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## Water quality, human health risk, and pesticides accumulation in African catfish and Nile tilapia from the Kitchener Drain-Egypt

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Pesticides are toxic and could negatively impact humans and the ecosystem. The Kitchener Drain is among the longest drains in Egypt and carries a wide range of wastewater from the agriculture sector, which contains pesticides and may pollute the ecosystem. Thus, water quality, human health risk, and pesticide accumulation in African catfish and Nile tilapia from the Kitchener Drain-Egypt. The water and fish samples were collected from Kitchener Drain in Kafr Elsheikh Governorate, Egypt, during the four seasons. The results indicated that heptachlor and diazinon were undetected during the four seasons. However, endosulfan, chlorpyrifos, and dicofol were detected in winter and autumn. Only p,p'-DDT was detected during spring. Endosulfan, heptachlor, and aldrin were detected in Nile tilapia during winter. Only heptachlor and aldrin were detected during spring. Endosulfan, heptachlor, dicofol, p,p'-DDT, chlorpyrifos, and diazinon were detected in the autumn season. In summer, dicofol and p,p'-DDT were detected, while endosulfan, heptachlor p,p'-DDT, aldrin, chlorpyrifos, and diazinon were not detected. In African catfish, endosulfan, heptachlor, dicofol, and p,p'-DDT were detected during winter, while chlorpyrifos, aldrin, and chlorpyrifos, aldrin, and diazinon were not detected. In the spring season, endosulfan, heptachlor, and aldrin were detected. Endosulfan, heptachlor, dicofol, p,p'-DDT, aldrin, chlorpyrifos, and diazinon were detected in the autumn season. Similarly, in the summer season, endosulfan, heptachlor, dicofol, p,p'-DDT, aldrin, chlorpyrifos, and diazinon were detected. The sequence of estimated daily intake (EDI) in Nile tilapia during the four seasons is heptachlor > endosulfan > dicofol > p,p'-DDT > aldrin > diazinon > chlorpyrifos. The sequence of EDI in African catfish during the four seasons is endosulfan > p,p'-DDT > heptachlor > aldrin > dicofol > diazinon > chlorpyrifos. In conclusion, the results confirmed the absence of a hazard index for consuming Nile tilapia and African catfish collected from the Kitchener drain.

A considerable number of pesticides and insecticides are used in the agriculture sector<sup>1</sup>. Directly or indirectly, these toxicants' derivatives reach the water bodies and induce negative impacts on the ecosystem<sup>2</sup>. Many studies tackled the impacts of accumulated pesticides and their derivatives on water drains, sediments, and living organisms, especially fish<sup>3</sup>. The hazards of water pollution with pesticides affect human health since accumulated derivatives could reach the human body through the water or fish as food<sup>4</sup>. Fish are utilized as bioindicators in case of high pollution in the water bodies due to their low digestion capacity for the accumulated pesticides<sup>5-7</sup>. Pesticides and toxicants can accumulate in the fish's body through the gills, skin, and intestines<sup>8</sup>.

Pesticides are known for their toxic effects on humans and the ecosystem due to their long persistence, high bioaccumulation capacity, and long-range transport<sup>9</sup>. Organochlorine and organophosphorus pesticides are heavily used in agriculture, and their derivatives could pollute the water bodies and cause severe impacts<sup>10</sup>. Besides, organochlorine and organophosphorus compounds are known for their toxic effects on humans and the ecosystem due to their long persistence, high bioaccumulation capacity, and long-range transport<sup>9</sup>. Further, the sediments and some fish species, such as Nile tilapia and African catfish, are rich in organochlorine and organophosphorus derivatives and may have human health risk<sup>11,12</sup>. One of the famous drains in the northern area

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of Egypt is the Kitchener drain which collects water from the agricultural and industrial sectors<sup>13</sup>. More specifically, the existing section of the Kitchener drain in Kafrelsheikh governorate, which is famous for agriculture and fish farming activities. Nile tilapia is a known species worldwide and can grow under farming conditions or in the wild<sup>14</sup>. Another well-known fish species, famous for its delectable taste, is the African catfish which prefers to live in the bottoms of water bodies. This results in a high possibility of organochlorine and organophosphorus accumulation through the sediments<sup>15</sup>. Both fish species thrive in the Kitchener drain and can be captured to be introduced into the human food chain. Therefore, the human food chain is expected to get polluted with pesticide derivatives through the water and fish. Hence, this study was conducted to test the presence of organochlorine and organophosphorus in the Kitchener drain using Nile tilapia and African catfish as bioindicators. Further, the pesticides were tested in the muscles of Nile tilapia and African catfish, as well as the human risk assessment.

Pesticide pollution is increasingly spreading, especially in developing countries, due to the lack of awareness and regulations<sup>16</sup>. Egypt is famous for agricultural activity, which depends on using a wide range of pesticides. Nevertheless, enormous amounts of pesticides threaten the water bodies, and consequently, their waste pollutes the drainage water<sup>17</sup>. Kitchener drain is a central drain that crosses through several vital crowded cities in the Delta area. Its water is full of pesticides and industrial waste that can reach the human food chain and cause severe health risks<sup>11, 18</sup>. The aquatic system is also expected to suffer from the pollution of pesticides that may accumulate in the fish's edible tissues<sup>19</sup>. The bioaccumulation of pesticides was detected earlier in some famous consumed fish species in Egypt, such as Nile tilapia and African catfish<sup>11, 12</sup>. Hence, this study tested the presence of organochlorine and organophosphorus in the Kitchener drain using Nile tilapia and African catfish as bioindicators. Further, the pesticides were tested in the muscles of Nile tilapia and African catfish and the human risk assessment.

## Materials and methods

### Site location and sampling

The Kitchener Drain is among the longest in Egypt, with a total of 69 km, and passes through three governorates in the Delta area (Dakahlia, Gharbia, and Kafr El-Sheikh). Forty-six kilometers of the Kitchener Drain is located inside Kafr El-Sheikh governorate before draining the water to the Mediterranean Sea. El-Burullus lagoon and surrounding areas located in Baltim city in Kafr El-Sheikh are famous for aquaculture-related activities where the water in Kitchener Drain is used for fish farming.

The samples were collected from Kitchener Drain in Kafr Elsheikh Governorate, between longitudes 31° 08' 25.6" E and latitudes 31° 18' 02.4" N (Fig. 1). Water and fish samples were collected from the Kitchener Drain during four seasons from April 2021 to March 2022. The samples were collected in May (spring), August (summer), November (autumn), and February (winter). Two fish species were collected from Kitchener Drain (Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*)) were collected. Fish was collected and kept in an ice box at 4 °C. Subsequently, water samples were collected 20 cm below the water surface and kept in sterile water containers while treated with 1 mL of HCL to eliminate microbial activity.



**Figure 1.** The sampling site for fish species and water samples were assessed in this study (Satellite image created by using Google Earth Pro version 7.3.0.3832 <https://www.neowin.net/news/google-earth-pro-7303832/>).

### Water samples and analysis

The collected water samples were filtered through 0.45 µm fiberglass filters (Whatman) to remove suspended materials. Water samples were collected and kept in 500 mL sterile plastic containers. After filtration, samples were stored in dark glass vials for GC determination. Water samples were divided into two parts, the first part for determining the water's physical parameters and the second part for analysis of pesticides.

The water samples were prepared and analyzed sequentially for endosulfan, heptachlor, dicofol, p,p'-DDT, aldrin, chlorpyrifos, and diazinon according to the extraction technique for aqueous matrix was carried out according to Edgell and Wesselman<sup>20</sup> to analyze semi-volatile and non-volatile organic compounds. Water samples (500 mL) were transferred into a 1.000 mL separatory funnel. The samples were extracted thrice with 100 mL portions of 1:1 (v/v) ethyl acetate dichloromethane. The separatory funnel was clapping for 30 min to allow phase separation. The combined organic phases were collected into a 500 mL beaker, with the aqueous phase discarded. The combined organic layer was dried from the aqueous substance with 20 g of anhydrous sodium sulfate and allowed to settle. The organic content was decanted into a 300 mL round bottom flask, and the content was evaporated to dryness using the rotary evaporator at 40 °C. The pesticide was dissolved and collected with 2 mL of ethyl acetate and transferred into a 2 mL vial to be ready for cleanup<sup>21</sup>.

### Fish samples and analysis

Two fish species (Nile tilapia and African catfish) were caught from the Kitchener drain during the four seasons (Table 1). Twelve fish specimens of each were collected per season, washed with deionized water, put in cleaned plastic bags, and stored frozen until analysis was carried out. A 20 g sample of fish muscles was weighed into a 150 mL conical flask, and then 20 g and 5 g of sodium hydrogen carbonate and anhydrous sodium sulfate were added, respectively. The fish samples were added to 100 mL of the 1:1 (v/v) ethyl acetate: dichloromethane combination mixed well by shaking the conical flask while it was corked. The conical flask's contents were then supplemented with 20 g of anhydrous sodium sulfate and 20 g of sodium hydrogen carbonate. The mixture was agitated vigorously for 10 min while tightly corked the conical flask. Three hours were given for the content to stand. The organic layer was evaporated at 40 °C after being decanted into a 200 mL round bottom flask. The pesticide in the rotary flask was dissolved, collected with 2 mL of ethyl acetate, and transferred into a 2 mL vial to be ready for the cleanup<sup>22</sup>.

### Assessment of human risk

The estimated daily (EDI) or weekly intake (EWI) of endosulfan, heptachlor, dicofol, p,p'-DDT, aldrin, chlorpyrifos, and diazinon by fish consumption were examined using the two equations below:

$$EDI = (C_m \times IR) / BW$$

$$EWI = EDI \times 7$$

where,  $C_m$  represents the organo-chlorine concentrations in fish samples (µg/g-ww); IR is the daily intake rate of fish (62.25 g/person/day) and BW is the average body weight (15 kg for a child, 40 kg for a youth, and 70 kg for an adult)<sup>23</sup>.

$$THQ = (EF \times ED \times IR \times C) / (RfD \times WAB \times ATn \times 10^{-3})$$

EF: the exposure frequency (days/year); ED: the exposure duration-years; IR: the ingestion rate -g/day; C: the metal concentration in fish (µg/kg); RfD: the oral reference dose (endosulfan = 0.006, heptachlor = 0.0005, dicofol = 0.0004, DDT = 0.0005, aldrin = 0.001, and chlorpyrifos = 0.0025) mg/kg/day; WAB: the average (kg) body weight, and ATn: the average exposure time (days/year × ED) for non-carcinogens.

The hazard index (HI) has been performed to assess the probable human health hazard of organochlorine and organophosphorus compounds. The HI refers to the sum of all THQ for various organochlorine and organophosphorus compounds exposures as shown in the equation below:

		Nile tilapia	African catfish
Winter	Weight (g)	235.74 ± 44.85	626.40 ± 167.03
	Length (cm)	22.36 ± 1.98	39.50 ± 5.10
Spring	Weight (g)	94.18 ± 26.38	366.53 ± 88.23
	Length (cm)	19.35 ± 2.37	32.87 ± 4.43
Autumn	Weight (g)	130.04 ± 46.19	374.03 ± 107.45
	Length (cm)	16.91 ± 1.23	33.95 ± 6.54
Summer	Weight (g)	205.57 ± 56.43	567.27 ± 167.41
	Length (cm)	15.85 ± 1.92	28.91 ± 5.67

**Table 1.** The weight and length of fish species were assessed in this study (derived from Metwally et al.<sup>7</sup>). Values (± SD) with a total number of 12 fish per season.

$$\text{HI} = \Sigma \text{TTHQs} = \text{THQ endosulfan} + \text{THQ heptachlor} + \text{THQ dicofol} \\ + \text{THQ DDT} + \text{THQ aldrin} + \text{THQ chlorpyrifos}$$

where  $\Sigma$  TTHQs is the target hazard quotients of all organochlorine and organophosphorus compounds; while, the hazard index becomes over 1, the possible human health risk is expected<sup>24</sup>.

### Consent to participate

The authors are informed and agree to the study.

### Ethical approval

The ethical committee of the Faculty of Aquatic and Fisheries Sciences, Kafrelsheikh University approved the experimental protocol and all methods in the present study for treating animals for scientific purposes. All experiments were performed in accordance with relevant guidelines and regulations. Our reporting of research involving animals follows the recommendations of the ARRIVE guidelines.

## Results and discussion

### Organochlorine and organophosphorus compounds in water samples

In this study, the water samples were collected from Kitchener Drain (Table 2), and the results indicated that the heptachlor and diazinon were not detected during the four seasons. However, the levels of endosulfan were  $29.7 \pm 2.48$  and  $11.4 \pm 1.48$  ppb during the winter and autumn, respectively. Dicofol was also detected in the water during autumn and summer at  $14.6 \pm 3.19$  and  $33.2 \pm 5.63$  ppb, respectively. Only the DDT was detected during spring and showed a value of  $10.8 \pm 1.25$  ppb. In summer, aldrin was only detected in the water samples at  $21.1 \pm 3.71$  ppb. Chlorpyrifos was detected during winter and autumn at  $12.1 \pm 1.91$  and  $68.7 \pm 7.83$  ppb, respectively but did not detect during spring and summer in the Kitchener drain. The results are comparable with Shalaby et al.<sup>15</sup>, who stated that the levels of endosulfan (18.6–40 ppb), heptachlor (22.8–47.1 ppb), dicofol (17.4–31.8 ppb), p,p'-DDT (25.8–88.3 ppb), and chlorpyrifos (37–53.8 ppb) were detected in the water samples collected from the river Nile during the four seasons. According to the European Water Framework Directive (WFD, 2000/60/EC)<sup>25</sup>, the detected pesticide levels in this study are not significantly harmful and toxic. Several factors affect the drainage water in big drains, such as the effluents of agricultural and industrial wastes and untreated sewage water<sup>26</sup>. Kitchener Drain receives drainage from several agricultural drains containing pesticides and insecticides<sup>13</sup>. Organochlorine and organophosphorus based pesticides are heavily used in agriculture, but their derivatives could pollute the water bodies and cause severe impacts<sup>10</sup>. The pesticides are applied in the agriculture sector, where the water runoff can affect the dilution of organochlorine and organophosphorus compounds<sup>3</sup>. Indeed, soil erosion and the level of suspended derivatives, including organochlorine and organophosphorus compounds, are strongly affected by rainfall events<sup>27</sup>. Hence, the high flood rate of water during the summer results in high dilution for the organochlorine and organophosphorus compounds<sup>15</sup> and, thereby, low presence in the water and fish samples.

### Organochlorine and organophosphorus compounds in fish muscles

Table 3 shows the levels of analyzed organochlorine and organophosphorus compounds in Nile tilapia and catfish collected from the Kitchener drain during four seasons.

In Nile tilapia, endosulfan ( $15.2 \pm 4.15$  ppb), heptachlor ( $16.4 \pm 5.15$  ppb), and aldrin ( $14.03 \pm 2.65$  ppb) were detected during the winter season. Only heptachlor ( $20.8 \pm 4.87$  ppb) and aldrin ( $12.2 \pm 1.9$  ppb) were detected in Nile tilapia during spring. In the autumn season, endosulfan ( $35.6 \pm 6.95$  ppb), heptachlor ( $6.3 \pm 1.73$  ppb), dicofol ( $21.3 \pm 6.53$  ppb), p,p'-DDT ( $15.3 \pm 5.56$  ppb), chlorpyrifos ( $10.8 \pm 3.92$  ppb), and diazinon ( $17.5 \pm 4.53$  ppb) were detected in Nile tilapia. In summer, dicofol ( $24.3 \pm 5.92$  ppb) and p,p'-DDT ( $16.6 \pm 3.42$  ppb) were detected, while endosulfan, heptachlor p,p'-DDT, aldrin, chlorpyrifos, and diazinon were not detected in Nile tilapia. In line with the current study, Shalaby et al.<sup>15</sup> stated that pesticides were also detected in tilapia collected from the river Nile, Cairo, Egypt, during the four seasons. Generally, the levels of endosulfan showed the highest detected pesticides with a total of 50.8 ppb in Nile tilapia during the four seasons, which is within the permitted levels as indicated by FAO<sup>28</sup>. Endosulfan is commonly used in agriculture, but the high accumulated levels cause

Pesticides	Winter	Spring	Autumn	Summer
Endosulfan	$29.7 \pm 2.48$	ND	$11.4 \pm 1.48$	ND
Heptachlor	ND	ND	ND	ND
Dicofol	ND	ND	$14.6 \pm 3.19$	$33.2 \pm 5.63$
p,p'-DDT	ND	$10.8 \pm 1.25$	ND	ND
Aldrin	ND	ND	ND	$21.1 \pm 3.71$
Chlorpyrifos	$12.1 \pm 1.91$	ND	$68.7 \pm 7.83$	ND
Diazinon	ND	ND	ND	ND

**Table 2.** Organochlorine and organophosphorus pesticides in the collected water samples (ppb) from Kitchener Drain during the four seasons. Values ( $\pm$  SD) (n = 3). ND Not detected.

Fish	Season	Endosulfan	Heptachlor	Dicofol	p,p'-DDT	Aldrin	Chlorpyrifos	Diazinon	Total
Nile tilapia	Winter	15.2±4.15	16.4±5.15	ND	ND	14.03±2.65	ND	ND	45.63
	Spring	ND	20.8±4.87	ND	ND	12.2±1.9	ND	ND	33
	Autumn	35.6±6.95	6.3±1.73	21.3±6.53	15.3±5.56	ND	10.8±3.92	17.5±4.53	106.8
	Summer	ND	ND	24.3±5.92	16.6±3.42	ND	ND	ND	40.9
Total		50.8	43.5	45.6	31.9	26.23	10.8	17.5	
African catfish	Winter	19.21±3.95	10.93±1.68	9.6±1.23	10.10±1.63	ND	ND	ND	49.84
	Spring	21.3±3.95	10.6±1.51	ND	ND	8.23±3.1	ND	ND	40.13
	Autumn	10.70±2.65	13.85±2.64	5.5±1.71	21.50±6.54	16.51±4.96	4.70±0.7	6.6±0.073	79.36
	Summer	13.60±3.61	2.60±0.7	10.65±2.85	5.70±0.83	11.6±4.18	3.30±0.02	11.80±1.31	59.25
Total		64.81	37.98	25.75	37.3	36.34	8	18.4	
Permitted levels	FAO <sup>28</sup>	100–200	200	–	500	200	1000	200	–
	USFDA <sup>29</sup>	–	300	–	300	300	–	–	–
	CFIA <sup>30</sup>	–	5	–	5000	100	–	500	–
	FSANZ <sup>31</sup>	–	5	–	1000	100	–	500	–

**Table 3.** Organochlorine and organophosphorus pesticides in the muscle samples (ppb) of Nile tilapia and African catfish from Kitchener Drain during the four seasons. Values ( $\pm$  SD) ( $n = 3$ ). *ND* Not detected.

endocrine disruption involved in fish growth and development. The detected heptachlor is 43.5 ppb which is within the permitted levels as reported by FAO<sup>28</sup> and USFDA<sup>29</sup>, while it is over the permitted levels reported by CFIA<sup>30</sup> and FSANZ<sup>31</sup>. The total detected p,p'-DDT (31.9 ppb), and aldrin (26.23 ppb) during the four seasons are within the accepted levels as indicated by FAO<sup>28</sup>, USFDA<sup>29</sup>, CFIA<sup>30</sup>, and FSANZ<sup>31</sup>. Chlorpyrifos showed a total of 10.8 ppb during the four seasons, which is considered a safe level as indicated by FAO<sup>28</sup>, while diazinon showed a total of 17.5 ppb, which is also safe compared to the reports of FAO<sup>28</sup>, CFIA<sup>30</sup>, and FSANZ<sup>31</sup>. It is worth noting that the highest organochlorine and organophosphorus compounds have been detected in Nile tilapia in autumn (106.8 ppb), followed by winter (45.63 ppb), then summer (40.9 ppb) and spring (33 ppb), respectively. This might be as a result of the high hydrophobicity and lipophilicity of these compounds as well as their potential retention in organisms' organic phases<sup>32</sup>.

In African catfish, endosulfan (19.21±3.95 ppb), heptachlor (10.93±1.68 ppb), dicofol (9.6±1.23 ppb), and p,p'-DDT (10.10±1.63) were detected during the winter season while chlorpyrifos, aldrin, and diazinon were not detected. In the spring season, endosulfan (21.3±3.95 ppb), heptachlor (10.6±1.51 ppb), and aldrin (8.23±3.1 ppb) were detected in African catfish. In the autumn season, endosulfan (10.70±2.65 ppb), heptachlor (13.85±2.64 ppb), dicofol (5.5±1.71 ppb), p,p'-DDT (21.50±6.54 ppb), aldrin (16.51±4.96 ppb), chlorpyrifos (4.70±0.7 ppb), and diazinon (6.6±0.073 ppb) were detected in African catfish. Similarly, in the summer season, endosulfan (13.60±3.61 ppb), heptachlor (2.60±0.7 ppb), dicofol (10.65±2.85 ppb), p,p'-DDT (5.70±0.83 ppb), aldrin (11.6±4.18 ppb), chlorpyrifos (3.30±0.02 ppb), and diazinon (11.80±1.31 ppb) were detected in African catfish. The analyzed pesticides are in line with Shalaby et al.<sup>15</sup> who stated that pesticides derivatives were detected in African catfish collected from the river Nile, Cairo, Egypt, during the four seasons. In the same manner as Nile tilapia, endosulfan showed the highest detected level (64.81 ppb) in African catfish during the four seasons but still within the permitted levels, as reported by FAO<sup>28</sup>. The detected heptachlor is 37.98 ppb which is within the permitted levels as reported by FAO<sup>28</sup> and USFDA<sup>29</sup>, while it is over the permitted levels reported by CFIA<sup>30</sup> and FSANZ<sup>31</sup>. The total detected p,p'-DDT (37.3 ppb), and aldrin (36.34 ppb) during the four seasons are within the accepted levels as indicated by FAO<sup>28</sup>, USFDA<sup>29</sup>, CFIA<sup>30</sup>, and FSANZ<sup>31</sup>. Chlorpyrifos showed a total of 8 ppb during the four seasons, which is considered a safe level as indicated by FAO<sup>28</sup>, while diazinon showed a total of 18.4 ppb, which is also safe compared to the reports of FAO<sup>28</sup>, CFIA<sup>30</sup>, and FSANZ<sup>31</sup>. The detected pesticides in African catfish followed the sequence of autumn (79.36 ppb) > summer (59.25 ppb) > winter (49.84 ppb) > spring (40.13 ppb). Shalaby et al.<sup>15</sup> reported similar results where the pesticides residues showed the same manner (autumn > summer > winter > spring) in African catfish and tilapia collected from the river Nile, Cairo, Egypt. Both fish species are potential targets for organochlorine and organophosphorus compounds accumulation from the pesticides polluted water. In African catfish, the high-fat content allows the soluble lipids organochlorine and organophosphorus compounds to accumulate massively in edible fish tissue causing severe pollution.

### Estimated organochlorine and organophosphorus pesticides

The accumulation of pesticides in fish affects the food chain through daily intake<sup>33</sup>. Hence, this study evaluated the estimated daily intakes (EDI) of pesticides in Nile tilapia and African catfish collected from the Kitchener drain. Several organizations report the permissible daily intake (PDI) of pesticides in fish to compare with EDI and predict the possibility of human risk<sup>34,35</sup>. The data in Table 4 indicates that the EDI of endosulfan (0–47.66 µg/kg BW/day), heptachlor (0–0.0018 µg/kg BW/day), dicofol (0–0.021 µg/kg BW/day), p,p'-DDT (0–0.013 µg/kg BW/day), aldrin (0–0.012 µg/kg BW/day), chlorpyrifos (0–0.009 µg/kg BW/day), and diazinon (0–0.015 µg/kg BW/day) in Nile tilapia collected during the four seasons. However, the EDI during the winter (for dicofol, p,p'-DDT, chlorpyrifos, and diazinon), during the spring (for endosulfan, dicofol, p,p'-DDT, aldrin, chlorpyrifos, and diazinon), during autumn (for aldrin), and during summer (for heptachlor, aldrin, chlorpyrifos, and diazinon) recorded 0 µg/kg BW/day. The sequence of EDI in Nile tilapia during the four seasons is

Fish	Season	Endosulfan	Heptachlor	Dicofol	p,p'-DDT	Aldrin	Chlorpyrifos	Diazinon
Nile tilapia	Winter	0.013	0.014	0	0	0.012	0	0
	Spring	0	0.018	0	0	0.010	0	0
	Autumn	0.047	0.05	0.018	0.013	0	0.009	0.015
	Summer	0.009	0	0.021	0.012	0	0	0
Total		0.069	0.082	0.039	0.025	0.022	0.009	0.015
African catfish	Winter	0.017	0.009	0.008	0.009	0	0	0
	Spring	0.018	0.009	0	0	0.007	0	0
	Autumn	0.009	0.012	0.004	0.019	0.014	0.004	0.005
	Summer	0.012	0.002	0.009	0.005	0.010	0.002	0.010
Total		0.056	0.032	0.021	0.033	0.031	0.006	0.015
PDI <sup>1</sup>		6	0.1		100	0.1		
PDI <sup>2</sup>			300			300		

**Table 4.** The estimated daily intakes (EDI) of pesticides ( $\mu\text{g}/\text{kg}$  BW/day) of Nile tilapia and African catfish from Kitchener Drain during the four seasons by adult people (70 kg per person). <sup>1</sup>Permissible daily intake (PDI,  $\mu\text{g}/\text{kg}$  bwt) according to codex Alimentarius<sup>34</sup>. <sup>2</sup>The PDI according to FDA tolerance or critical limit for human consumption of fish<sup>35</sup>.

heptachlor > endosulfan > dicofol > p,p'-DDT > aldrin > diazinon > chlorpyrifos. The results also indicate that the EDI in Nile tilapia collected from the Kitchener drain during the four seasons is lower than the PDI according to codex Alimentarius<sup>34</sup> and FDA<sup>35</sup> ( $\mu\text{g}/\text{kg}$  bwt). Further, the results are similar to Barakat et al.<sup>36</sup> and Shalaby et al.<sup>15</sup>, who stated that the EDI of Nile tilapia collected from Lake Qarun and Nile River in Cairo were not over the PDI.

In African catfish, the EDI of endosulfan (0.009–0.018  $\mu\text{g}/\text{kg}$  BW/day), heptachlor (0.002–0.012  $\mu\text{g}/\text{kg}$  BW/day), dicofol (0–0.009  $\mu\text{g}/\text{kg}$  BW/day), p,p'-DDT (0–0.019  $\mu\text{g}/\text{kg}$  BW/day), aldrin (0–0.014  $\mu\text{g}/\text{kg}$  BW/day), chlorpyrifos (0–0.002  $\mu\text{g}/\text{kg}$  BW/day), and diazinon (0–0.01  $\mu\text{g}/\text{kg}$  BW/day) during the four seasons. Nevertheless, the EDI during the winter (for aldrin, chlorpyrifos, and diazinon) and during the spring (for dicofol, p,p'-DDT, chlorpyrifos, and diazinon) recorded 0  $\mu\text{g}/\text{kg}$  BW/day. The sequence of EDI in African catfish during the four seasons is endosulfan > p,p'-DDT > heptachlor > aldrin > dicofol > diazinon > chlorpyrifos. The results also indicate that the EDI in African catfish collected from the Kitchener drain during the four seasons is lower than the PDI<sup>34</sup> and FDA<sup>35</sup>. Similarly, Shalaby et al.<sup>15</sup> stated that the EDI of African catfish collected from the Nile River in Cairo was not over the PDI.

In Nile tilapia or African catfish, the differences in the EDI during the four seasons can be altered by the surface runoff of water and levels of suspended pesticides. Concisely, the precipitation rate of pesticides may differ as a response to seasonality effects on the surface water runoff during rainy and dry seasons<sup>37</sup>. In addition, the consumed pesticides in agriculture is a season-dependent practice that may affect the presence of specific pesticide residuals in the surface waters<sup>38</sup>.

### Target hazard quotient

The values of the target hazard quotients (THQ) refer to the possible health risk for the pesticides, where a value over one indicates health risk<sup>39</sup>. In this study, the THQ for Nile tilapia and African catfish collected from Kitchener drain less than one in the case of all detected organochlorine and organophosphorus compounds during the four seasons (Table 5). Besides, the hazard index (HI) recorded less than one for all organochlorine and organophosphorus compounds in the Nile tilapia and African catfish collected during the four seasons. The results are in line with Shalaby et al.<sup>15</sup>, Barakat et al.<sup>36</sup>, and Abbassy et al.<sup>32</sup>, who stated that no hazardous effects for pesticides in the fish collected from Nile River in Cairo, Lake Qarun, and Edko lake, respectively.

Fish	Season	Target Hazard Quotient (THQ)							Hazard index (HI)	Human risk
		Endosulfan	Heptachlor	Dicofol	p,p'-DDT	Aldrin	Chlorpyrifos	Diazinon		
Nile tilapia	Winter	0.0022	0.029	0	0	0.024	0	0	0.056	No
	Spring	0	0.036	0	0	0.021	0	0	0.058	No
	Autumn	0.0052	0.011	0.047	0.027	0	0.009	0.006	0.106	No
	Summer	0.0016	0	0.054	0.024	0	0	0	0.079	No
African catfish	Winter	0.002	0.018	0.021	0.017	0	0	0	0.060	No
	Spring	0.003	0.018	0	0	0.014	0	0	0.036	No
	Autumn	0.0015	0.024	0.012	0.038	0.029	0.004	0.002	0.112	No
	Summer	0.002	0.004	0.023	0.010	0.020	0.002	0.004	0.068	No

**Table 5.** Target hazard quotient (THQ) for pesticides in Nile tilapia and African catfish from Kitchener Drain during the four seasons.

Usually, health problems could emerge from the persistent pesticide accumulation in human body tissues due to consuming polluted fish<sup>32</sup>.

## Conclusion

The results concluded that endosulfan, heptachlor, dicofol, p,p'-DDT, aldrin, chlorpyrifos, and diazinon were detected in the water of Kitchener drain but in a season-dependent manner. It is worth noting that the highest organochlorine and organophosphorus compounds have been detected in Nile tilapia in autumn, followed by winter, then summer and spring. In addition, organochlorine and organophosphorus compounds were detected in African catfish following the sequence of autumn > summer > winter > spring. The estimated daily intake for all detected organochlorine and organophosphorus compounds was below the referenced permissible daily intake in Nile tilapia and African catfish. Besides, the results confirmed the absence of a hazard index for consuming Nile tilapia and African catfish collected from the Kitchener drain. However, future studies are suggested to confirm the results obtained by considering having more sampling sites along the Kitchener drain.

## Data availability

Data are available upon request from the corresponding author.

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### Author contributions

A.A.M.: Conceptualization, Supervision, Data curation, Formal analysis, Software, Writing—original draft, Writing—review & editing. M.M.K.: Conceptualization, Supervision, Investigation. M.A.O.D.: Investigation, Supervision, Writing—review & editing. All authors contributed equally to this manuscript.

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The authors declare no competing interests.

### Additional information

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