

# ASSESSMENT OF THE LEVELS OF PERSISTENT ORGANIC POLLUTANTS IN THE GHABAWI LANDFILL IN JORDAN

By

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## Abstract

**Introduction:** In the early 2003s, the Jordanian municipality of Al-Ghabawi began operating a municipal solid waste dump. As a result of inefficient waste management, it might be a substantial source of contaminants in the environment and a hazard to human health. All environmental elements (water, air, soil, and biota) are contaminated as a result of inefficient garbage disposal. The pollution of the environment in the area of garbage dumps and landfills is a big concern, caused by wind, uncontrolled waste burning, and evaporation of organic components. As a result, landfills may be hazardous to employees and the environment. **Aim of Work:** Residues of selected Persistent Organic Pollutants (POPs) as chemical pollutants were evaluated in leachate, soil, and groundwater in the Al-Ghabawi site to assess environmental quality in the landfill and the surrounding area. **Materials and Methods:** Samples were collected during 2020 in order to know their content of Polychlorinated biphenyls (PCBs), Organochlorine Pesticides (OCPs) and their metabolites. The sampling and analysis were conducted according to international standard methods. **Results:** The results of this study showed that the concentration ( $\mu\text{g L}^{-1}$ ) of PCBs congeners ranged between (0.51–0.53  $\mu\text{g L}^{-1}$ ) in the test 1 and (0.15–0.33  $\mu\text{g L}^{-1}$ ) in the leachate of Ghabawi landfill, whereas less than (1.00  $\mu\text{g L}^{-1}$ ) in the mixed leachate from five cells. Some targeted PCBs were detected and it was distributed as this order: PCB189 and PCB169 > PCB77 > PCB167 > PCB157, PCB81, PCB126 and PCB156 > PCB123 and PCB105 > PCB118 > PCB114. The concentration of total DDT varied from 2.16  $\mu\text{g/L}$  to 3.38  $\mu\text{g/L}$  in leachate samples; 3.19 ng/g to 2.91 ng/g in soil samples and 0.25  $\mu\text{g/L}$  to 1.94  $\mu\text{g/L}$  in groundwater

samples. The ratio of  $\sum (DDD + DDE)/PDDT > (13.17 \mu\text{g/L})$  in groundwater indicated an “aged” mixture, but the ratio of the Ghabawi well test in 2020 was  $< 0.73 \mu\text{g/L}$ . This is because of slow degradation or recent input of DDTs into the study area. **Conclusion and Recommendations:** The study concluded that there were some pollutants in the landfill area and the surrounding environment. These pollutants pose threat to the workers in the landfill. POPs regulations and control measures should be enforced to protect human health and the environment. Ensure safe and sound disposal methods for the waste containing POPs, considering the final destruction of POPs or irreversibly transformed; so no longer have the characteristics of POPs.

**Keywords:** Persistent Organic Pollutants, Polychlorinated biphenyls (PCBs), Organochlorine Pesticides (OCPs), Al- Ghabawi Landfill and Jordan

## Introduction

The amount of garbage produced rose dramatically as more resources were consumed in our everyday lives in contemporary countries. In most nations, trash landfilling is the most common method of Municipal Solid Waste (MSW) disposal. Polychlorinated biphenyls (PCBs) and pesticides, for example, might be found in landfills (Gabryszewska and Gwore., 2021, Lou et al., 2016 and Melnyk et al., 2015). Jordan, like many other countries in the world, witnessed an increasing population (11 million, with a 2.6% of growth rate) and consistent developments, particularly in main cities such as Amman, Irbid, and Zarqa (Greater Amman Municipality, 2018). The high population growth rate and rapid development, in addition to the lack of attention to the waste problem from the industrial and agricultural sector and citizens in general, plays

an important role in the accumulation of this waste without sorting and disposing of it in an unsafe way, and increases the difficulty of processing it in the landfill. The institutional nature of municipalities, lack of waste management infrastructure, increased poverty, the influx of refugees, and most importantly, behavioral changes among citizens due to lack of awareness have contributed to the exacerbation of the waste problem. Moreover, a large part of the waste is not collected, collected to temporary places, or incinerated, as a result of low awareness in different groups of society (Alamgir and Ahsan, 2007).

Polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) have the potential to harm human health and the environment. Because POPs are persistent in the environment, they can spread from the environment to humans through the food chain (Molla

et al, 2021). Toxic compounds known as Persistent Organic Pollutants (POPs) have a negative impact on human health and the environment all around the world. POPs are distinguished by their long-term environmental persistence, great resistance to degradation, capacity to bio-accumulate in live creatures' tissues, and potential for long-range atmospheric transport (Petrovic, 2018, Guo et al., 2019 and Jayara et al., 2016). Solid waste management is a global issue that affects many countries. It can endanger both human health and the environment.

Consumer products in Jordan are disposed off as general waste into municipal landfill sites in the Ghabawi area. The Ghabawi landfill serves Amman, Zarqa, and Ruseifa in the waste dumping process, although the latter two do the waste collection separately. For this reason, the Ghabawi landfill currently serves more than 50% of Jordan's population (approximately 5,670,000). According to (GAM, 2019) Ghabawi landfill sites for municipal waste receive mainly domestic and household waste (organic waste (50%), plastics waste (16%), paper and cardboard (15%), textiles and napkins (8%), glass and metals (4%), compost material (1%), hazardous waste (1%)

and unclassified combustibles (5%). Therefore, the importance of this research lies in being the first research aimed at assessing the levels of POP in the Ghabawi waste dump and developing proposals for appropriate scientific solutions to reduce the impact of these pollutants on the surrounding environment.

### **Aim of Work**

The residues of selected Persistent Organic Pollutants (POPs) as chemical pollutants were evaluated in leachate, soil, and groundwater in the Al-Ghabawi site to assess environmental quality in the landfill and surrounding area.

### **Materials and Methods**

**Study design:** It was planned to collect samples of leachate, soil, and groundwater from the landfill of Ghabawi, Jordan, in addition to recording the practice done in this site and asking the workers about the main problems encountered there.

**Duration of study:** This study was conducted during July and October 2020 at Jordan University, Ghabawi landfill, Jordan.

### **Study area description**

Al-Ghabawi landfill is located in the Ghabawi area, in Madonna,

Sahab municipality within the GAM jurisdiction, 40 km east to Amman with coordinates of 31° 55' 44.0" N. and 36° 10' 56.0" E; and with an approximate area of 2 km<sup>2</sup> (Figure 1). The site extends over 1.4% from the southeast to the northwest (Figure 1). Al-Ghabawi landfill is the first of its kind at Jordan. The landfill was planned for and built with gas collection systems. The landfill consists of cells in which the wastes are being dumped since 2003 (Yamin, 2017).

This landfill is designated to serve three areas (Amman, Zarqa, and Ruseifa) that are heavily crowded with residents. Jordan has a Mediterranean climate with a rainy season from November to April and very dry conditions for the remainder of the year. The climatic data for the study area indicated the average annual temperatures, with the hottest months between June and September. The period from December to February is the coldest period, with an average temperature of 9.5°C. The period from June to September is the warmest period with an average temperature near 26.7°C. Air humidity and sunrise the average relative humidity in the winter months is about 61%, while it decreases in the summer months to about 45%. The landfill faces a moderate climate in

terms of relative humidity, and a long dry period in summer, in addition to low humidity, leads to dry conditions that are likely to intensify dust suppression activities. Approximately 16.3% of the wind readings came from the northwest (NW); most showed speeds between 7.0-11.08 knots and 1.081-117.1 knots while the lowest value is more than 21.58 knots. In addition, approximately 15.5% of the readings came from the West-Northwest (WNW) trend; most are between 1.08-117.1 knots and 11.08-17.11 knots while the lowest value is more than 21.58 knots. Al-Ghabawi landfill is located in general in the western parts of the plateau of the Jordanian desert known as flint and limestone, which is dominated by carbonate rocks belonging to the late Cretaceous period. The main geological structure of this area plays a key role in choosing a site of the landfill due to the ability of some rocks to impede the transfer of pollutants. The Ghabawi landfill is located on the Al-Muwaqqar unit of the loamy chalk, which is an impermeable layer, and the vertical hydraulic conductivity is very low ( $10^{-11}$  \*2) m/s, which can delay the flow of pollutants from the surface to the groundwater system. The hydrological situation of the area belongs to semi-

arid climatic conditions. The soil inside the landfill is a thin layer, has medium permeability, and includes stones and rocks (Jordan Meteorological Department, Open files).

### **Study methods:**

#### **Samples collection:**

Samples were collected to examine soil quality, water quality, and leachate content of pollutants at a rate of two samples (three replicates of each samples cell) in order to know their content of PCBs and OCPs. All sample techniques were followed in general according to GERG (1994) and Wade et al, (1994). Glass sampling bottles were used to collect the water samples. Each sampling bottle was completely filled with water during the sampling process without air bubbles. The samples have been collected and sent to the laboratory for processing and analysis immediately. The soil samples were collected by sweeping a plastic brush as the soil samples. All samples were stored in brown glass sample bottles and sent to the laboratory for processing and analysis immediately once they have been collected. During transportation, the samples were stored at 4 °C.

Special precautions were taken to avoid sample contamination in

all steps to prevent contamination of tools, instruments, and other materials. Sample preparation and analysis methods have been described in (Wade et al.,1994 and Mavakala et al, 2016). Aliquots of the homogenized samples were extracted and analyzed for PCBs and OCPs at laboratories of Greater Amman Municipality.

#### **Sample extraction and analysis**

Soil samples, water, and leachate samples were analyzed at in the laboratories of Greater Amman Municipality and Water, Environment and Desertification Control Center at Al-Bayt University. The sample was repeated three times and the average was taken. Leachate samples and groundwater samples were strictly processed according to (GERG 1994, Wade and Cantillo, 1994).

#### **Consent**

Consent was taken from Al-Ghabawi landfill authorities (the Greater Amman Municipality). Privacy and confidentiality were ensured for data and analysis.

#### **Ethical Approval**

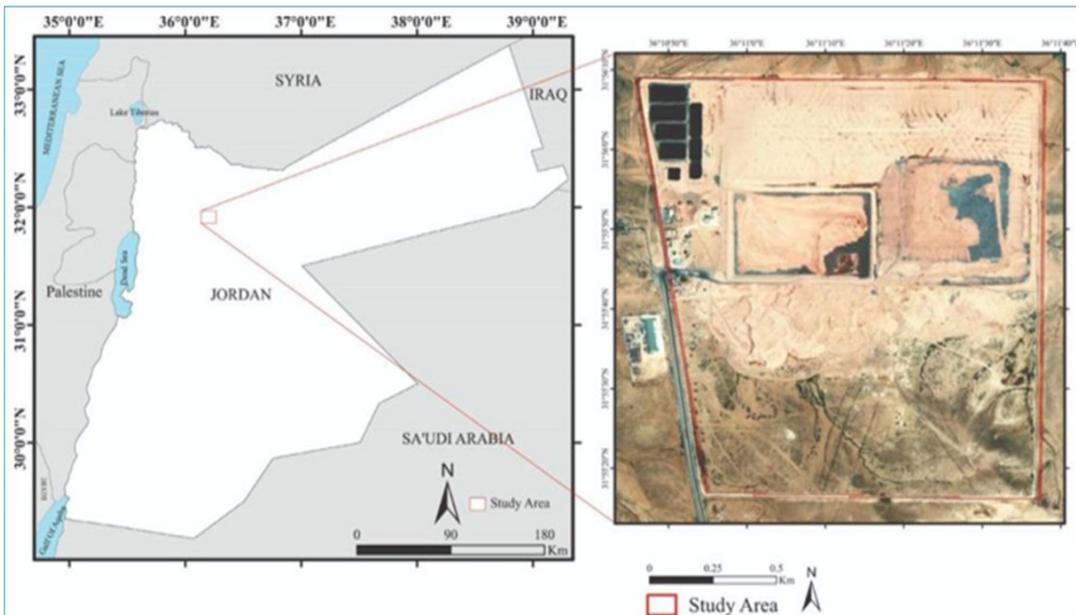
The study was approved by the Ethical Committee of the department of the programme of Environmental

Science and Management, Faculty of Higher Education, Jordan University. the study was carried out in accordance with the ethics of the profession and the literature of scientific research.

## Data Management

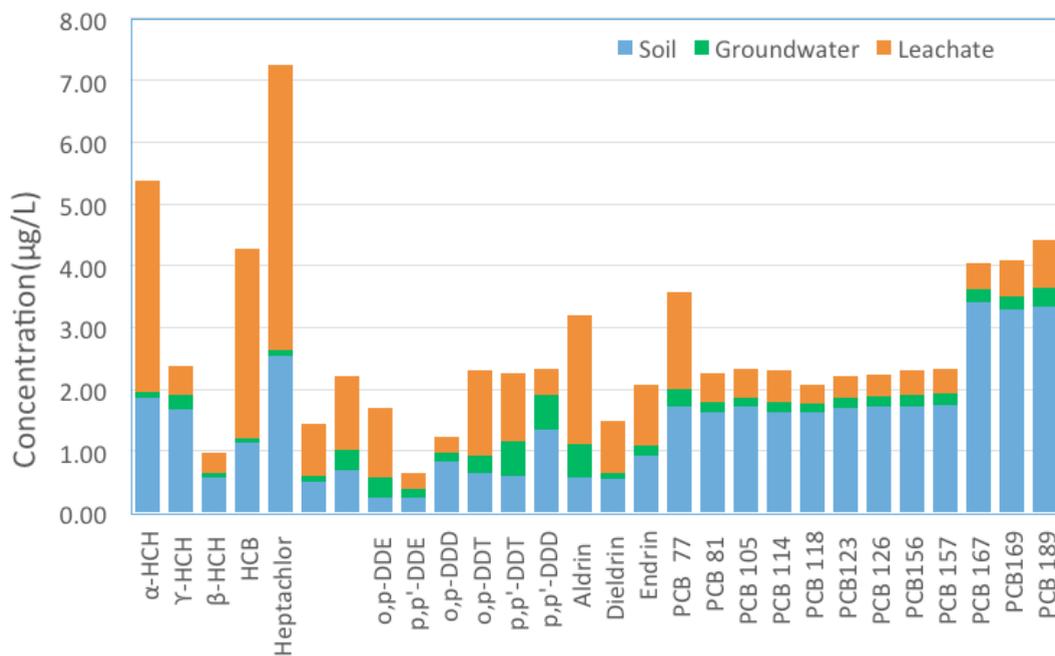
The results of this study were treated using the software of Statistical Package for Social Science (SPSS) version 21.0.

## Results



**Figure 1: The location of Al-Ghabawi landfill in the study area Polychlorinated biphenyls (PCBs)**

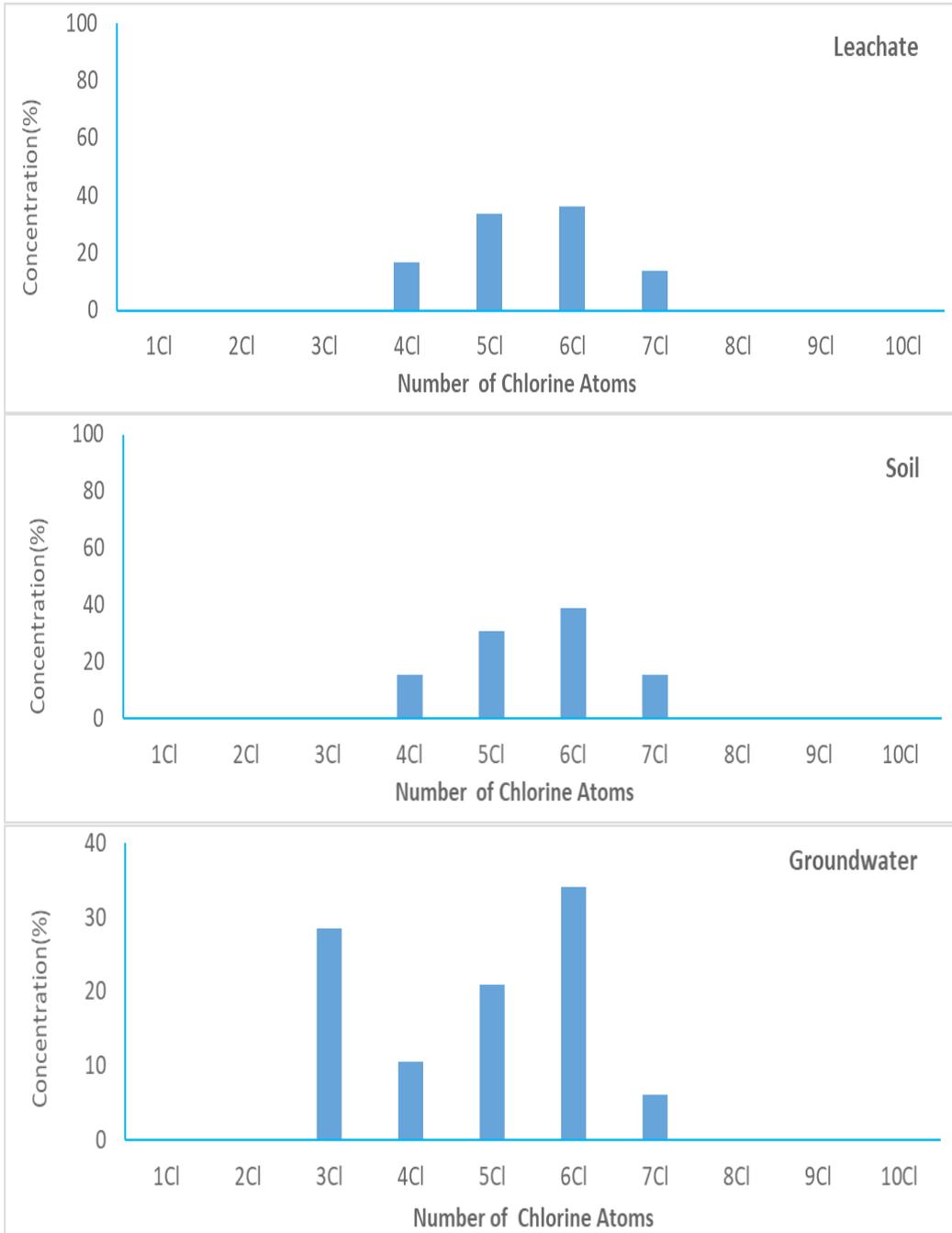
The total of PCBs and their metabolites exhibit various toxic effects including mutagenicity, carcinogenicity, and hormonal disruption (Šrédlová et al, 2020). The results of the current study are expressed in ( $\mu\text{g L}^{-1}$ ). The PCBs congeners and organochlorine pesticides in leachate, soil, and groundwater were illustrated in Figure 2. The amount of PCBs congeners ranged between ( $0.51\text{--}0.53 \mu\text{g L}^{-1}$ ) and ( $0.15\text{--}0.33 \mu\text{g L}^{-1}$ ) in the leachate samples of Ghabawi landfill, whereas less than ( $1.00 \mu\text{g L}^{-1}$ ) in the mixed from five cells. Some targeted PCBs were detected in the leachate of Ghabawi landfills such as PCB77, PCB81, PCB105, PCB157, and PCB189.



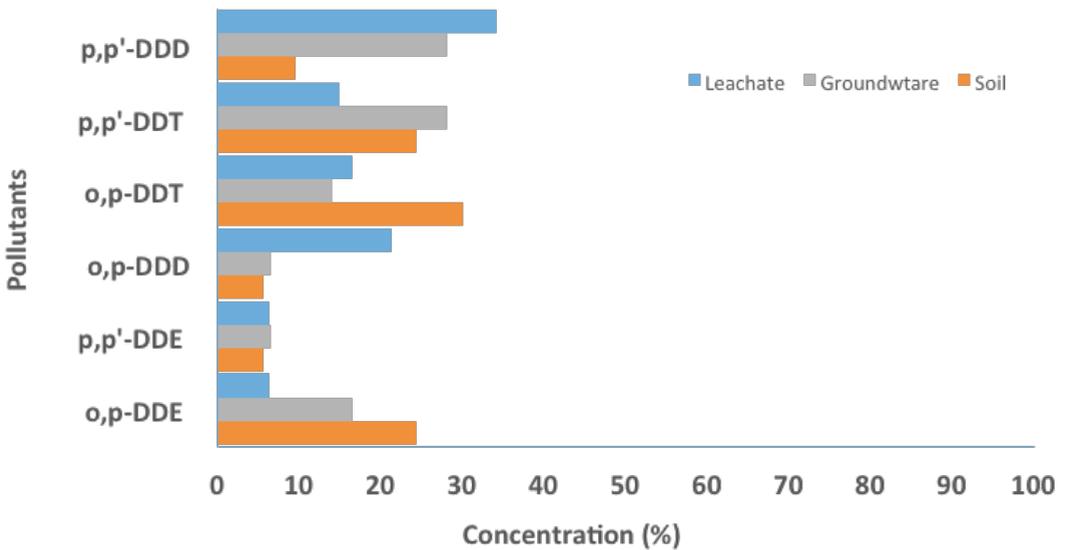
**Figure 2: Distribution of PCBs and OCPs in samples of Ghabawi landfill Organochlorine Pesticides(OCPs)**

The results of total Organochlorine Pesticides that are including Dichloro Diphenyl Trichloroethane (DDTs) and related compounds (DDT, DDD, and DDE), Hexachlorocyclohexanes and their metabolites ( $\alpha$ -HCH,  $\beta$ -HCH,  $\gamma$ -HCH, and  $\delta$ -HCH), in addition to other pesticides (Aldrin, Endrin and Diieldrin, Heptachlor, Heptachlor-oxo-epoxide, and Heptachlor-endoperoxide) in samples (leachate, soil, and groundwater) were illustrated in Figure (3). The concentration of DDTs in leachate samples ranged from  $2.16 \mu\text{gL}^{-1}$  to  $3.38 \mu\text{gL}^{-1}$ . The DDD has the highest percentage in two tests ( $62.72 \mu\text{gL}^{-1}$  and  $62.04 \mu\text{gL}^{-1}$ ), followed by DDT ( $29.59 \mu\text{gL}^{-1}$  and  $25.93 \mu\text{gL}^{-1}$ ) and DDE ( $12.04 \mu\text{gL}^{-1}$  and  $7.69 \mu\text{gL}^{-1}$ ). Whereas, the concentration of total DD in soil samples was  $3.19 \text{ ng g}^{-1}$  and  $2.91 \text{ ng g}^{-1}$ . The concentrations of DDT and its metabolites, DDD and DDE, were in the range of  $0.6$ – $0.9 \text{ ng g}^{-1}$ ,  $0.08$ – $0.10 \text{ ng g}^{-1}$ , and  $0.58$ – $0.80 \text{ ng g}^{-1}$ , respectively as shown in Figure 4. The total HCH concentration in the leachate of the Ghabawi landfill was  $1.8 \mu\text{gL}^{-1}$  in Test1 and  $2.41 \mu\text{gL}^{-1}$  in Test2. The leachate of Test2 is mixed of five cells

in the leachate. The ( $\alpha$ - HCH) contributed by the highest concentration (73.33% and 87.55%) than  $\gamma$ -HCH (17.78% and 6.22 %) and  $\beta$ - HCH (8.89% and 6.22%) from the total concentration of HCHs. This is indicating on recent input of HCH into the study area. The concentration of HCB, Aldrin, Endrin and Dieldrin, Heptachlor, Heptachlor-oxo-epoxide, Heptachlor-endoperoxide, of the two tests in Ghabawi leachate are shown in Figure (3). It recorded (0.15 and 1.56  $\mu\text{gL}^{-1}$ ) for HCB, (0.63 and 0.22  $\mu\text{gL}^{-1}$ ) for Aldrin, (1.21 and 0.36  $\mu\text{gL}^{-1}$ ) for Endrin, (0.64 and 0.36  $\mu\text{gL}^{-1}$ ) for Dieldrin, (3.31 and 1.32  $\mu\text{gL}^{-1}$ ) for Heptachlor, (0.67 and 0.22  $\mu\text{g/L}$ ) for Heptachlor-oxo-epoxide, and (0.65 and 0.47  $\mu\text{gL}^{-1}$ ) for Heptachlor-endoperoxide. The leachate of Al-Ghabawi landfill is affected by wastewater discharge from liquid waste tanks that discharge its loading into the landfill area, in addition, empty containers of various types of pesticides that arrive at the landfill site from the domestic and commercial waste. The distribution of HCB, Aldrin, Endrin and Dieldrin, Heptachlor, Heptachlor-oxo-epoxide, Heptachlor-endoperoxide were in the same pattern in soil.



**Figure 3: Congeners of PCBs distributed according to chlorine substitution.**



**Figure 4: DDTs and their metabolites Practices**

Through field visits and observations, it was found that most of the workers were not wearing personal equipment and they were suffering from unpleasant odors emitted from the landfill.

### Discussion

The order of PCBs congeners was as follows: PCB189 and PCB169 > PCB77 > PCB167 > PCB157, PCB81, PCB126 and PCB156 > PCB123 and PCB105 > PCB118 > PCB114. The PCBs compounds with 4, 5, 6, and 7 chlorine atoms were dominating in the leachate of the Ghabawi landfill (Figure 2.). The concentration of PCBs ( $0.01\text{--}3.1 \mu\text{g L}^{-1}$ ) in the Ghabawi dump was reported to be lower than the PCB levels in leachates from municipal

waste landfills (Innocentia et al, 2019). There was a higher concentration of PCBs with 4, 5, 6, and 7 chlorine atoms in the raw sewage, which means that sewage purification does not remove PCBs. The same of targeted PCBs were detected in soil samples of the Ghabawi landfill (Figure 2). It was distributed according to this order: PCB167 > PCB189 > PCB169 > PCB157 > PCB126, PCB156, PCB105, PCB81 and PCB123 > PCB81, PCB114, and PCB118. The PCBs in the amount PCBs

congers in two tests ranged between (0.81–1.70) (Figure 2). The presence of tetrachlorobiphenyls (PCB77 and PCB 81), pentachlorobiphenyls (105, 114, 118, 123, and 126), and hexachlorobiphenyls (PCB156, PCB157 and PCB167 and PCB 169) suggest a contribution from the commercial mixtures, which have been widely used in transformers, electrical equipment, and other industries in several countries (Barakat et al., 2002). Moreover, the additional sources of PCBs include local anthropogenic sources such as diesel-powered electrical generators and activities of both repair and maintenance facilities (IARC 2016). The most abundant PCB congeners detected in groundwater samples were PCB77, PCB81, PCB81, PCB105, PCB114, PCB118, PCB123, PCB126, PCB156, PCB157, PCB167, PCB169 and PCB189 that are commonly found in environmental samples (Barakat et al., 2002).

The content of  $\sum$ PCBs in groundwater was as follows PCB114 (0.15), PCB 81 0.15, and PCB89 0.33 content was found in the year of 2020 (Figure 2). The order of congeners concentrations ( $\mu\text{gL}^{-1}$ ) was observed in this rank: PCB189 (0.33) > PCB169 (0.29) > PCB159 (0.21) and PCB169

(0.21), PCB156 (0.20) and PCB126 (0.18) > PCB123 (0.17) and PCB105 (0.17) > PCB123(0.16) and PCB77 (0.16) > PCB114 (0.15) and PCB 81 (0.15).

The concentrations of PCB189 and PCB169 were the predominant contaminant and occupied around 13.87% and 12.19% respectively of total PCBs detected in groundwater (Figure 2.). PCB congeners that are more toxic, such as PCB77, PCB81, PCB126, PCB169, and PCB105 (Fernández et al., 1999), were found at low amounts. The lack of the highly chlorinated congeners PCB128 and PCB187 and PCB194 indicate that no substantial PCB sources exist locally.

The presence of tetrachlorobiphenyls (PCB77 and PCB81), pentachlorobiphenyls (PCB105, PCB114, PCB118, PCB123, and PCB126), and hexachlorobiphenyls (PCB156, PCB157, and PCB167 and PCB169) were in agreement with (Brajnović et al., 2018) in their study on the levels of polychlorinated biphenyls in human milk samples in European countries. In addition, other anthropogenic sources of PCBs in the research region include diesel-powered electrical generators, as

well as operations of both repairing facilities and maintenance operations. When distributing representative PCBs congeners as chlorination levels (Figure 3), the Hexachlorobiphenyl (6Cl), Trichlorobiphenyl (3Cl), Pentachlorobiphenyl (5Cl) are dominant in the analysis of both 2019 and 2020. The raising of percent of the High Homolog (High-Molecular-Weight (HMW) of PCBs (52.10%) in the water samples means low degradation of the HMW in the environment. The Low Molecular-Weight (LMW) (4Cl and 5Cl) and HML 6Cl and 7Cl were degraded from the leachate and appeared in small amount in soil and groundwater, respectively.

Dichloro Diphenyl Ethylene (DDE) was recorded as the least content from the total Dichloro Diphenyl Trichloroethane (DDTs) (0.19 and 0.17 ng g<sup>-1</sup>) for Test1 and Test2 respectively, followed by DDT (1.5 and 1.28 ng g<sup>-1</sup>) and DDE (1.5 and 1.46 ng g<sup>-1</sup>) in simple variation (Figure 4). According to Yuan et al., (2001), the ratio of  $\sum (DDD + DDE) / \sum DDT > 2$  indicated an “aged” mixture, but the ratio of Ghabawi soil test on 2020 was  $< 1.20$ . This may be attributed to slow degradation or recent input in the study area. The dominance of DDDs in soil samples (48.52.00%)>

DDT (45.57%) > DDE (5.90%).

In water samples, the concentration of total DDT ( $\mu\text{gL}^{-1}$ ) ranged from 0.25  $\mu\text{gL}^{-1}$  in the environmental Social Impact Assessment (ESIA) that measure in (Ghabawi Well) value to 1.94  $\mu\text{gL}^{-1}$  in 2020. DDT and its metabolites, DDD and DDE, were found in amounts ranging from 0.06 to 1.12, 0.13 to 0.56, and 0.06 to 0.26, respectively. DDE, DDE, and DDT were the DDTs with the least amount of content. According to Alimi 2008, in the measurement of SEIA of Ghabawi well (13.17), the ratio of  $(DDD + DDE)/PDDT > 2$  indicated an “aged” combination, whereas the ratio of Ghabawi well test on 2020 was 0.73 (Figure 4). This might be due to the study area’s sluggish decline or recent input. In these sediments, the preponderance of DDDs over DDEs (52.00 % and 28.87 % of total DDT) implies reductive dechlorination of DDTs to DDDs under anaerobic conditions (Al-Alimi 2008).

The total Hexachlorocyclohexane (HCH) concentration in the Ghabawi well test1 and the test2 in 2020 were 0.11  $\mu\text{g/L}$  and 0.39  $\mu\text{g/L}$  respectively. The ( $\gamma$ -HCH) recorded the highest concentration than Beta ( $\beta$ ), Figure (3) showed Gamma ( $\gamma$ - HCH) contributed by the highest

percentage (45.45%) of total HCHs, Alpha ( $\alpha$ ) HCH 27.27% and Beta HCH 27.27% in the SEIA of Ghabawi well test and 58.97%, 23.08% and 17.95% in test of Ghabawi well in 2020 respectively. In the samples, the isomeric makeup of HCHs was not consistent; % $\beta$ -HCH% was always lower than % $\gamma$ -HCH% and % $\alpha$ -HCH% isomers. Because both the  $\alpha$ - HCH and  $\gamma$ - HCH isomers are more volatile, these molecules may be transported over great distances (Sarkar et al., 1997). The findings of HCH point to recent input into the research area's ecosystem. The results of HCHs isomers were equal to or exceeding the highest standards. In general, the OCPs were degraded in different ratios from the leachate and appeared in small amounts in soil and groundwater.

### **Conclusion:**

There are some PCBs congeners that appeared in the environment of the landfill such as PCB77, PCB81, PCB105, PCB114, PCB118, PCB123, PCB 126, PCB156, PCB157, PCB167, PCB169, and PCB189. In addition, Dichloro diphenyl trichloroethane (DDTs) and related compounds, (DDD) and (DDE) and (DDT) were detected in different percentages that an "aged" mixture and recent input.

**Recommendations:** POPs regulations and control measures should be enforced to protect human health and the environment. Ensure safe and sound disposal methods for the waste containing POPs. Authorities should consider following the technical guidelines for disposal of POPs under Article 6 of the "Stockholm Convention on Persistent Organic Pollutants" as Alkali metal reduction, Base-catalyzed decomposition or Hazardous-waste incineration. Those procedures emphasize the final destruction of POPs or irreversibly transformed, so no longer have the characteristics of POPs. The present study recommends making use of recyclable waste, economically, and creating new job opportunities. Treat the organic wastes before decomposition to reduce the emission of unpleasant odor (methane gases and sulfur dioxide). In addition, workers should adhere to safety instructions and encourage them to wear personal protective equipment.

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### **Conflict of Interest**

The authors declared that there was no conflict of interest.

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