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A Heavy Metal Exposure Risk assessment Model to Migratory Birds and Human in Burullus Lake, Egypt.

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Abstract:

Studying migratory birds wintering stopover areas has a global concern. The contamination with heavy metals is one of the serious threats to birds in wetland ecosystem. In the present study, heavy metal exposure risk to birds in Burullus Lake was assessed. The concentrations of Cr, Ni, Pb, Cd, and Co in water, plant and fish were determined in 10 bird habitats. A heavy metals' exposure risk assessment model to migratory birds in Burullus Lake had been done. It showed that small waders, represented by dunlin, are exposed to higher doses and risk than the waterfowls, represented by mallard. Evaluation of this risk to migratory birds could not be done using water exposure doses only, but food exposure including plant and fish must be included. It is a priority to perform more efforts to reduce the serious contamination with Co and Ni. The risk for fish feeders can be summarized according to the following order: Co > Ni > Cd > Pb > Cr, while the risk for plant feeders is: Co > Ni > Cr > Cd > Pb. Health risk of heavy metal exposures was calculated using Target Hazard Quotient **(**THQ) and Hazard index (HI). Results showed that THQs for all metals were below the standard (<1), while HI values were lower than one except for Co and Cd. HI for these two metals are considered an appreciable hazard risk to human health. Therefore, it is recommended to analyze the heavy metal risk on a temporal basis.

Keywords: Birds, heavy metals, Ramsar, Burullus, Egypt.

Introduction:

Wetlands are considered as one of the most important ecosystem components that provide the essential requirement for livelihood, especially for birds and human. One of the major consequences of anthropogenic activities is the pollution of wetlands ecosystem especially contamination of heavy metals (Sayadi *et al*., 2010). Bioaccumulation and biomagnification of heavy metal can be achieved via food chain through inhalation, ingestion and skin contact (Yi *et al*., 2011; Tang *et al*., 2013) Continuous exposure to heavy metals can lead to sever physiological disorders, change in behaviour (Scheuhammer, 1987), affect the reproductive process and reduce the fitness (Jackson et al., 2011), which can lead to decline in population size. It has been proved that contamination with chromium (Cr), lead (Pb), or cadmium (Cd) cause embryonic development disorder in mallard duck (Kertész *et al*., 2006).

Examination of migrant's wintering stopover areas, especially wetlands, currently has a global concern (Cui *et al*., 2011; Salamat *et al*., 2014). From ecotoxicological point of view, determination of heavy metal exposure risk to migratory birds can provide information of overall habitat health (Dauwe *et al*., 2002; Lodenius and Solonen, 2013). The wide range of bird activities and mobility, leads to heavy metal transfer from one place to another through feces (Liang *et al*., 2015). Feces can deposit heavy metals at high level than food items (Morrissey *et al*., 2005). Little research has been done on heavy metal exposure risk to migratory birds in wetlands.

Past studies have shown remarkable heavy metal pollution in Burullus Lake (Chen *et al*., 2010; Khalil and El-Gharabawy, 2016; El-Badry and Khalifa 2017, El-Badry and El-Kammar, 2018; Shaheen *et al*., 2019). However, there is still data deficiency on heavy metal exposure risk to migrants in this important wintering habitat. This study was conducted to assess the exposure risk of heavy metal to migratory bird through food chain in a Ramsar site and one of globally important bird areas that is located in Egypt: Burullus Lake. An integrated risk model has been performed to evaluate heavy metal exposure to migratory birds in wetland ecosystem, considering water and food items like plants and fishes as exposure routes. This study gives a reliable and measurable tool for heavy metal exposure risk determination to migratory birds, avoiding injury of birds using the traditional methods of egg or feathers collection, especially for rare species that are hard to capture.

In this study, the prediction of heavy metal exposure risk to migratory birds in Burullus Lake was conducted. Mallard duck (*Anas platyrhynchos*), a representative for plant feeder and waterfowl group, and Dunlin (*Calidris alpina*), a representative for fish feeder and small waders group, were chosen for this model in the present study. Also, human health risks of heavy metals in tilapia fish were assessed and the non-carcinogenic and carcinogenic health risks to adults associated with eating fish were calculated.

Material and Methods:

1. Study Area

Burullus Lake, in the central part of Nile Delta between the two arms of Nile branches, with approximate coordinates of 31 º33' 0.379" N; 31 º6' 2.212" E and 31 º25' 38.233" N; 30 º34' 0.137" E (Fig. 1). It is connected with the Mediterranean Sea via Boughaz El-Burullus at its northeastern side. The total area is nearly 460 km^2; the water area represent 370 km^2 (Hereher *et al*., 2010) and the remaining area includes several islands inside the lake dominated mainly with reedbeds (*Pharagmitis australis*) which act as a main habitat for both migratory and resident birds, especially the song birds and waterbirds. The lake is 13 km in width and 53km long and the water depth varies from 0.5 to 2.5 m (Frihy and Dewidar, 1993). After Manzala Lake, Burullus Lake is considered as the second largest Nile Delta Lake. It is declared as a Ramsar site and is an Important Bird Area (IBA) (Sayoud *et al*., 2017). Delta lakes, including Burullus Lake, are located in the African-Eurasian flyway migration route and considered as important stopover and wintering habitats for migratory birds, especially waterbirds (Meininger and Atta, 1994; Green *et al*., 2002).

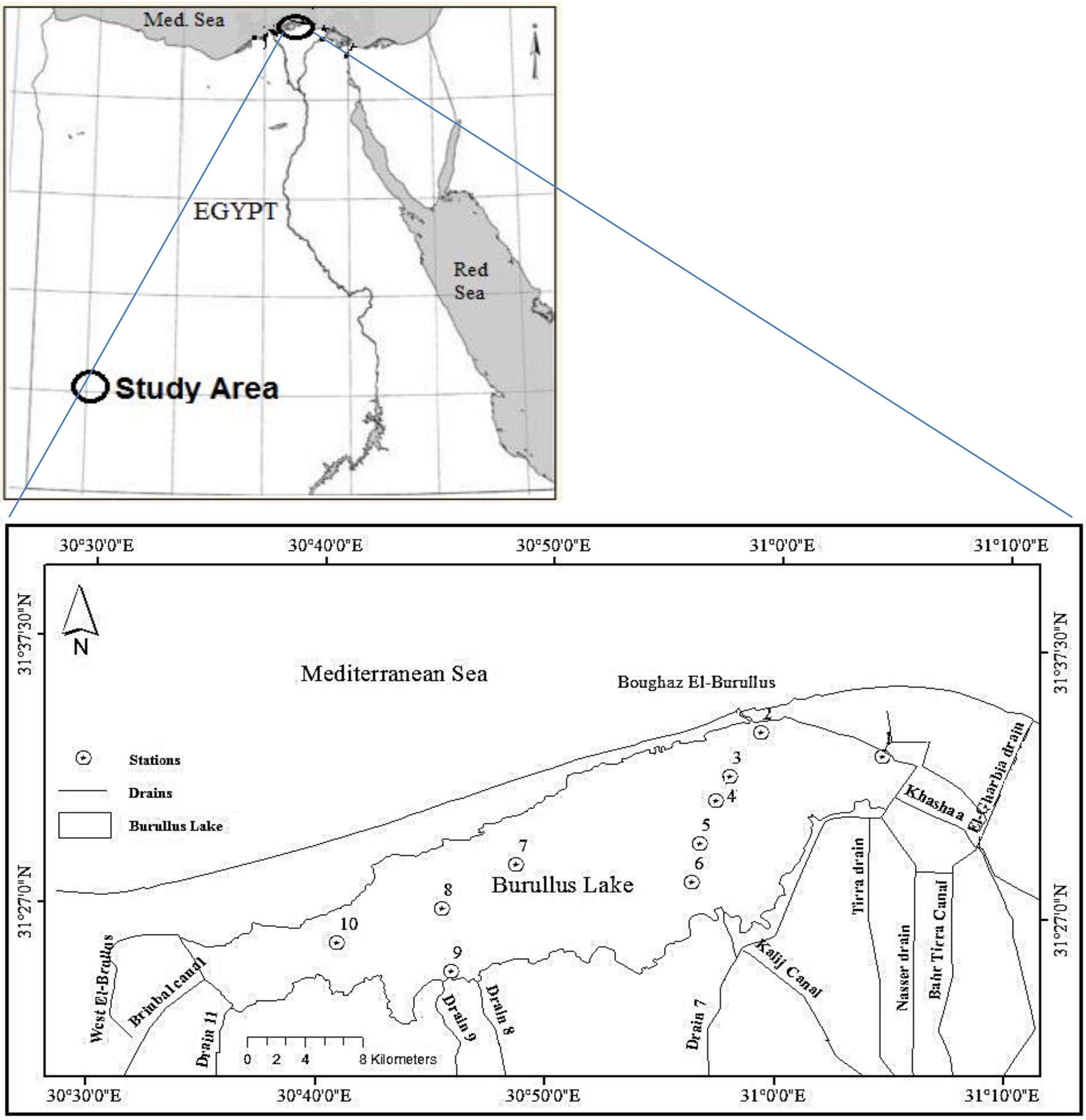

Fig (1): Studied sites location at Burullus lake.

2. Sample collection and analysis

Water, fish and plant samples have been collected from geo-referenced 10 main migratory habitats, mainly dominated with migratory birds (Fig. 1) in February 2017. Water samples were collected in 1L bottles, then acidified with 1 mL HNO_3 and stored at 4 ℃. Fish and plant samples have been collected from each site and stored for further analysis of their metal content.

2.1. Water

A volume of 750 ml of filtered water samples using 0.45 um membrane filters was used in extraction process of heavy metals in water. Solvents used in the experiment of extraction are ammonium pyrrolidine di-thiocarbamate (APDC) and methyl isobutyl ketone (MIBK). Water samples were pre-concentrated with APDC-MIBK extraction procedure as described by standard methods (APHA, 1989).

2.2. Plant

A known dry weight in grams of plant samples was added to Teflon beakers and digested with HNO3/H2O2 (3:1 v/v) at high temperature until evolution of nitrous gas had stopped and the digest became quite clear. The digests were diluted with distilled water up to a known volume (Allen et al., 1974).

2.3. Fish

Fish samples were homogenized, then 1g was weighed and transferred to 50 mL conical flasks. For digestion, samples were soaked overnight in a mixture of 10 ml (HNO_3/$HClO_4$, 9:1) and then digested at high temperature. After digestion, samples were diluted to 50 mL with deionized water and the solutions were filtered using filter paper (Türkmen and Ciminli, 2007).

The concentrations of Cr, Ni, Pb, Cd, and Co in water, plant and fish were determined by the Flame Atomic Absorption Spectrophotometer. Samples were measured in duplicates; blank and standard samples were analyzed for all samples. The results were expressed as µg L^{-1} for water and mg kg^{-1} for plant and fish.

3. Integrated exposure risk model calculation for migratory birds.

The exposure model risk model was calculated according to (Liu et al., 2015). This model is based on contamination exposure via oral ingestion from surrounding environment. The heavy metal risk to migratory birds was calculated as follows:

3.1. Food consumption rate (I_{df})

$$I_{df} = 0.648 * BW^{0.651}$$

Food is either plant or fish, BW: is the body weight which is 2000g for Mallard and 60g for dunlin.

3.2. Water consumption rate (I_w)

$$I_w = 59 * BW^{0.67}$$

3.3. Oral exposure dose (E_j)

Ej is the oral exposure dose of heavy metal (j) (mg kg^{-1}); m is the number of absorbing medium (for example: food, water or soil); Ii is the absorptivity of medium (i) (g $^{-1}$or mL^{-1}); and Cij is Concentration of metal (j) in medium (i) (mg kg^{-1}or mg L^{-1}).

$$E_j = \sum_{i=1}^{n} (I_i * C_{ij})/BW$$

4. Health risk assessment of heavy metals for Human

The health risk is associated with the consumption of the samples analyzed in this study. Values were assessed based on the estimated daily intake (EDI), Target hazard quotient (THQ) and carcinogenic risk (CR) of the heavy metals by using the equations stated below (Zhong, et al., 2018):

4.1. Estimated Daily Intake (EDI)

EDI of heavy metals is based on both of fish concentration of metals and average consumption of the fish samples. EDI is calculated according to the following equation:

$$\mathrm{EDI} = \frac{\text{concentration of metals} \times \text{Daily intake}}{\text{Average Body weight}}$$

Where: EDI is the Estimated Daily Intake; Average daily fish intake is 0.102 mg/Kg/day and average body weight is 60 kg; (Zhong *et al*., 2018).

4.2. Target hazard quotient

Target Hazard Quotient **(**THQ) is used to identify the risk of non-carcinogenic effects. It is assumed by dividing exposure to reference oral dose (RfD_{ing}). If the ratio is lower than one, it gives indication to the absence of metal health risk on the exposed population. if the ratio is equal to or more than one, exposed populations are prone to experience health risks.

THQ was calculated based on the equation below:

$$\mathrm{THQ} = \frac{\text{concentration of metals} \times \text{Daily intake}}{\text{RfDing} \times \text{Average Body weight}}$$

Where: THQ is target hazard quotient; RfD_{ing} is reference oral dose; Average body weight is 70 kg; Average daily fish intake is 0.102 mg/Kg/day (Zhong *et al*., 2018).

4.3. Hazard index (HI)

A total HI was employed by summing calculated THQ values of heavy metals as follows:

$$\mathbf{HI} = \sum_{i=1}^{n} THQ$$

4.4. Carcinogenic Risk (CR)

This factor generally assesses cancer risk associated with consumption of toxic substances. The carcinogenic factor is a function of the estimated daily intake and ingestion cancer slope factor (CSF_{ing}). The Ingestion Cancer Slope Factors evaluate the probability of an individual developing cancer from oral exposure to contaminants levels over a lifetime. Ingestion cancer slope factors are expressed in units of $(mg/kg/day)^{-1}$. Lifetime probability of contracting cancer due to exposure to site-related chemicals is calculated as follows:

$$\mathrm{CR} = \mathrm{EDI} \times \mathrm{CSFing}$$

Where: CR is carcinogenic risk; EDI is the estimated Daily Intake of each heavy metal (mg/kg/day); CSF_{ing} is the ingestion Cancer Slope Factor $(mg/kg/day)^{-1}$.

The standards used for these calculations are as shown in (Table 1). According to USEPA standards, 10^{-6} to 10^{-4} represent a range of permissible predicted lifetime risks for carcinogens. The risk associated with the carcinogenic effect of target metal is expressed as the excess probability of contracting cancer over a lifetime of 70 years (Zhong *et al*., 2018).

Results and Discussion

1. Heavy metal concentrations

The average concentrations of Cr, Ni, Pb, Cd, and Co in water, plant and fish are represented in (Table 2).

They take the following orders; Co>Ni>Cr>Pb>Cd, Co>Ni>Cr>Cd>Pb and Co>Ni>Cd>Pb>Cr for water, plant and fish, respectively.

Table (1): Toxicological characteristics of heavy metals in fish.

Metals	RfD_{ing}(mg/Kg/person/day)	CSF_{ing}(mg/Kg/day)
Cr	1.5	0.5
Cd	0.001	0.38
Pb	0.0035	0.0085
Ni	0.02	1.7
Co	0.02	-

Table (2): Average concentrations of heavy metals in water, plant and fish in Burllus Lake. "dw: dry weight".

	Water (ug L^{-1})	Plant (mg kg^{-1}, dw)	Fish (mg kg^{-1}, dw)
Cd	1.56±0.15	2.62±0.82	6.67±27.2
Ni	73.32±27.29	9.58±3.89	15.60±6.25
Co	106.46±29.02	17.65±4.38	44.06±11.06
Cr	4.1±1.69	4.35±1.27	4.94±0.78
Pb	2.69±0.24	1.71±0.65	6.59±2.06

2. Heavy metal exposure doses to migratory birds

The estimated exposure doses of Cr, Ni, Pb, Cd and Co for Mallard and Dunlin have been calculated (Fig 2). Dunlin demonstrated higher exposure doses than mallard. This result matched that of Liu *et al*. (2015), who concluded that the lighter the bird, the higher is the exposure risk. This was explained by Suter (2011) who found that oral exposure by small animals is higher than that of large animals due to their higher metabolic rate. Also, Fig. 2 shows that feeding on fish and plant had a remarkable accumulative effect on the exposure dose of migratory birds than if they were exposed to water only. So, evaluation of migratory birds' exposure risk cannot be done without evaluating the food items (fish and plant), and measuring heavy metals in water only cannot give indication of the real situation. Control of heavy metals in Burullus Lake should be taken in consideration in future strategy plans to conserve waders, waterfowl's bird groups and all other water birds in this place.

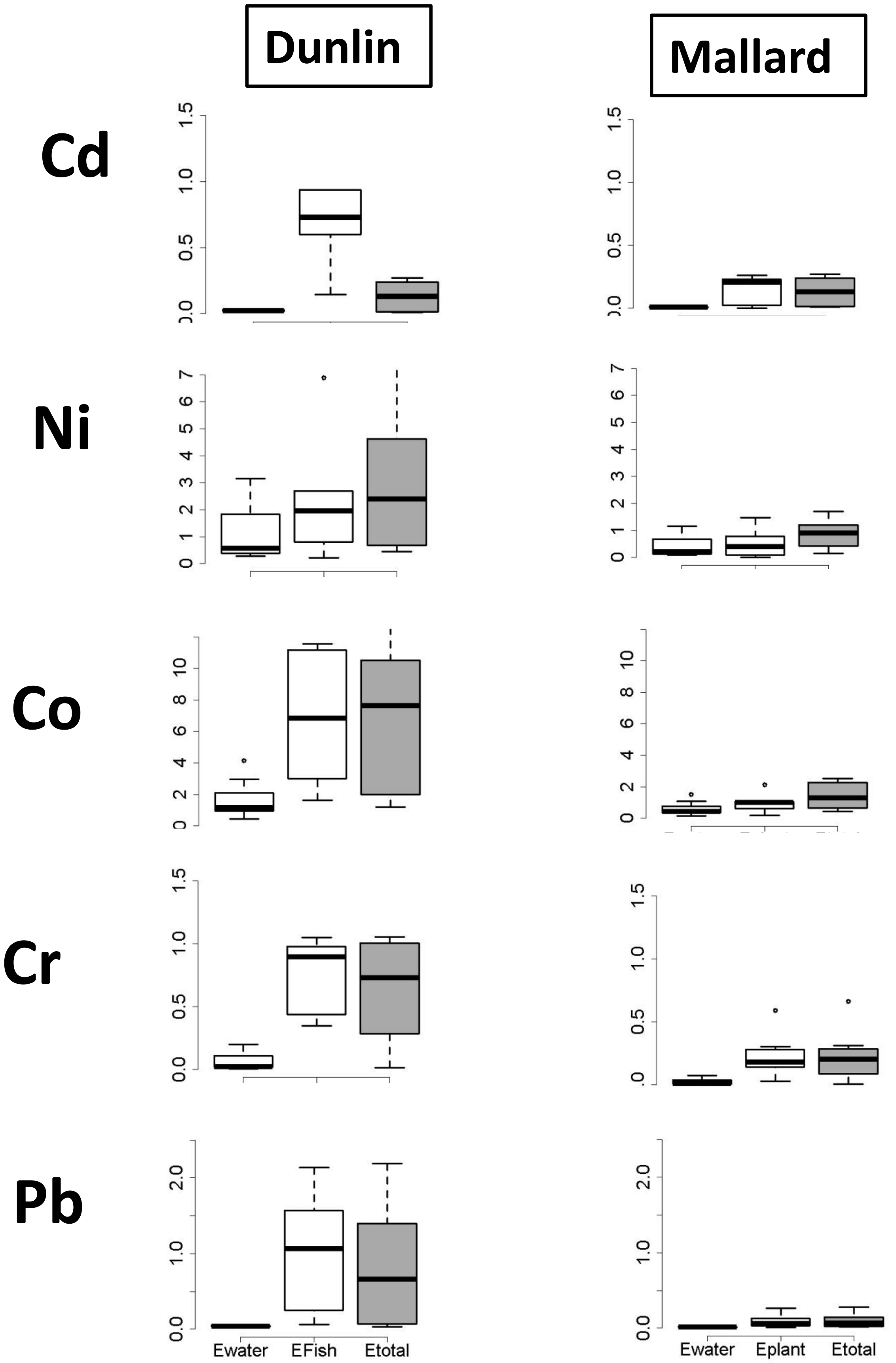

Fig (2): Water, plant, fish and total exposure doses of heavy metals to Dunlin and Mallard .
Efish: exposure dose by feeding on fish ; Eplant: exposure dose by feeding on plant; Etotal: exposure dose by both food and water.

3. Health risk assessment for Human

Heavy metals are considered the most important constituents of pollution from the environment due to toxicity and accumulation by organisms. The accumulation of these heavy metals in fish may represent a health risk, especially for populations with high consumption rates (Liao and Ling, 2003). Therefore estimated daily intake or 'tolerable intake' is widely used to describe 'safe' levels of intake of heavy metals. The estimated daily intakes (EDI) of heavy metals through consumption of Nile tilapia from Burullus Lake are shown in (Fig.3).

The trend of heavy metals EDI in all the samples can be arranged as Co>Ni>Pb>Cr>Cd. The EDI value is very much below the tolerable daily intake level (1.5 mg kg^{-1} BW/day) established by USEPA (2016) and FAO/WHO.

The EDI values are in agreement with that of Rahman *et al*. (2012) who reported that the daily intake in (mg/day/person) of metals Pb, Cd and Cr from fish in Bangshi River at Bangladesh is: 0.0203, 0.0013 and 0.0049, respectively. Taweel *et al*. (2013) recorded the daily intake of Cu, Pb and as for tilapia fish in Cempaka Lake (Bangi, Malaysia) as 4.55, 1.20 and 0.45 µg g-1/bw/day, respectively.

Our results indicate that there is no potential health risk for people who have a high consumption rate.

The estimated Target Hazard Quotient (THQ) of heavy metals through the consumption of Nile tilapia collected from Burullus Lake are shown in (Fig. 4). The THQs for all metals are below the standard THQ (<1), while HI values are lower than one may except for Co and Cd. HI for these two metals are considered as an appreciable hazard risk to human health. Nevertheless, this needs to be further examined in future studies.

A THQ below 1 means the exposed population is unlikely to experience obvious adverse effects; whereas a THQ above 1 means that there is a chance of carcinogenic effects, with an increasing probability as the value increases (Saha and Zaman, 2012).

THQ of all metals was less than 1, suggesting that people would not experience significant health risks from the intake of individual metals through consumption. However, Pb may be considered as one of the health risk contributors (Fig. 5). When the hazard index exceeds 1.0, there is concern for potential health effect (Huang *et al*., 2008) as exposure to more than one contaminant may produce an additive effect on the consumer.

Conclusion and recommendations

Measuring the metal content in two principal species like birds and fishes is important for the conservation of biodiversity. Also identifying the risk and calculating the adverse impact either "non or carcinogenic" may have impact for stakeholders in aiding to the conservation of the people's health. Based on the results, HI values are lower than one except for Co and Cd. These levels might be due to lack of anthropogenic inputs as there is no industrial activity around the lake.

Different exposure factors and risk analysis identify also the most contaminant in different biotic and abiotic components in the lake. This may aid in the management of this contaminant in further future solutions.

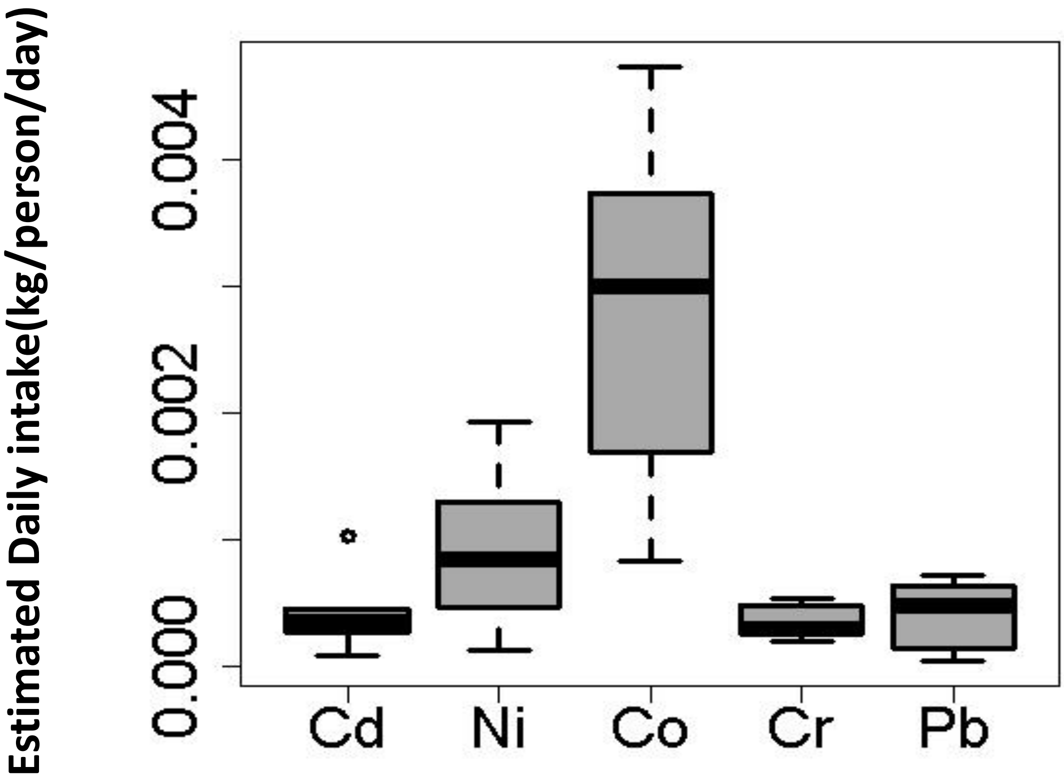

Fig (3): Estimated Daily Intake (EDI) (kg/person/day) of heavy metals through consumption of Nile *Tilapia* from Burullus Lake.

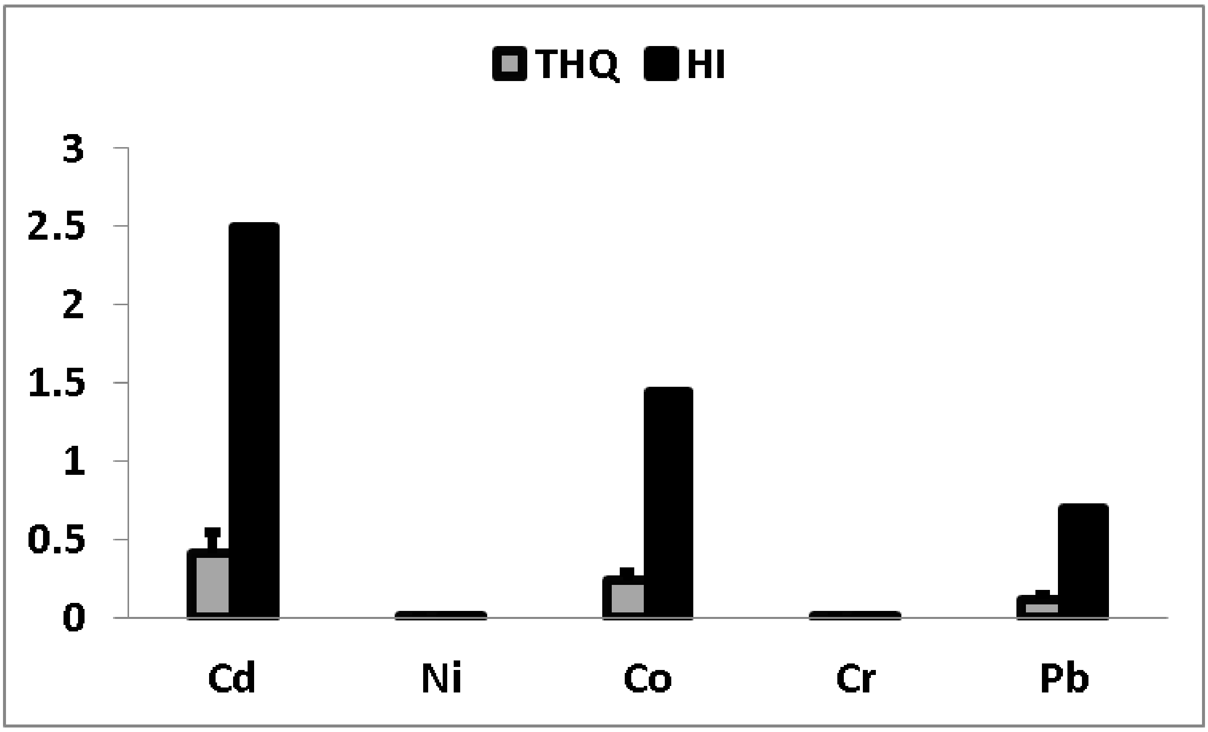

Fig (4): Target Hazard Quotients (THQ) and hazard index (HI) of heavy metals through consumption of Nile Tilapia from Burullus Lake.

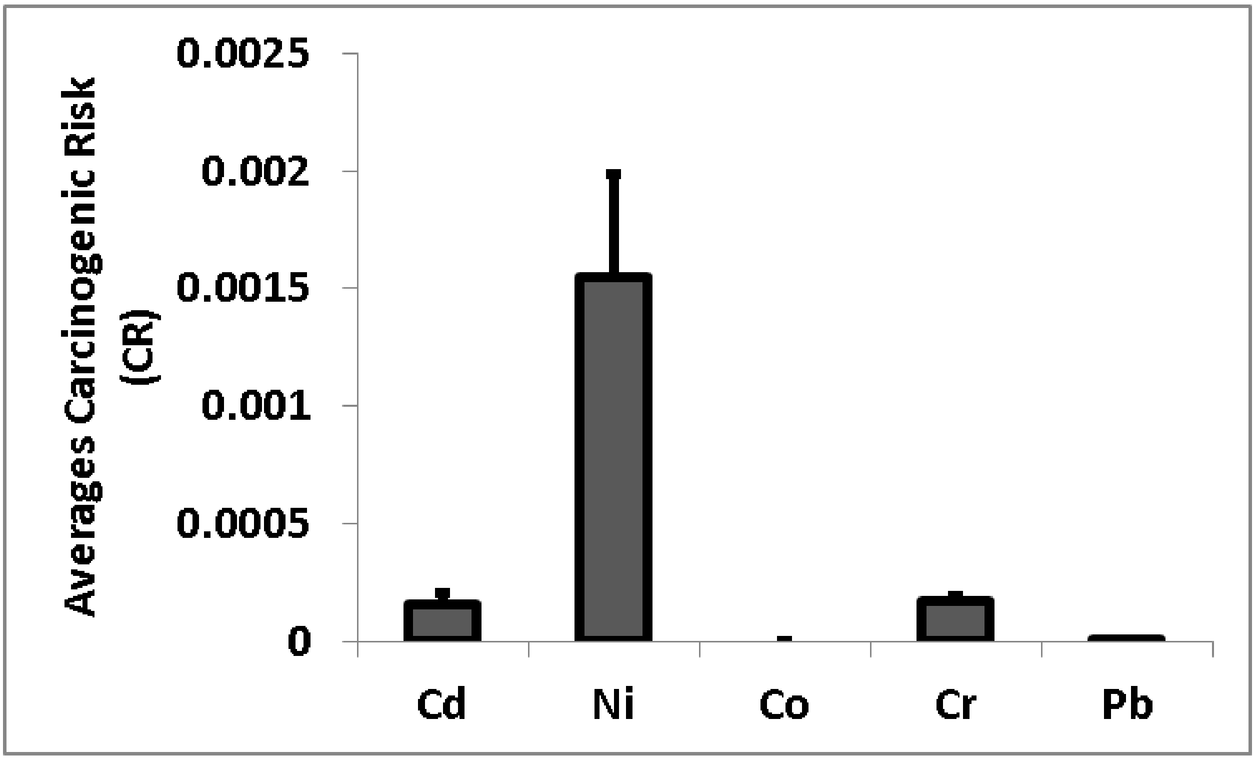

Fig (5): The averages Carcinogenic Risk (CR) of Cd, Cr, Ni, Co and Pb through the consumption of Nile Tilapia from Burullus Lake

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