OBSERVING OF POLYBROMINATED DIPHENYL ETHERS (PBDES) IN SOME SOIL/SEDIMENT SAMPLES RESULTED FROM the ELECTRNOIC WASTE (CASE STUDY: KUWAIT COUNTRY)

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ABSTRACT

Electronic waste is Kuwait's fastest-growing waste stream and one of the largest per capita producers among Gulf Cooperation Council (GCC) countries. Due to the increased obsolescence of technologies and the quickening pace of technological advancement, this waste stream is anticipated to grow 5 to 7% annually. Furthermore, Kuwait uses the same landfills to dispose of both traditional and electronic trash. Serious questions are raised about the potential effects on locals' and the environment's wellbeing. Based on the present state of knowledge, strategies and laws can then be suggested for Kuwait to lessen human exposure to e-waste. The present study explored the level of Polybrominated Diphenyl Ethers (PBDEs) in four different locations in Kuwait. Al Shaqaya – Amghara- Shuab - Kisr from October 2021 till October 2022.Total BDEs ranged from 88738.2 to 124310.3 pg/g (110259.6 ± 13747.6 pg/g). Both the mean values of Σ10BDEs and BDE-209 showed a trend of Shuaiba > Amghara > Al Shaqaya > KISR.The risks that PBDEs in the soil and air bring to the local population in those areas were also assessed. The case study made obvious the long-term cancer risks that the prevalent BDE-209 posed to the local population.

Keywords: Soil; Polybrominated diphenyl; Health risk assessment; electronic waste management

INTRODUCTION

Electronic waste, often known as e-waste, is all Electrical and Electronic Equipment (EEE) and its components that have been thrown out as trash by its owners with no intention of being used again (UNU and Step, 2014). Electronic garbage, often known as e-waste, is also known as Waste Electrical and Electronic Equipment (WEEE), electronic garbage, or e-scrap globally. Almost any appliance or commercial device with circuitry or electrical components with power or battery supply is included in this category of waste (Balde *et al*., 2015). To put it another way, any obsolete electronic devices that are used for either domestic or commercial purposes are referred to as electronic waste (e-waste) (Singh *et al.,* 2013).The problem is made worse by customers in poor economies' lack of knowledge about appropriate e-waste disposal techniques. Furthermore, poor informal recycling practices and the disposal of e-waste in open landfills prepare the way for the release of dangerous pollutants (Patil and Ramakrishna, 2020).Domestic equipment makes up around half of the e-waste (45%), followed by technology and communications equipment (33.9%) and consumer electronics (13.7%) (Chakraborty et al., 2022). Driven by the rapid improvement in technology and shorter shelf-life of electronic items, a 60% spike in worldwide e-waste creation was noted from 2010 to 2019 which is anticipated to reach (75 Mt, Metric ton) by 2030.

In almost all GCC countries, there is minimal to zero legislation on e-waste, with minor differences in e-waste management between the respective countries. Although numerous initiatives pertaining to waste recycling including segregation of plastics, metals and paper has been taken in Bahrain, the country lacks comprehensive law related to e-waste management. Similarly, there is an absence of proper regulatory system in both Kuwait and Saudi Arabia which is the highest generator of e-waste among the GCC countries wherein most of the e-waste recycling is taken up by private enterprises and NGOs. Given the exponential increase in the e-waste generation in Qatar, the authorities have recognized the importance of waste management, however no significant actions have been taken till date. Among all GCC countries, the UAE stands out, given the modern inventiveness taken up by the country regarding e-waste. At present, the regulatory authorities of the UAE government are working on facilitating a holistic approach to address e-waste recycling (Widmer, 2021).Among GCC countries, Kuwait, although a small country has surprisingly high number of landfills covering 18 km^2 of the total area of 17,820 km^2 (Zafar, 2019). Once, e-waste is discarded in the landfills, it can lead to the release of several POPs including polychlorinated biphenyls, plasticizers, flame retardants and other heavy materials (Ankit *et al*., 2021). The present study aims to portray the level of PBDEs, which are originated from the e-waste in the soil matrix and possible risk assessment studies.

MATERIALS AND METHODS

The samples were collected from 4 locations along Kuwait from October 2021 till october 2022, and these are displayed in Figure

1. Al Shaqaya
2. Amghara
3. Kisr
4. Shuab

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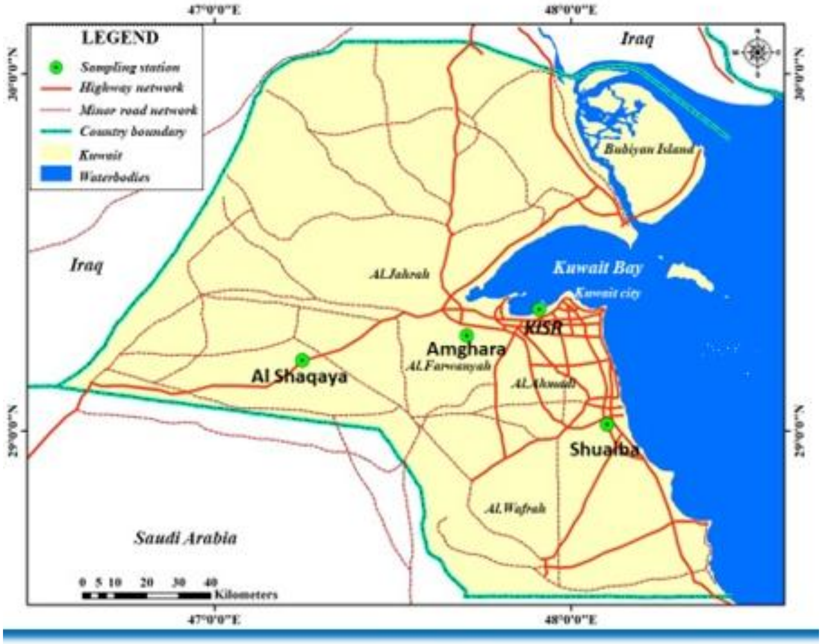


Figure(1): Study area showing sampling points (the sampling locations are highlighted in bold)

1. Soil Sample Collection: Surface soil/Deposit composite samples over an area of 50 m x 50 m were collected using a pre-cleaned stainless-steel scoop after rigorous mixing. Samples were wrapped in aluminum foil and stored at -4 °C before extraction.

Soil samples were extracted based on the method given elsewhere (Gevao *et al.*, 2006a, 2006b). Briefly, 20g of samples were homogenized using anhydrous Na_2SO_4 after adding the recovery standards (BDE-35 and BDE-181) and were extracted for 16h using Soxhlet apparatus. The extracts were then column cleaned using silica (10g) and alumina (5g). 100mL of 1:1; v: v hexane: DCM was used as eluting solvent and the eluents were concentrated to 2mL using TurbovapTM. Samples were further reduced using nitrogen after the addition of dodecane and transferred to 100 µL glass inserts. Each sample were then added with 10 ng/µL of Mirex as internal standard before quantification.

Shimadzu GC 2010 (Shimadzu, Tokyo, Japan) gas chromatograph mass selective detector with negative chemical ionization incorporated with a 15 m DB 5MS column (0.25 mm i.d., 0.25 μm film thickness) was used for quantification of PBDEs in soil samples. Initial oven temperature was set at150 °C with a holding time of 1 min, and then increased to 250 °C (20 °C/min) and further increased to 290 °C (4 °C/min) with a holding time of 25 min. Injector, ion source, quadrupole and transfer line temperatures were set at 250 °C, 230 °C, 106 °C and 300 °C, respectively

2. **Quality Assurance and Quality Control (QA/QC) Procedures:** Precise analytical measurements depend largely on the proper use of good laboratory practices, proven methodology, and low noise instrumentation (Moosavi and Ghassabian, 2018). Certain aspects of the QA/QC procedure are summarized subsequently.

A) Instrument/Equipment Testing, Inspection, and Maintenance: The GC-MS performances were evaluated regularly by tuning performance standard perfluorotributylamine (PFTBA) prior to each run and by running intra-day and inter-day variability of standards. The peak area, shape, and electron multiplier setting (sensitivity) were all subjectively evaluated. The calibration response factors used for quantitation were determined from a set of no less than three standards run at the same time as a given set of samples. Method detection level (MDL) was calculated based on 3 times the SD of 7 spiked blanks. Balances were calibrated using standard calibration weights every time the balance was used. This is standard operating procedure and is not recorded separately from the weighing activity.

B) Blanks : Field blanks, laboratory procedural blanks were treated identically with the samples. Field blanks were obtained from each site whenever samples were collected. Procedural blanks were run with a set of every 5 samples to determine cross-contamination in laboratory. Instrumental blanks were also run for a set of 10 samples and all the samples were blank corrected.

3. Risk Assessment: The risk assessment was carried out based on the methodology given by Chen et al. (2020). The estimated daily intake (EDI) via ingestion of soil particles was estimated, based on the following Eq. (1)

$$EDI_{soil} = \frac{C_{soil} \times IF_{soil} \times ADI}{BW} \qquad (1)$$

where EDI_{soil} (pg/kg.d) is EDI via ingestion of soil, C_{soil} is PBDE concentration in soil (pg/g), IF_{soil} ingestion factor for soil (0.302 for child and 0.237 for adult), ADI is ingestion rate of soil (63 mg/d for child and 26 mg/d for adult) and BW is body weight (15 kg for child and 70 kg for adult).

The Hazard Quotient (HQ) and the theoretical Lifetime Cancer Risk (LCR) values were calculated using the following Eqs. (2) and (3)

$$HQ = \frac{EDI_{soil}}{RfD} \qquad (2)$$

$$LCR = \frac{EDI_{soil} \times ED \times CSF}{(AT)} \qquad (3)$$

RfD refers to reference of PBDE congener given by US EPA (available only for 4 congeners) in (mg/kg.d), *ED* is the exposure duration years (30 yr), *AT* is the average lifespan (70 yr), *CSF* is the carcinogenic slope factor. BDE-209 is now the only known carcinogenic congener with a *CSF* of 7×10^{-4} kg.d/mg.

RESULTS AND DISCUSSION

1) Current Practices in the e-waste management in Kuwait: Given the climatic conditions, energy requirements and the unprecedented growth in population, Kuwait face a massive challenge for addressing the solid waste issue. The most common e-waste produced by Middle East/North Africa countries (that includes Kuwait) include large and small household appliances, IT and telecommunications equipment, lighting equipment, electrical and electronic tools, monitoring and control instrument, consumer equipment and medical devices (Al-Anzi *et al.*, 2017). Like other countries around the globe, Kuwait faces the same challenge in the increasing growth rate of e-waste generation. In 2019 alone, Kuwait produced 74 kilo tons of e-waste with a per-capita generation of 15.8 kg. The e-waste generation is anticipated to reach 100000 tons per year compared to the global 50 million tons estimates (Alrobayee, 2022). Mobile phones alone contributed to 3000 tons of e-waste in Kuwait. Life cycle assessment on mobile phones in Kuwait suggested due to the import of electronic goods and consumerism, a high e-waste generation is expected in only 2 years (Al-Anzi *et al.*, 2017). However, the country still lacks specific policies and regulations based on e-waste management (Forti *et al.*, 2020)

Majority of the e-waste in Kuwait is destined to the landfills. Although there are a total of 18 landfills in the country, more than 75% of them are not in use. However, measures are being taken to increase the landfill areas from 45.5 km^2 to 60 km^2 by 2025. Similar to other GCC countries, landfills in Kuwait also act as open dumpsites wherein waste is dumped without any safety considerations. In 2020, Kuwait generated 2.51 Metric Ton of Municipal Solid Waste Incineration (MSWI) with a per capita of 1.4kg (Alrobayee, 2022, Al-Jarallah and Aleisa, 2014). In a typical Municipal Solid Waste (MSW)from Kuwait, organic waste contributes to 50% followed by paper, plastic and other waste. There lies a huge dearth of knowledge on the composition of e-waste generated from Kuwait. Given the limited information among consumers and the lack of infrastructure on e-waste management in Kuwait, e-waste dumped in the landfills can lead to detrimental effects on both human and environmental health. Consequently, a recent study have shown elevated levels of heavy metals at these landfill sites with almost all the sites exceeding Canadian and Australian limits (Al-Salem *et al.*, 2020).

2) **Comparison of e-waste laws in the state of Kuwait to the international policies:** Although, Kuwait signed the Basel Convention in 1993, one of the major challenges faced by the country is the lack of proper infrastructure for waste

management. Furthermore, the absence of laws and regulations based on waste management aggravates the problem further. Kuwait transmitted the Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution to the Basel Secretariat, which is the enabling law (Basel Convention). The regional law applies to the marine environment and is not specific to e-waste or hazardous waste. Kuwait allows the export of such wastes under Basel Convention conditions only where no plant for recycling or treating such wastes exists within the exporting country.

In Kuwait, waste is managed via two specific laws, viz., Decision No. 210/2001 Pertaining to the Executive By-Law of the Law of Environment Public Authority and Law No. 42 of 2014 Promulgating the Environment Protection Law. The first initiative that was taken towards addressing the rising issue with chemicals with POPs came into action via the development and implementation of the Kuwait National Implementation Plan (NIP) (NIP, 2021). Kuwait is also signatory to the Rotterdam Convention and Minamata Convention.

Despite being the second-largest per capita producer of e-waste (16.6 kg) in the world, best strategies for e-waste management can be seen in the European countries, particularly by Switzerland and Netherlands (Bhutta *et al.*, 2011; Khetriwal *et al.*, 2009). This is solely attributed due to presence of a robust collection system, wherein more than 35% of the e-waste is collected. Also has the highest collection rate (35%). Furthermore, certain novel initiatives such as common charger for all electronic devices by autumn 2024 will help in further reducing the quanta of e-waste generated. Unlike European countries, till date due to the absence of additional recycling facilities in Kuwait, landfills are still the dominant destination for solid waste containing e-waste. Moreover, Kuwait should come up with new strategies and policies to improve e-waste management in Kuwait.

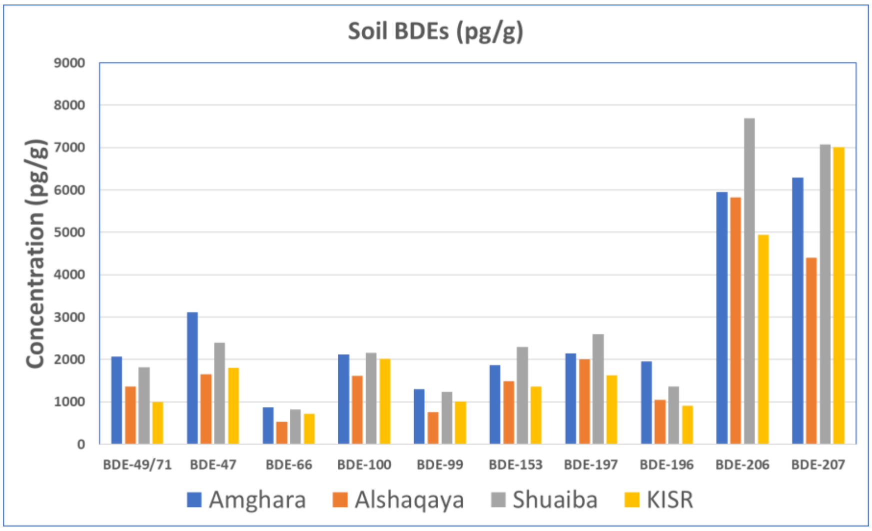
3) Levels and comparison

Table(1): Soil BDE Concentrations across four locations in Kuwait

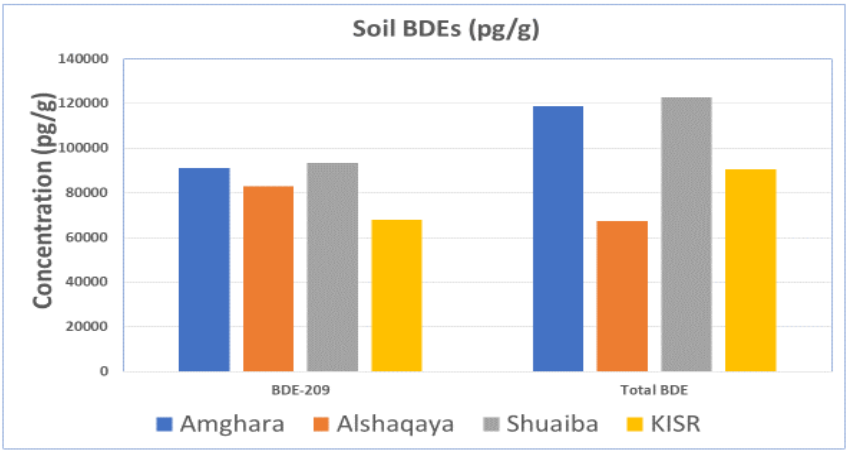
PBDEs (pg/g)	Range	Mean ± stdev
PBDE-49/71	965.3–2124.8	1624.4 ± 425.5
PBDE-47	1754.4–3149.5	2355.7 ± 519.4
PBDE-66	621.2–885.6	769.6 ± 98.4
PBDE-100	1987.7–2254.4	2084.9 ± 84.8
PBDE-99	914.6–1452.9	1122.2 ± 191.9
PBDE-153	1247.4–2347.7	1857.2 ± 367.7
PBDE-197	1458.4–2654.3	2194.5 ± 409
PBDE-196	845.7–2054	1353 ± 421.4
PBDE-206	4865.4–7785.3	6411.2 ± 1129.31
PBDE-207	5876.4–7147.4	6624.5 ± 515.9
Σ_{10}PBDEs	21916.5–29742.2	26396.7 ± 2835.2
PBDE-209	65879.2–95612	83862.9 ± 11008.3
Total BDE	88738.2–124310.3	110259.6 ± 13747.6

PBDEs: Polybrominated diphenyl ethers

The mean soil PBDE concentrations across four locations ranged from BDE-66 (769.6 ± 98.43 pg/g) to BDE-209 (83862.9 ± 11008.25 pg/g) (Table 1). BDE-209 ranged between 65879.2–95612 pg/g (83862.9 ± 11008.3 pg/g). Σ10BDEs ranged from 21916.5–29742.2 pg/g (26396.7 ± 2835.2 pg/g). Total BDEs ranged from 88738.2 to 124310.3 pg/g (110259.6 ± 13747.6 pg/g). Both the mean values of Σ10BDEs and BDE-209 showed a trend of Shuaiba > Amghara > Al Shaqaya > KISR (Figures 2, 3).



Figure(2):. Soil concentration profiles of each brominated diphenyl ethers (BDEs) congener



Figure(3): Soil concentration profiles of BDE-209 and total brominated diphenyl ethers (BDEs)

Shuaiba region comprises of industries under Shuaiba industrial area (SIA), which is the first industrial complex in Kuwait and is considered the largest industrial area in the Arabian Gulf. This may be the reason for higher BDEs in this region. Moreover, the soil samples were collected from wastewater treatment plan area in this region.

Mean Σ10BDEs (26.4 ± 2.83 ng/g) in the present study were much higher than those in Shanghai, China (0.7 ± 0.5 ng/g) (Jiang et al., 2010); Tibetan Plateau, China (0.01 ng/g) (Wang et al., 2009); Ny-Ålesund, Norway (0.04 ± 0.02 ng/g) (Wang et al., 2015); Eastern China (9.2 ng/g) (Yin et al., 2021); and Mt. Meru, Tanzania (0.39 ± 0.20 ng/g) (Parolini et al., 2013) although the number of congeners analyzed in the present study were lower than those studies (Table 2).

Table(2): Comparison of the soil PBDEs in the present study with other studies

Place/ Country	Year	Range (ng/g)	Mean ± stdev	No. of congeners	Dominant congeners	Reference
Kuwait	2022	21.92–29.74	26.4 ± 2.83	10	BDE-206, BDE-207	Present study
Kuwait	2022	88.74–124.31	110.26 ± 13.75	11	BDE-209	Present study
Shanghai, China	2010	0.03–3.8	0.7 ± 0.5	29	BDE- 209, 47, 99, 100, 119, 183	(Jiang *et al.*, 2010)
Guandong province, China	2014	13.9–13251	898.3	41	BDE-209	(Wang *et al.*, 2014)
Tibetan plateau, China	2009	0.004 – 0.03	0.01	14		(Wang *et al.*, 2009)
River Ravi, Pakistan	2013	0.6–500	40 ± 98	7	BDE- 99, 183	(Syed *et al.*, 2013)
Ny-Ålesund, Norway	2015	0.01–0.09	0.04 ± 0.02	12	BDE-99	(Wang *et al.*, 2015)
Eastern China	2021	3.05–1.34	9.2	21	BDE- 209	(Yin *et al.*, 2021)
Jiangsu province, Eastern China	2019	2.21–18,451	1004	13	BDE-85, BDE-153, BDE-183 and BDE-209	(Xu *et al.*, 2019)
Mt. Meru, Tanzania	2013	0.14–0.95	0.39 ± 0.20	13	Tetra & Penta BDEs	(Parolini *et al.*, 2013)
Kuwait	2011	0.02–0.3	-	6		(Gevao *et al.*, 2011)
Agricultural Fields, China	2021	0.002–1.80	0.243	7		(An *et al.*, 2022)
Background site, Central China	2019	0.03–0.24	-	8	BDE- 209	(Zhan *et al.*, 2019)
Inner Mongolia, Northern China	2020	1.3–13.3	3.62	8	BDE-28, 47, 209	*(*Yijing Chen *et al., 2020)*
Dilovasi Industrial Region, Turkey	2019	0.2–286	14.5 ± 25.1	8	BDE- 47, 99, 209	(Cetin *et al.*, 2019)
Yangtze River Delta, China	2014	0.04–2.2		7	BDE- 47, 99, 100, 153, 183	(Shi *et al.*, 2014)

PBDEs: Polybrominated diphenyl ethers

BDE-209 was the dominant congener in this study and is consistent with the results observed in many Chinese regions such as Guandong Province (Wang et al., 2014), Eastern China (Yin *et al*., 2021), and Background site in Central China (Zhan *et al*., 2019). PBDEs in a previous study in Kuwait by Gevao et al. (2011) were much lower than in the present study; however, only six congeners were observed. BDE-209 was the major congener in all the sampling sites, which could be ascribed to the fact that PBDEs are produced and used in Kuwait mostly as the commercial DeBDE products (Jiang *et al*., 2010). Moreover, the recent observations in Kuwait (Alshemmari *et al,* 2022) shows the comparable results with the present findings.Specific congeners have predominated in industrial mixtures and are hence commonly examined in environmental samples as indicators of individual formulations. The contribution of BDE-209 to total PBDE pollution is usually greater than 60%, and it may also exceed 90% or higher (Cetin and Odabasi, 2007; Syed *et al*.,2013).In areas with higher populations, flame retarded products are more prevalent, and the release of these products from homes, businesses, and automobiles is believed to be the main source of PBDEs and NBFRs in the atmosphere. Studies show that food is the primary source of human exposure to POPs like PBDEs (particularly the lower brominated congeners) (Schecter *et al*, 2008; Domingo, 2012). Urban soils had higher levels of PBDE pollution. It was determined that PBDEs and the degree of urbanization were closely related. (Stapleton *et al*. 2005). Another explanation could be that there was a correlation between the locations of industrial plants and the amounts of pollution in the studied areas.

4) Health Risk Assessment: Open burning of the PBDE containing-waste may thus be the major cause for the release of PBDEs and its associated elevated carcinogenic risk. Since PBDEs can be bioaccumulated and biomagnified in the ecosystem, they may be accumulated in human bodies. The risk values were generally higher for children than for adults. The HQ values were found to be low; thus, the non-cancer health risks were acceptable (Tables 3, 4). The LCR for BDE-209 via soil ingestion is within the range of 1.8×10^{-3} to 2.47×10^{-3}, while the risk due to inhalation is close to 0.25×10^{-3} to 1.67×10^{-3} (Table 5). This indicates that the LCR values were above 1×10^{-6}, indicating potential carcinogenic risks. The overall incidence of cancer in adolescents was higher than in adults at every site in the current study. These pollutants enter the body primarily through the dermal and gastrointestinal tracts. The inhalation pathway is extremely minimal. It was worth noting that as the BDE-209 concentrations in the samples were high, it can pose cancer risks to the local people in long term.

Table(3): Hazard Quotients based on soil concentrations for adult and children

PBDEs	Adults (× 10-6)				Child (× 10-6)			
	Amghara	**Al Shaqaya**	**Shuaiba**	**KISR**	**Amghara**	**Al Shaqaya**	**Shuaiba**	**KISR**
BDE-47	2.74	1.86	2.11	1.59	39.4	26.8	30.4	22.9
BDE-99	1.15	0.83	1.09	0.89	16.5	11.9	15.7	12.8
BDE-153	0.82	0.84	1.01	0.6	11.9	12.1	14.6	8.63
BDE-209	1.15	1.04	1.18	0.86	16.5	15	16.9	12.3

PBDEs: Polybrominated diphenyl ethers

Table(4): Hazard Quotients based on air concentrations for adult and children

PBDEs	Adults (× 10-6)				Child (× 10-6)			
	Amghara	**Al Shaqaya**	**Shuaiba**	**KISR**	**Amghara**	**Al Shaqaya**	**Shuaiba**	**KISR**
BDE-47	2.16	0.93	0.15	0.56	26.5	11.5	17.9	6.87
BDE-99	0.79	0.45	0.54	0.54	9.65	5.54	6.68	6.65
BDE-153	0.6	0.39	0.43	0.22	7.36	4.77	5.29	2.77
BDE-209	0.79	0.14	0.13	0.12	9.75	1.78	1.6	1.46

PBDEs: Polybrominated diphenyl ethers

Table(5): Lifetime Cancer Risks based on BDE-209 concentrations in soil and sir

BDE-209	Adults (× 10-3)				Child (× 10-3)			
	Amghara	**Al Shaqaya**	**Shuaiba**	**KISR**	**Amghara**	**Al Shaqaya**	**Shuaiba**	**KISR**
Soil	2.41	2.19	2.47	1.8	34.7	31.5	35.6	25.9
Air	1.67	0.3	0.27	0.25	20.5	3.73	3.36	3.07

PBDEs: Polybrominated diphenyl ethers

CONCLUSION

Kuwait ranks fairly high in e-waste generation and is one of the GCC nations with the highest per capita e-waste production rates. The majority of e-waste is dumped in landfills alongside conventional waste without regard for the safety and environmental risks involved because there are insufficient environmental laws.As a case study of the dangers presented by e-waste, four sites in Kuwait were examined for the presence of PBDEs, a significant chemical found in printed circuit boards, plastic casings, cables, etc. The dangers to the local population were also assessed. It was discovered that Kuwait had some PBDE contamination, and the levels of PBDEs in the soil were greater than in some parts of China. Even more PBDEs were found in the soil than in prior research done in Kuwait. The non-cancer health risks presented by PBDEs to the local population were minimal and tolerable, whereas higher concentrations of BDE-209 can put the local population at risk for long-term cancer.

RECOMMENDATIONS

1. Kuwait should develop and implement comprehensive e-waste legislation that incorporates the environmental law principles to ensure effective recycling of e-waste
2. Kuwait should include EPR-based legislation with a clear objective of reducing pollution and enhancing recycling
3. Kuwait should consider revising their international commitments in tackling hazardous wastes, especially under the Basel Convention
4. Effective partnerships between government and private players in e waste collection and recycling
5. Feasibility studies on the different technologies used in e-waste recycling should be conducted to identify the most efficient and cost-effective in the context of Kuwait

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مراقبة إيثر ثنائي الفينيل متعدد البروم (PBDES) في بعض عينات التربة / الرواسب الناتجة من النفايات الالكترونية (دراسة حالة- دولة الكويت)

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المستخلص

يشهد الطلب على المعدات الكهربائية والإلكترونية ارتفاعًا ثابتًا في كل من الدول المتقدمة والنامية. وقد أدى معدل استهلاك السلع الإلكترونية المرتفع إلى ظهور تيار جديد من النفايات يعرف باسم النفايات الإلكترونية أو المخلفات الإلكترونية (**e-waste**) حيث تعد دولة الكويت واحدة من أكبر دول مجلس التعاون الخليجي (منتجي النفايات الإلكترونية للفرد)، إذ أن النفايات الإلكترونية هي أسرع تيار للنفايات المتزايدة في الكويت ومن المتوقع أن تزيد بمعدل ٥-٧% سنويًا بسبب قدرة التكنولوجيا على التقدم والتطور السريع. علاوة على ذلك، تستخدم الكويت نفس مواقع التخلص من النفايات لكل من تيارات النفايات العادية والنفايات الإلكترونية. مما يثير الأمر قلقًا جديًا بشأن الآثار الصحية المحتملة على السكان المحليين والبيئة. وفي هذا السياق، قمنا بتلخيص المعلومات العلمية الحالية حول النفايات الإلكترونية. كما توضح الدراسة أيضًا التعامل مع النفايات الإلكترونية في الدول المتقدمة والنامية، مع التركيز الرئيسي على الكويت وتعرض الإنسان للنفايات الإلكترونية من خلال المسارات المختلفة الممكنة. كما تم مناقشة تلوث وسائط البيئة المختلفة بالنسبة للمركبات السامة من النفايات الإلكترونية. حيث أشارت الدراسات إلى أن التعرض للنفايات الإلكترونية قد يسبب مخاطر صحية للإنسان. و بناء على هذه الحالة الحالية للمعرفة، يمكن اقتراح استراتيجيات ولوائح في الكويت لتقليل تعرض الإنسان للنفايات الإلكترونية. كما تم تحليل تراكيز **PBDEs** في التربة والهواء في أربعة مواقع في الكويت كدراسة حالة للتلوث المحتمل من النفايات الإلكترونية. وتم تقييم المخاطر التي تشكلها **PBDEs** في التربة والهواء على السكان المحليين في تلك المواقع. وأظهرت الدراسة الحالية تحديدًا، المخاطر السرطانية طويلة الأمد التي يتعرض لها الناس المحليون من خلال **BDE-209** المسيطر.

الكلمات المفتاحية: تربة؛ ثنائي الفينيل متعدد البروم ؛ تقييم المخاطر الصحية ؛ إدارة النفايات الإلكترونية