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RESEARCH PAPER

# Baseline Concentration of Heavy Metals in Fish Collected from Gaza Fishing Harbor in the Mediterranean Sea along Gaza Coast, Palestine

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**Abstract**

The concentrations of manganese (Mn), copper (Cu), zinc (Zn), nickel (Ni), cobalt (Co), lead (Pb) and cadmium (Cd) in the muscles of grey mullet (*Mugil cephalus*) that were collected from Gaza fishing harbor and the surrounding areas were investigated in this study. Eight sampling locations were selected to conduct the study along the coast of Gaza. The samples were taken in September, November 2013 and March 2014. Heavy metals were identified and analyzed by Flame Atomic Absorption Spectrophotometer. The mean concentrations of heavy metals in soft tissues of fish were as follows: Mn:0.90 µg/g; Cu:13.15 µg/g; Zn:25.87 µg/g; Ni:1.10 µg/g; Co:0.68 µg/g; Pb:1.82 µg/g and Cd:0.27 µg/g, respectively. The highest concentrations of metals in fish tissues were found to be detected for zinc (13.56-40.43 µg/g) and the lowest were for cobalt (nd-2.93 µg/g) and cadmium (0.02-0.51 µg/g). The heavy metal concentrations in most fish samples were found to be below the acceptable limits proposed for fish by various international standards such as European Union (EU), World Health Organization (WHO), and Turkish guidelines (TFC). Therefore, it can be concluded that no risk on human health would be elevated at present from the consumption of fish collected from Gaza fishing harbor.

*Keywords:* Heavy metals, Pollution, Fish, Gaza fishing harbor, Mediterranean Sea.

## Introduction

The seawater and sediments in the fishing harbor along the coast of Gaza in the Mediterranean Sea are highly polluted by untreated sewage water discharged from about 17 sewage outfalls into the coastal water, according to some estimations, more than 90,000m³/day (Ashour *et al*., 2009). The pumping of sewage water into the sea causes a number of hazards to marine life; including phytoplankton, zooplankton, and crustacean, macro-algae and fish species. The main causes of these hazards are: biodegradable organics, refractory organics, dissolved in-organics, heavy metals, suspended solids, pathogens, nutrients, pesticides and the insecticides being used intensively in agriculture and some small-scale industries (MEnA, 2001).

Water contamination by heavy metals adversely affects marine life and poses significant environmental jeopardies and concerns (Cajaraville *et al.,* 2000; Ravera, 2001). Monitoring programs and investigations on the existence of heavy metals in marine water environments have increased significantly due to alarms over the accumulation of contaminants and toxic effects in marine organisms and to humans over the food chain (Otchere, 2003). Mackevičiene *et al.,* (2002) reported that contaminants can stay for several years in sediments of rivers and marine systems where they embrace the possible to affect human health and the surrounding environment. Sediments are an imperative basin of assortment of contaminants, predominantly heavy metals and may attend as a supplemented source for benthic organisms (Wang *et al.,* 2007) particularly in estuarine ecosystems.

Dissolved substances in the seawater along Gaza coast and fishing harbor however pose a threat not only to the marine ecosystem but also to the groundwater quality and may be dangerous to the humans by causing unpredictable human diseases. Accordingly, the food chain of marine ecology of Gaza is highly affected through several factors including: urbanization, industrialization, tourism, shipping and agricultural runoff. These factors are key to cause pollution of the marine environment and coastal waters along Gaza coast. Gaza fishing harbor is one of the areas being at risk of having high levels of heavy metal pollutants due to several activities. Through the food chain heavy metals including Pb, Cd, Zn, Mn, Cu and Hg in seawater, sediments, fish and other marine fauna may affect the health of human beings. Untreated sewage outfalls contain

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organic and inorganic toxic substances, such as nitrates and heavy metals. The quality of fishes caught near the shore of Gaza is not examined to identify the effects of sewage on fish health. There is also evidence of poorly looking fish near the sewage outlets at the beaches. More important is that the very young stages of fish (larvae and juveniles) grow up in the near shore zone, where the water quality is heavily affected by the raw sewage outfalls. This poses a severe threat to the fish populations of Gaza whereas many wastewater outfalls discharges untreated sewage into the sea (UNEP, 2009). Therefore, it is need to investigate the level of these heavy metals in the fishes collected from Gaza fishing harbor and surrounding areas along Gaza coastline.

Bioaccumulation means an increase in the degree of a chemical content in a living organism over time, compared with chemical's level in the environment. Heavy metals can be the reason of serious health effects with different signs depending on the nature and the amount of the metal consumed (Adepoju-Bello and Alabi, 2005). Liang and Wong (2003) documented that environmental contamination by heavy metals influences negatively human health. Their remediation ascertains to be difficult because of the persistence and non-degradability of heavy metals. The high level of heavy metals in marine species can be associated with high level in marine sediments. The accumulated metal contents in marine sediments can affect the distribution and composition of benthic groupings (Kress *et al.,* 2004) and this may be accompanying to high concentration noted in living organisms (Pempkowiak *et al.,* 1999). Hornberger *et al.,* (1999) revealed that human activities have significantly increased heavy metal deliveries to estuaries and bays. Because many metals are toxic to aquatic organisms at trace levels, even relatively small changes in their concentrations may have ecosystem-wide implications. Vernet (1991) reported that the environmental pollution with toxic metals is becoming a worldwide concern. As a result of the increasing concern with the possible effects of the metallic contaminants on human health and the environment, the research on essential, useful and health phases of trace metals in the environment is cumulative. Many of the heavy metals are toxic to organisms at low concentrations. However, some heavy metals, such as copper and zinc are also essential elements. Concentrations of essential elements in organisms are normally homeostatically-controlled, with uptake from the environment regulated according to healthful demand. Effects on the organisms are noticeable when this guideline mechanism breaks down as a result of either lacking (deficiency) or additional (toxicity) metal (Duffus, 2002).

Mourtaja (2008) investigated the concentrations of Zn, Cd, Pb and Cu in three marine fishes including: *Mugil cephalus*, *Barracuda* and *Sigan* species. In his study the average metals concentration found to be 4.675, 0.096, 2.606, 0.3743 (μg/g dry wt.) in Grey mullet, 6.050, 0.092, 2.618, 0.247 (μg/g dry wt.) in *Barracuda* and 6.258, 0.123, 2.389, 0.570 (μg/g dry wt.) in *Sigan*, respectively. Soegianto *et al.,* (2010) studied the accumulation of heavy metals in marine animals collected from coastal waters of Gresik in Indonesia. Results showed that the level of metals in all samples contained metals within the acceptable range for consumption. Yilmaz *et al.,* (2007) recorded heavy metal levels in two fish species including: *Leuciscus cephalus* and *Lepomis gibbosus*. The concentrations of metals were determined in muscle, gill and liver of these fishes collected from Saricay, South-West Anatolia. Khaled (2004) evaluated seasonal variations of some heavy metals in muscle tissue of two fish species collected from Alexandria coastal area along Egyptian coast. The concentrations of the selected heavy metals including: Cd, Cu, Fe, Mn, Ni, Pb and Zn were noticed seasonally in *Siganus rivulatus* and *Sargus* collected from El-Mex Bay and Eastern Harbor. Haung (2003) analyzed heavy metal concentrations in common benthic fishes. Zinc, copper, cadmium and lead concentrations were determined in muscle, gills, intestine and liver of twenty benthic fishes of the most common commercial fish caught from the coastal waters of eastern Taiwan. Canli and Atli (2003) studied heavy metal levels in six Mediterranean fish species and indicated correlation between metal accumulation and fish species habitat. Madany *et al.,* (1996) studied the trace metal concentrations in fish and shellfish samples collected from the coastal areas of Bahrain in the Arabian Gulf. Al-Mohanna (1994) determined the heavy metals level in various fish tissues collected from Red Sea coast of Jizan in Saudi Arabia.

This study is the first effort for investigating the level of heavy metals in fish species in Gaza fishing harbor area. In view of the potential risks to human being through the food chain and the surrounding activities at the Gaza coastline, it is important to constantly assess the pollution status of the marine ecosystem. Hence, this study provides information that is useful towards the status of heavy metals in fish species collected from Gaza fishing harbor and surrounding areas. Dissemination of these findings will be helpful to the main stakeholders or agencies that monitor environmental pollution such as Ministry of Health and Municipalities.

## Materials and Methods

### Study Area

To assess the level of heavy metals contamination in fish species collected from the coastal waters of Gaza Strip, however, Gaza fishing harbor and the surrounding areas in north and south of the harbor were selected as study area.

Gaza fishing harbor is located on the Mediterranean Sea at Gaza beach. The harbor was constructed between 1994 and 1998 (Figure1) on a traditional sandy beach supported by sand dunes. The length of the current main breakwater is 1,000 m and that of the protection breakwater is 300 m. The head of focal breakwater is at water depth of 9 m, and the entry of the harbor was 6 m deep when it was constructed. The entering of Gaza harbor is seaward from the shore to a distance of about 500 m (Abualtayef *et al.,* 2012).

**Samples Collection and Analysis**

To investigate the distribution of heavy metals in fish tissues (grey mullet) in the fishing harbor of Gaza, however, the data was collected from 5 sites in the vicinity of the harbor and two sites in the north and one site in the south of the harbor. This made the total number of sampling sites 8 during this study (Figure 1).

The sampling frequency during this study was three times started from September 2013 and ended on March 2014. The sampling was conducted in the months of September, November 2013 and March 2014.

Before analysis, the fish were thawed and the muscular tissues from dorsal, abdominal and tail regions of grey mullet were taken out and homogenized. Four grams of the homogenized muscles (without skin) were taken and placed in 300 ml Kjeldahl digestion tubes. A digestion mixture containing 5 ml of high purity nitric acid, 9 ml of hydrochloric acid (Aqua regia) and 5 to 15 ml of hydrogen peroxide was added to every tube (modified from Manutsewee *et al.,* 2007; Bernhard, 1976). The samples were then heated at 70-100°C by Kjeldahl heating digester until clear solution was achieved. After microwave digestion process was completed, the samples were cooled at room temperature, and then added with 25 ml of 2% of nitric acid and kept for two hours (Canli and Atli, 2003). The samples were then filtered through Whatman filter paper (No.42) and diluted to a final volume of 50 ml using deionized water. A Unicam Model 929 AA flame atomic absorption spectrometer with deuterium lamp and air-acetylene burner was used for the determination of heavy metal levels in all samples (Elmer, 1996).

At each step of the digestion processes, acid blanks (laboratory blank) were made using an identical procedure to ensure that the samples and chemicals used were not contaminated. They were analyzed by flame atomic absorption spectrometer before the samples and their values were deducted to guarantee that the apparatus read only the precise values of heavy metals. Every set of digestion has its individual acid blank and was rectified by using its blank.

The absorption wavelengths and detection limits for the heavy metals were respectively 279.5 nm and 0.02 mg/l for Mn, 324.8 nm and 0.033 mg/l for Cu, 213.9 nm and 0.01 mg/l for Zn, 232.0 nm and 0.05 mg/l for Ni, 240.7 nm and 0.06 mg/l for Co, 217.0 nm and 0.07 mg/l for Pb and 228.8 nm and 0.013 mg/l for Cd.

Direct method technique was used to determine the heavy metal levels in fish samples when the matrix is negligible. The calibration graph is normally linear at low absorbance value only and the samples were diluted to be with in this range. For each standard the measured absorbance value was plotted

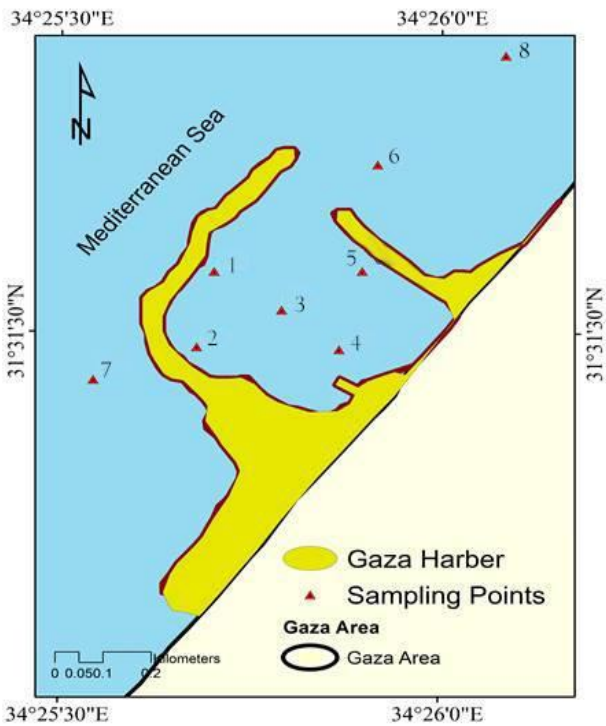


**Figure1.** Map shows sampling stations in Gaza fishing harbor.

against the known concentration of each metal. The samples concentration was calculated directly from the linear equation of the graph. For each metal, calibration range and coefficient of determination ($R^2$) values are given in Table 1.

**Quality Control and Assurance**

In this study, to check the efficiency of the digestion procedures and the subsequent recovery of the metal, homogeneous mixtures of five samples of fish muscles were picked up with multi element solution which consists of standard solutions for all metals considered in this study. The element solution was spiked in a mode to achieve ultimate concentrations of 1 and 4µg/g. In addition, a mixture without any metal was used for controlling purpose. All mixtures were prepared by the digestion method. The subsequent solutions were analyzed in triplicate for metal concentration consistent with the same procedures as the samples to make assurance in the accuracy and reliability of the achieved data. The amount of pointed metal recovered after the digestion of the spiked samples was used to calculate percentage recovery as follows: % recovery= [(t-c)/t] 100. Where t= concentration of a metal in treatment sample and c= concentration of a metal in control sample.

Procedural blanks and standard solutions were also included for analytical quality control to assure the precision and reproducibility of the results. The results of recovery test used for fish muscle samples are given in Table 2. The result of recovery test of various heavy metals found to follow the following order: Pb> Zn>Cu>Mn>Ni>Cd>Co. High recovery of samples ensure the accuracy and reproducibility of analytical method used for digestion purpose in present investigation.

**Statistical Analysis**

Mean concentrations ± S.E.M (the standard error of the mean) in µg/g wet weight, min, max and standard deviation were calculated. In addition the Pearson correlation coefficient (a measure of linear association) was used to detect significant variations of heavy metals among the samples. All statistical calculations were performed with Statistical Package for Social Sciences, IBM-SPSS Statistics V20.0 for Windows (IBM Corp, 2011).

## Results and Discussion

**Recovery Test**

Results from the recovery process showed good recoveries of spiked samples of ratios ranged from 93.33% to 99.80%, using solutions from 3 to 5 µg/g (Table 2). These values indicate an accuracy of analytical procedure.

**Distribution of Heavy Metals in Fish Species**

Results for the basic statistical analysis of heavy metals concentrations in muscle tissues of gray mullet during this study are discussed as follows and given in Table 3.

Manganese is a vital element for most of marine organisms. Some organisms such as, molluscs, sponges and diatoms, can accumulate manganese in their tissues. Fish species can have up to 5 µg/g and mammals up to 3µg/g in their soft tissues, although typically they have around 1µg/g due to its vital role in human health, however, excesses or lacks of manganese concentrations level can cause health effects (Wafi, 2015). The concentrations of Mn were ranged from 0.26 to 1.26 µg/g with a mean concentration of 0.90 µg/g. The proposed permissible limit of manganese concentrations in fish species as recorded by Turkish guidelines known as Turkish Food Codes (TFC) is about 20 µg/g (Dural *et al.*, 2007; Turkmen *et al.*, 2009; Yilmaz, 2009; TFC, 2002). In general it can be seen that the concentrations of Mn found in tissues of gray mullet in the present study are still considered as those of uncontaminated fish (<20).

Copper is a needed component that is judiciously controlled by biological mechanisms in the majority of organism species (Erdoğrul and Ates, 2006). Though, it poses possible risks that threaten both animal and human health. Cupper can be found in a natural environment and is important for the normal growth and metabolism of most living organisms (Eisler, 1998). In this study, the Cu concentrations were ranged from 3.01 to 17.47µg/g with a mean concentration of 13.15 µg/g. The proposed acceptable limits of Cu concentrations in fish species as recorded by FAO/WHO (1989), EU (2001) and Turkish guidelines (TFC) is about 30 µg/g, 10 µg/g and 20 µg/g, respectively (Yilmaz, 2009). In general it can be seen that the concentrations of Cu found in muscle tissues of grey mullet in the present study are still considered as those of uncontaminated fish (<20 , 10 and 30).

Zinc is an important element for many marine organisms and, as such, is readily bio- accumulated. Zn concentrations were ranged from 13.56 to 40.43µg/g with a mean concentration of 25.87µg/g. This finding is in agreement with previous observations recorded by Al-Yousuf *et al.*, (2000), Canli and Atli (2003), and Monday and Nsikak (2007). Though, Zn is critical for aquatic organisms, including fishes; however, Zn becomes poisonous when it exceeds its maximum value. Many researchers have stated that dietary Zn is the fundamental reason for increased Zn in marine fish (Xu and Wang, 2002). The Zn concentrations in the muscles of fish documented in the literature elsewhere in the world, such as those of marine culture fishes collected from Hong Kong (20.1 µg/g to 68.3 µg/g, dry weight) (Wong *et al.*, 2001) and those of different

**Table 1.** Calibration Range and $R^2$ value for each metal in fish samples

| Metals | Calibration Range (µg/g) | $R^2$ |
|---|---|---|
| Manganese | 0.3-2 | 0.9997 |
| Zinc | 0.25-2 | 0.9978 |
| Nickel | 0.3-3 | 0.9999 |
| Copper | 0.5-3 | 0.9992 |
| Lead | 0.3-3 | 0.9993 |
| Cobalt | 0.2-1 | 0.9952 |
| Cadmium | 0.5-2 | 0.9989 |

**Table 2.** Recovery of various metals from fish muscles

| Metal | Concentration of metal added (µg/g) | Concentration of metal recovered (µg/g) | Recovery (%) |
|---|---|---|---|
| Pb | 5 | 4.95 | 99 |
| Mn | 4 | 3.91 | 97.75 |
| Cu | 3 | 2.95 | 98.33 |
| Ni | 3 | 2.89 | 96.33 |
| Zn | 5 | 4.99 | 99.80 |
| Cd | 3 | 2.88 | 96.00 |
| Co | 3 | 2.80 | 93.33 |

**Table 3.** Summary of heavy metals statistical analysis in Gaza fishing harbor fish muscles

| Heavy metals/elements | Min | Max | Mean± SE | StDev |
|---|---|---|---|---|
| Manganese Mn(µg/g) | 0.26 | 1.26 | 0.90±0.068 | 0.28 |
| Copper Co(µg/g) | 3.01 | 17.47 | 13.15±1.08 | 4.45 |
| Zinc Zn(µg/g) | 13.56 | 40.43 | 25.87±1.92 | 7.94 |
| Nickel Ni(µg/g) | 0.05 | 2.52 | 1.10±0.14 | 0.55 |
| Cobalt Co (µg/g) | nd | 2.93 | 0.68±0.19 | 0.82 |
| Lead Pb(µg/g) | 0.73 | 3.24 | 1.82±0.20 | 0.78 |
| Cadmium Cd(µg/g) | 0.02 | 0.51 | 0.27±0.03 | 0.13 |

marine fish species captured from Tuzla Lagoon, Turkey (16.48 µg/g to 37.39 µg/g) (Dural *et al.*, 2007), were higher than those observed during this study. Additionally, the Zn concentrations in the muscles of different marine fishes harvested from Aqaba Gulf, Red Sea, Jordan (10.61 µg/g to 21.38 µg/g, dry weight) (Abu Hilal and Ismail, 2008) were lower than those reported in this study. The acceptable limits of Zn set by FAO/WHO (1989) is about 40 µg/g and by Turkish guidelines (TFC) is about 50 µg/g (Yilmaz, 2009) which is higher than the values observed during this study. Zinc does not appear to present a contaminant hazard to fish within this portion of concentration values.

The concentrations of Ni were ranged from 0.05 to 2.52 µg/g with a mean concentration of 1.10 µg/g. The proposed limit of Ni concentrations in marine fish species as recorded by FAO (1983) is about 10µg/g. In general it can be seen that the concentrations of Ni found in tissues of fish species in this study are still considered as those of uncontaminated fish (<10). According to Baumann and May (1984) nickel concentrations of 2.3 µg/g or greater, may cause reproductive impairment and lack of recruitment in fishes. Only one sample out of 17 samples in this study approached these levels of concern. Hence, Ni concentrations in the entire species of fish do not found any treat upon the consumption of these species of fish.

In this study, Co concentrations were ranged from nd to 2.93µg/g with a mean concentration of 0.68µg/g. The found concentrations of Co in this study were higher when compared with the concentrations documented in Masan Bay with an average of 0.01µg/g (Kwon and Lee 2001). Suresh *et al*., (2007) recorded lower concentrations of cobalt as compared to our study with a range of 0.05-0.28 µg/g in Parangipettai coast of India. Topcuoglu *et al*., (2002) reported lower concentrations of cobalt when compared with the present study with a range <0.05-0.40 µg/g in the black Sea coast.

Rompala *et al.*, (1984) documented that the biological effects of sublethel concentrations of lead may include delayed embryonic development, suppressed reproduction and inhalation of growth, increased mucous formation, neurological problems, enzyme inhalation and kidney failure. In this study, Pb concentrations were ranged from 0.73 to 3.24 µg/g with a mean value of 1.82 µg/g. Jinadasa *et al*., (2010) recorded lower concentrations of Pb as compared to our study with a range of nd-0.24 µg/g and mean concentration of 0.06 µg/g in important marine fish species in Sri Lanka coast. Mwashote (2003) reported higher concentrations of Pb when compared with the present study with a mean concentration of 1.0 µg/g during dry season and 6.0 µg/g during wet season in Gazi bay in Mombasa of Kenya. The EU, FAO/WHO and Turkish guidelines (TFC) acceptable residue limits of Pb in fish species is about 0.1 µg/g, 0.5 µg/g and 1 µg/g respectively (Yilmaz, 2009, Dural *et al*., 2007; EU, 2001; FAO/WHO, 1989). Hence, Pb appear to present a contaminant hazard to fish within this portion of concentrations.

The found cadmium concentrations were ranged from 0.02 to 0.51µg/g with a mean concentration of 0.27µg/g. This finding is in agreement with previous observations recorded by Suresh *et al*., (2007) for commercially valuable marine eatable fishes from Parangipettai coast, south east coast of India (0.18-0.54 µg/g dry wt.). Canli and Atli (2003) documented higher concentrations of Cd as compared with this study where Cd mean concentrations were ranged between 0.37 and 0.79 µg/g in the fish species of Mediterranean Sea. Bashir *et al*., (2013) reported lower concentrations of Cd as compared to our study with mean concentration of 0.058 µg/g and 0.027 µg/g for fish muscles collected from Kapar and Mersing coastal waters in Malaysia. Additionally, the Cd concentrations in the muscles of different marine fishes harvested from Masan Bay, Korea (0.02 µg/g to 0.05 µg/g, dry weight) (Kwon and Lee 2001) were lower than those reported in our study. Kalay *et al*., (1999) reported higher concentrations of Cd as compared to this study with mean concentrations ranged from 1.28-1.60 µg/g for marine fish samples collected from Mediterranean Sea in 1996. The proposed limits of Cd set by FAO/WHO (1989), EU in 2001 and TFC for eatable fish is about 0.5 µg/g, 0.1 µg/g and 0.1 µg/g dry wt., respectively ( Yilmaz, 2009) which is lower than 70% of the values observed during this study. Thus, cadmium appear to present a contaminant hazard to fish within this percentage of concentrations.

### Pearson Correlation of Heavy Metals

Correlation analysis is principally calculates the association between two or more functionally independent parameters. The value of correlation coefficient ranges between -1 and 1. The value which is close to +1 shows a strong positive correlation. When r is close to -1 is showing a strong negative correlation between the two parameters. The closer the value of r is to zero, it means the correlation is weak (Armah *et al*., 2012). Table 4 shows the result of correlation coefficients between various heavy metals in fish samples collected from Gaza fishing harbor and surrounding area.

From Table 4 it can be seen that Co is not significantly correlated with Pb, Cu, Zn, Mn, Ni, and Cd. Positive significant correlation is observed to be between Mn and Cu (0.76); Mn and Zn (0.73); Cu and Zn (0.82); Ni and Cd (0.79). Moreover, moderate positive correlation is found between Mn and Ni (0.67); Mn and Cd (0.57); Cu and Ni (0.59); Cu and Pb (0.52); Zn and Pb (0.50). These obtained results may confirm that the seven heavy metal elements investigated in this study have similar sources and having similar sources can be related to same topographical area (El-Serehy *et al*., 2012).

### Health Risk Evaluation for Fish Consumption

As intake of fish is a possible source of metal accumulation in humans, there is an important interest in calculation of the daily and weekly consumptions of heavy metals through fish eating. The estimated daily and weekly intakes (EDI; EWI) of heavy metals (1&7g/day, week/person) through eating of caught fish (gray mullet) from Gaza fishing harbor by Palestinian individuals in the Gaza Strip are illustrated in Table 5. Daily and weekly consumption of heavy metals was calculated on the basis of the concentrations measured in fish muscle and weekly fish consumption rate (126 g). Average Palestinian body weight is assumed to be 70 kg. Existing metal intakes were compared with the relevant permissible tolerable weekly intake for a 70 kg person (PTWI70) (1-7g/day-week). It can be seen in Table 5 that the values of estimated weekly intakes (EWI) of Mn, Cu, Zn, Ni, Pb and Cd in muscle tissues of fish in the present study are healthy below their consistent permissible tolerable weekly intake for 70 kg individual (PTWI70) values. The amount of a toxic metal that one gets from fish though, not only depends on the concentration of specific metal in fish, but also on the quantity of fish consumed. As extraordinary eating of fish are traditional components of the diet of some Palestinian individuals, weekly amount of fish species also calculated that should be eaten in order to reach the permissible tolerable weekly intake of metal for 70 kg individual, PTWI70. Therefore, Palestinian individual will be at risk of the deleterious effects of a metal only if his/her weekly eating of the fish included in this study exceeded their particular PTWI70. Seeing normal eating traditions, it can be confidently state that the calculated weekly intake of fish is far from the actual weekly amount of fish consumed by most Palestinian individuals in general (Table 5) and then, no risk of normal fish consumption originating from the fishing harbor on Palestinian people’s health. Although levels of heavy metals are not high, care must be taken considering some people regularly consume large quantities of fish according to Turkmen *et al*., (2009) and FAO/WHO (2004).

**Table 4.** Correlation coefficient matrix among seven heavy metals in fish muscles

| Heavy metals | Mn | Cu | Zn | Ni | Co | Pb | Cd |
|---|---|---|---|---|---|---|---|
| Mn | 1 | | | | | | |
| Cu | 0.76* | 1 | | | | | |
| Zn | 0.73* | 0.82* | 1 | | | | |
| Ni | 0.67* | 0.59 | 0.48 | 1 | | | |
| Co | 0.04 | -0.09 | -0.04 | 0.05 | 1 | | |
| Pb | 0.30 | 0.52 | 0.50 | 0.26 | -0.18 | 1 | |
| Cd | 0.57 | 0.43 | 0.46 | 0.79* | 0.38 | -0.05 | 1 |

*: Significant correlations

**Table 5.** Estimated daily and weekly intake of metals in a mature man on fish consumption

| Metals | Fish | PTWI[a] | PTWI[b] | PTDI[c] | EWI[d] | EDI[e] |
|---|---|---|---|---|---|---|
| Manganese (Mn) | 0.90 | 980 | 68,600 | 9,800 | 113.4 | 16.2 |
| Copper (Cu) | 13.15 | 3,500 | 245,000 | 35,000 | 1656.9 | 236.7 |
| Zink (Zn) | 25.87 | 7,000 | 490,000 | 70,000 | 3259.6 | 465.6 |
| Nickel (Ni) | 1.10 | 35 | 2450 | 350 | 138.6 | 19.8 |
| Lead (Pb) | 1.82 | 25 | 1750 | 250 | 229.3 | 32.7 |
| Cadmium (Cd) | 0.27 | 7 | 490 | 70 | 34.04 | 4.86 |

a: Permissible Tolerable weekly intake in µg/week/kg body weight, b: PTWI for 70 kg adult person (µg/week/70 kg body weight), c: PTDI, permissible tolerable daily intake (µg/week/70 kg body weight), d: EWI = average concentration (µg/g) × consumption [126 g/w/bw (70 kg)] e: calculated from EWI. The permissible tolerable daily and weekly intake of metals was calculated from (FAO/WHO, 2004) and (Türkmen et al., 2009).

## Conclusion

This study was made to provide information on the level of heavy metals in fish tissues (grey mullet) collected from Gaza fishing harbor area in the Mediterranean Sea. Gaza fishing harbour is one of the most polluted areas due to the adverse effect of effluents from land-based sources. Domestic untreated wastewater discharges and fishing activities in the harbour area may possibly are the major source of the observed heavy metals contamination. The present study revealed that, the highest concentrations of metals in the studied fish (grey mullet) were detected for zinc (13.56-40.43 µg/g) and the lowest were for cobalt (nd-2.93 µg/g) and cadmium (0.02-0.51 µg/g). The heavy metal concentrations in most samples are within the reported values and below the limits proposed for fish by various international standards such as EU, WHO and TFC. Moreover, the present concentrations are well below the documented toxic levels for human consumption, but a continuous monitoring of heavy metals in caught fish species from Gaza fishing harbor and surrounding coastal areas is necessary to insure the prescribed worldwide limit.

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