to the illegal use of banned EDCs. Pesticides like DDT and endosulfan, which are restricted or banned, continue to be widely used on crops in Malaysia, including strawberries, guava, eggplant, and long beans, and have been detected in rivers in Cameron Highlands [48].

6. Conclusion

Malaysia faces significant environmental challenges due to the widespread use of endocrine-disrupting chemicals (EDCs) in both agricultural and industrial sectors. Pesticides like Diuron, once heavily used in oil palm plantations, have demonstrated persistence in soils for extended periods, increasing the risk of exposure to workers and potentially affecting surrounding ecosystems. Despite the ban on certain organochlorine pesticides, residues continue to appear in rivers and even tap water, particularly in regions like Cameron Highlands, where agricultural practices remain intense. The illegal use of banned pesticides is partly driven by their low cost and easy availability, which poses ongoing threats to both local communities and tourists. The rapid industrialization and urbanization of Malaysia have compounded these issues, introducing a variety of EDC pollutants such as PAHs, heavy metals, and plasticizers. The Klang district, for example, has experienced high levels of heavy metal contamination in soil and water due to industrial discharges and vehicular emissions. The improper handling and disposal of materials like crankcase oil have further exacerbated pollution in urban areas. These pollutants accumulate in rivers and soils, particularly in regions with heavy industrial and traffic activities, making them significant contributors to environmental degradation. Efforts to regulate EDC pollution are hampered by the absence of a comprehensive legal framework and a definitive list of EDCs for targeted regulation. While certain EDCs like BPA in baby bottles and some organochlorine pesticides have been banned, the lack of enforcement and continued use of restricted chemicals highlight gaps in regulatory practices. Moreover, the ongoing need for more research and data on EDC impacts underscores the difficulty in establishing effective controls. To mitigate EDC pollution, stronger legislation, better enforcement, and broader awareness of their environmental and health risks are necessary for long-term sustainability.

Acknowledgment

The authors would like to thank Enviro Malaysia, University of Kinshasa Democratic Republic Congo, and University of Dar es Salaam, Dar es Salaam, Tanzania.

Author Contribution

Michael Lie: writing, data analysis; Joseph Kasongo: Writing and review; Elias Mtui: Methodology; Rubiyatno: Writing and review, Jovale Vincent Tongco: Writing and review

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Wee, S.Y.; Aris, A.Z. (2017). Endocrine disrupting compounds in drinking water supply system and human health risk implication. *Environment International*, *106*, 207–233. http://doi.org/10.1016/j.envint.2017.05.004.

[2] Lee, D.H. (2018). Evidence of the possible harm of endocrine-disrupting chemicals in humans: Ongoing debates and key issues. *Endocrinology and Metabolism (Seoul)*, *33*, 44–52. http://doi.org/10.3803/EnM.2018.33.1.44.

[3] Ahn, C.; Jeung, E.-B. (2023). Endocrine-disrupting chemicals and disease endpoints. *International Journal of Molecular Sciences*, *24*, 5342. http://doi.org/10.3390/ijms24065342.

[4] Pironti, C.; Ricciardi, M.; Proto, A.; Bianco, P.M.; Montano, L.; Motta, O. (2021). Endocrine-disrupting compounds: An overview on their occurrence in the aquatic environment and human exposure. *Water*, *13*, 1347. http://doi.org/10.3390/w13101347.

[5] Interdonato, L.; Siracusa, R.; Fusco, R.; Cuzzocrea, S.; Di Paola, R. (2023). Endocrine disruptor compounds in the environment: Focus on women's reproductive health and endometriosis. *International Journal of Molecular Sciences*, *24*, 5682. http://doi.org/10.3390/ijms24065682.

[6] Virtuoso, S.; Raggi, C.; Maugliani, A.; Baldi, F.; Gentili, D.; Narciso, L. (2024). Toxicological effects of naturally occurring endocrine disruptors on various human health targets: A rapid review. *Toxics*, *12*, 256. http://doi.org/10.3390/toxics12040256.

[7] Di Pietro, G.; Forcucci, F.; Chiarelli, F. (2023). Endocrine disruptor chemicals and children's health. *International Journal of Molecular Sciences*, *24*, 2671. http://doi.org/10.3390/ijms24032671.

[8] Almeida, S.; Raposo, A.; González, M.A.; Carrascosa, C. (2018). Bisphenol A: Food exposure and impact on human health. *Comprehensive Reviews in Food Science and Food Safety*, *17*, 1503–1517. http://doi.org/10.1111/1541-4337.12388.

[9] Almeida, S.; Ozkan, S.; Gonçalves, D.; Paulo, I.; Queirós, C.S.G.P.; Ferreira, O.; Bordado, J.; Galhano dos Santos, R. (2023). A brief evaluation of antioxidants, antistatics, and plasticizers additives from natural sources for polymers formulation. *Polymers*, *15*, 6. http://doi.org/10.3390/polym15010006.

[10] Adeyi, A.A.; Babalola, B.A. (2019). Bisphenol-A (BPA) in foods commonly consumed in southwest Nigeria and its human health risk. *Scientific Reports*, *9*, 17458. http://doi.org/10.1038/s41598-019-53790-2.

[11] Ekici, M.; Çakır Biçer, N.; Yirün, A.; Demirel, G.; Erkekoğlu, P. (2024). Evaluation of exposure to bisphenol analogs through canned and ready-to-eat meal consumption and their possible effects on blood pressure and heart rate. *Nutrients*, *16*, 2275. http://doi.org/10.3390/nu16142275.

[12] Molina-López, A.M.; Bujalance-Reyes, F.; Ayala-Soldado, N.; Mora-Medina, R.; Lora-Benítez, A.; Moyano-Salvago, R. (2023). An overview of the health effects of bisphenol A from a one health perspective. *Animals*, *13*, 2439. http://doi.org/10.3390/ani13152439.

[13] Huang, L.; Zhu, X.; Zhou, S.; Cheng, Z.; Shi, K.; Zhang, C.; Shao, H. (2021). Phthalic acid esters: Natural sources and biological activities. *Toxins*, *13*, 495. http://doi.org/10.3390/toxins13070495.

[14] Wang, Y.; Qian, H. (2021). Phthalates and their impacts on human health. *Healthcare*, *9*, 603. http://doi.org/10.3390/healthcare9050603.
[15] Wang, Y.; Zhu, H.; Kannan, K. (2019). A review of biomonitoring of phthalate exposures. *Toxics*, *7*, 21. http://doi.org/10.3390/toxics7020021.
[16] Seo, M.Y.; Moon, S.; Kim, S.H.; Park, M.J. (2022). Associations of phthalate metabolites and bisphenol A levels with obesity in children: The Korean National Environmental Health Survey (KoNEHS) 2015 to 2017. *Endocrinology and Metabolism*, *37*, 249–260. http://doi.org/10.3803/EnM.2021.1235.
[17] Caporossi, L.; Viganò, P.; Paci, E.; Capanna, S.; Alteri, A.; Campo, G.; Pigini, D.; De Rosa, M.; Tranfo, G.; Papaleo, B. (2021). Female reproductive health and exposure to phthalates and bisphenol A: A cross-sectional study. *Toxics*, *9*, 299. http://doi.org/10.3390/toxics9110299.
[18] Ciaula, A.D.; Portincasa, P. (2019). The role of environmental pollution in endocrine diseases. In Endocrinology and Systemic Diseases, 1st Ed., Portincasa, P., Frühbeck, G., Nathoe H., Eds.; Springer: Cham, Switzerland. http://doi.org/10.1007/978-3-319-66362-3_16-1.
[19] Gao, X.; Kang, S.; Xiong, R.; Chen, M. (2020). Environment-friendly removal methods for endocrine disrupting chemicals. *Sustainability*, *12*, 7615. http://doi.org/10.3390/su12187615.
[20] State of science of endocrine disrupting chemicals – 2012. (accessed on 1 July 2024) Available online: https://www.who.int/iris/bitstream/10665/78101/1/9789241505031_eng.pdf?ua=1.
[21] Kamaruzaman, N.A.; Leong, Y.H.; Jaafar, M.H.; Khan, H.R.M.; Rani, N.A.A.; Razali, M.F.; Majid, M.I.A. (2020). Epidemiology and risk factors of pesticide poisoning in Malaysia: A retrospective analysis by the National Poison Centre (NPC) from 2006 to 2015. *BMJ Open*, *10*, e036048. http://doi.org/10.1136/bmjopen-2019-036048.
[22] Mnif, W.; Hassine, A.I.H.; Bouaziz, A.; Bartegi, A.; Thomas, O.; Roig, B. (2011). Effect of endocrine disruptor pesticides: A review. *International Journal of Environmental Research and Public Health*, *8*, 2265–2303. http://doi.org/10.3390/ijerph8062265.
[23] Shahid, S.; Sultana, T.; Sultana, S.; Hussain, B.; Al-Ghanim, K.A.; Al-Bashir, F.; Riaz, M.N.; Mahboob, S. (2022). Detecting aquatic pollution using histological investigations of the gills, liver, kidney, and muscles of *Oreochromis niloticus*. *Toxics*, *10*, 564. http://doi.org/10.3390/toxics10100564.
[24] Ylitalo, G.M.; Stein, J.E.; Hom, T.; Johnson, L.L.; Tilbury, K.L.; Hall, A.J.; Gulland, F.M.D. (2005). The role of organochlorines in cancer-associated mortality in California sea lions (*Zalophus californianus*). *Marine Pollution Bulletin*, *50*, 30–39. https://doi.org/10.1016/j.marpolbul.2004.08.005.
[25] Focaccetti, C.; Nardozi, D.; Benvenuto, M.; Lucarini, V.; Angiolini, V.; Carrano, R.; Scimeca, M.; Servadei, F.; Mauriello, A.; Mancini, P. et al. (2024). Bisphenol-A in drinking water accelerates mammary cancerogenesis and favors an immunosuppressive tumor microenvironment in BALB–neuT mice. *International Journal of Molecular Sciences*, *25*, 6259. http://doi.org/10.3390/ijms25116259.
[26] Cimmino, I.; Fiory, F.; Perruolo, G.; Miele, C.; Beguinot, F.; Formisano, P.; Oriente, F. (2020). Potential mechanisms of bisphenol A (BPA) contributing to human disease. *International Journal of Molecular Sciences*, *21*, 5761. http://doi.org/10.3390/ijms21165761.
[27] Nazari, E.; Suja, F. (2016). Effects of 17β-estradiol (E2) on aqueous organisms and its treatment problem: A review. *Reviews on Environmental Health*, *31*, 465–491. http://doi.org/10.1515/reveh-2016-0040.
[28] Samsudin, M.D.M.; Don, M.M. (2013). Municipal solid waste management in Malaysia: Current practices, challenges and prospect. *Jurnal Teknologi*, *62*, 95–101. http://doi.org/10.11113/jt.v62.1293.
[29] Norsa'adah, B.; Salinah, O.; Naing, N.N.; Sarimah, A. (2020). Community health survey of residents living near a solid waste open dumpsite in Sabak, Kelantan, Malaysia. *International*

Journal of Environmental Research and Public Health, *17*, 311. http://doi.org/10.3390/ijerph17010311.

[30] Jabatan Pengurusan Sisa Pepejal Negara. (2013). Survey on solid waste composition, characteristics & existing practice of solid waste recycling in Malaysia. Retrieved from https://jpspn.kpkt.gov.my/resources/index/user_1/Sumber_Rujukan/kajian/Final_Report_REVz.pdf.

[31] Liu, D.; Shi, Q.; Liu, C.; Sun, Q.; Zeng, X. (2023). Effects of endocrine-disrupting heavy metals on human health. *Toxics*, *11*, 322. http://doi.org/10.3390/toxics11040322.

[32] The toxic after-effects of imported plastic waste in Malaysia. (accessed on 1 July 2024) Available online: https://storage.googleapis.com/planet4-malaysia-stateless/2020/05/4dbab0db-the-recycling-myth-2.0-the-toxic-after-effects-of-imported-plastic-waste-in-malaysia.pdf.

[33] Montuori, P.; De Rosa, E.; Di Duca, F.; Provvisiero, D.P.; Sarnacchiaro, P.; Nardone, A.; Triassi, M. (2021). Estimation of polycyclic aromatic hydrocarbons pollution in Mediterranean Sea from Volturno River, Southern Italy: Distribution, risk assessment and loads. *International Journal of Environmental Research and Public Health*, *18*, 1383. http://doi.org/10.3390/ijerph18041383.

[34] Alam, M.M.; Morshed, G.; Siwar, C.; Murad, M.W. (2012). Initiatives and challenges of agricultural crop sector in ECER development projects in Malaysia. *American-Eurasian Journal of Agricultural & Environmental Sciences*, *12*, 922–931. http://doi.org/10.5829/idosi.aejaes.2012.12.07.1769.

[35] Department of Statistic Malaysia. (2019, November 29). Selected agricultural indicators, Malaysia, 2019. (accessed on 1 July 2024) Available online: https://www.dosm.gov.my/v1/index.php?r=column/pdfPrev&id=SEUxMEE3VFdBcDJhdUhPZVUxa2pKdz09.

[36] Kamarudin, N.A.; Zulkifli, S.Z.; Azmai, M.N.A.; Abdul Aziz, F.Z.; Ismail, A. (2020). Herbicide Diuron as endocrine disrupting chemicals (EDCs) through histopathological analysis in gonads of Javanese medaka (*Oryzias javanicus*, Bleeker 1854). *Animals*, *10*, 525. http://doi.org/10.3390/ani10030525.

[37] Xu, P.; Zhou, X.; Xu, D.; Xiang, Y.; Ling, W.; Chen, M. (2018). Contamination and risk assessment of estrogens in livestock manure: A case study in Jiangsu Province, China. *International Journal of Environmental Research and Public Health*, *15*, 125. http://doi.org/10.3390/ijerph15010125.

[38] Muhamad, H.; Ramli, M.I.; Zakaria, Z.; Sahid, I. (2013). The fate of Diuron in soil in a Malaysian oil palm plantation. *Journal of Oil Palm Research*, *25*, 149–158.

[39] Abdullah, M.P.; Abdul Aziz, Y.F.; Othman, M.R.; Wan Mohd Khalik, W.M.A. (2015). Organochlorine pesticides residue level in surface water of Cameron Highlands, Malaysia. *Iranica Journal of Energy & Environment*, *6*, 141–146. http://doi.org/10.5829/idosi.ijee.2015.06.02.10.

[40] Malaysia Petrochemical Country Report 2022 Asia Petrochemical Industry Conference (Apic 2023). (accessed on 1 July 2024) Available online: https://www.mpa.org.my/images/APIC2020/MPA_APIC_2023_Country_Report_FINAL.pdf.

[41] Wan, J.; Wang, Q.; Miao, S. (2024). The impact of urbanization on industrial transformation and upgrading: Evidence from early 20th century China. *Sustainability*, *16*, 4720. http://doi.org/10.3390/su16114720.

[42] Evanthia, D.K.; Bourguignon, J.P.; Giudice, L.C.; Hauser, R.; Prins, G.S.; Soto, A.M.; Gore, A.C. (2009). Endocrine-disrupting chemicals: An endocrine society scientific statement. *Endocrine Reviews*, *30*, 293–342. http://doi.org/10.1210/er.2009-0002.

[43] Ruiz, D.; Becerra, M.; Jagai, J.S.; Ard, K.; Sargis, R.M. (2018). Disparities in environmental exposures to endocrine-disrupting chemicals and diabetes risk in vulnerable populations. *Diabetes Care*, *41*, 193–205. http://doi.org/10.2337/dc16-2765.

[44] Yuswir, N.S.; Praveena, S.M.; Aris, A.Z.; Ismail, S.N.S.; de Burbure, C.; Hashim, Z. (2015). Heavy metal contamination in urban surface soil of Klang district (Malaysia). *Soil and Sediment Contamination*, *24*, 865–881. http://doi.org/10.1080/15320383.2015.1064090.

[45] Praveena, S.M.; Yuswir, N.S.; Aris, A.Z.; Hashim, Z. (2014). Contamination assessment and potential human health risks of heavy metals in Klang urban soils: A preliminary study. *Environmental Earth Sciences*, *73,* 8155–8165. http://doi.org/10.1007/s12665-014-3974-2.

[46] Zakaria, M.P.; Takada, H.; Tsutumi, S.; Ohno, K.; Yamada, J.; Kouno, E.; Kumata, H. (2002). Distribution of polycyclic aromatic hydrocarbons (PAHs) in rivers and estuaries in Malaysia: A widespread input of petrogenic PAHs. *Environmental Science & Technology*, *36*, 1907–1918. http://doi.org/10.1021/es011278+.

[47] Overview Report I: Worldwide initiatives to identify endocrine disrupting chemicals (EDCs) and potential EDCs. (accessed on 1 July 2024) Available online: https://wedocs.unep.org/bitstream/handle/20.500.11822/25633/EDC_report1.pdf?sequence=1&isAllowed=y.

[48] Zaidon, S.Z.; Ho, Y.B.; Hashim, Z.; Saari, N.; Praveena, S.M. (2018). Pesticides contamination and analytical methods of determination in environmental matrices in Malaysia and their potential human health effects – A review. *Malaysian Journal of Medicine and Health Sciences*, *14*, 81–88.