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DETERMINATION OF HEAVY METALS IN ENVIRONMENTAL SAMPLES BY INDUCTIVELY COUPLED PLASMA-MASS SPECTROMETRY (ICP-MS)

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LIST OF ABBREVIATIONS

As:	Arsenic
Cd:	Cadmium
Co:	Cobalet
Cr:	Chromium
Cu:	Copper
DNA:	Deoxyribonucleic acid
EC:	European Commission
EPA:	Environmental Protection Agency
ETAAS:	Electrothermal Atomic Absorption Spectroscopy
EU:	European Union
FAAS:	Flame Atomic Absorption Spectroscopy
FAO:	Food and Agriculture Organization
FDA:	Food and Drug Administration
Fe:	Iron
Hg:	Mercury
IC:	Ion Chromatography
ICP-AES:	Inductively Coupled Plasma – Atomic Emission Spectrometry
ICP-MS:	Inductively Coupled Plasma –Mass Spectrometry
ICP-OES:	Inductively Coupled Plasma -Optical Emission Spectrometry
Mg:	Magnesium
Mn:	Manganese

Mo:	Molybdenum
Ni:	Nickel
NRC:	National Research Council
Pb:	Lead
ROS:	Reactive Oxygen Species
Se:	Selenium
TSPCR:	Turkish Soil Pollution Control Regulations
WHO:	World Health Organization
Zn:	Zinc

ABSTRACT

Nowadays the concentration of toxic heavy metals reached to unacceptable levels that can adversely affecting human health and the environment in various sides. Especially aquatic systems are more sensitive to heavy metals pollution and this become due to the anthropogenic sources. The aims of this research was to investigate the presence and determine the concentration of heavy metals in sediments, water and fishes (*Cyprinus Carpio*) within Gonyeli Lake (TRNC) through applied modern technology (Inductively Coupled Plasma –Mass Spectrometry) for determination heavy metals composition and compare them with some international guidelines. The study results indicated that Chromium and Nickel sediment concentrations (212.82±16.24 mg/kg, 398.05±13.25 mg/kg respectively) exceeded level for the international sediments standard (USEPA) and (TSCR 2000). In water samples mean concentration of Arsenic (56.72±8.236 µg/l) highly elevated than (WHO), (EPA) and (EC) standard guidelines for drinking water. Levels of As, Pb, Cr and Fe in fish (*Cyprinus Carpio*) gills tissues samples mean concentration (0.419±0.133, 0.2574±0.422, 0.565±0.485 and 300.29±155.367 mg/kg) respectively were exceeded the recommended levels (FAO), (USFDA) and (WHO) for heavy metals in fish. The results of this study indicated the presence of pollution in the Gonyeli Lake is due to heavy metals, and the level is reasonably high.

Key words: Heavy metals, Gonyeli Lake, Fish, Sediment, Water, Pollution, ICP-M

1. INTRODUCTION

1.1 Environmental toxicology

Environmental toxicology is defined as the study of the outcome and effects of chemicals in the environment. Environmental toxicology branched into ecotoxicology and environmental health toxicology. Ecotoxicology concentrates on the effects of environmental contaminants upon ecosystems and it constituents while environmental health toxicology is the study of the adverse effects of environmental chemicals on human health (Levi *et al*., 2010).

Exposing to chemicals has many effects on human and the environment which has become a source of concern in toxicology. Because many data with respect to what at long last happens to the huge amounts of chemicals created and utilized by people are break up; there is worry about their persistence and potential accumulation in the environment. Accumulation via food or water occurs to some agents particularly in animals and aquatic forms of life. New chemical entities reach to the environment from other agents go through biological bacterial transformation. Still others appear in the groundwater or soils while additional products are converted by solar. Because of high degree of stability some other chemicals persist simply. Although it is known the environment as big contents sufficiently dissolve agent to concentration without biological effect, but this is not true. Also, the environment is not always a detoxification medium. For example when adding the chlorine to the drinkable water, the chlorine will appear in wastewater, where the reaction takes place with organic material to produce chlorinated hydrocarbons, some of these suspected carcinogens.

Although air and water contamination become as major problems, contamination of soil is considered more complicated in nature by man-made chemicals because the chemistry of soils is more complex comparing to the air and water. Additionally, microorganisms and their nutrients by-products appear in all soils, as well as air and water; this allows for the transfer of contaminants between these environments. Every individual physical-chemical property of each agent is involved in facilitating or inhibiting the translocation of the agent within the environment. Ascertaining the last station about waste chemicals and their results may be national will comprehension and controlling those possibilities to the event about unfriendly impacts with respect to people (Loomis *et al*., 1996).

Nowadays the challenge of environmental toxicology is to recognize the common principles that might allow extrapolation and prediction of the effects of toxicants on the environment. Environmental toxicology branched from traditional pharmacology or toxicology. To indicate relative toxicity of the various compounds in question, there are traditional methods for testing depends on the use of standard test organisms and laboratory methods. In place of, ecotoxicology deals with a more accurate set of consequences. How are pollutants turned into after their discharge into the surroundings? How creatures are exposed and how physiological changes effect on people dynamics and community build? What indirect effects occur at unexposed creatures when their prey, predators, or contenders are influenced? How do the effects of various mixes vary from those of a single one? Such inquiries are past the area of one-life form, one-compound laboratory tests. Eventually, eco-toxicological effects will be clarified through an integration of long term field perceptions and utilization of measures and models. The materials of the environmental toxicologist include organic tests, for example, for study individual development, mortality, propagation, metabolic rate, enzyme induction, etc. Field examinations, including concentrations of toxicants in tissue, species number and thickness, and inhabitant flow, are essential.

Field investigations for example the control of test creatures at contaminated areas and natural environmental experiment help in the development and testing of hypotheses. At long last, data are frequently incorporated into hypothetical models – scientific expectations of bioaccumulation or of species survival, for instance. The objective of this test is to give fundamental learning concerning the natural reactions of individual creatures to contaminations.

Direct toxicity to the creature is the basic course by which different impacts, for example, the impact of modified prey populations on predators, are intermediate. With a careful comprehension of the way of the real pollutants found in nature and their biological effects, the environmental toxicologist will hold the fundamental instruments for research coordinating different parts of the field. Environmental toxicology is a multidisciplinary science that include some different areas of study, such as chemistry (organic, analytical, and biochemistry), biology, anatomy, physiology, genetics, microbiology, ecology, soil, water, and atmospheric sciences, epidemiology, statistics, and law. Environmental toxicology is a comparatively young branch of science when compare with many other fields of study. However, its significance as a zone of study has been generally realized.

For sure, it is one of the most quickly developing fields of study. This is evident in view of the large number of papers and books distributed in the previous a few decades that related to environmental toxicology. So also, courses of environmental toxicology and related branches of knowledge are being educated at a developing number of schools and colleges. The results of environmental toxicology are utilized in the forecast of danger and risk of single chemicals and contaminated environment, supporting assessment making in environmental management and policy (Figure 1). Environmental toxicology in risk management has its main role in designing monitoring systems, in risk assessment, in establishing risk based environmental quality criteria, in the selection of the appropriate risk reduction measure and in the determination of the target value of the remediation (Gruiz *et al.*, 2001).

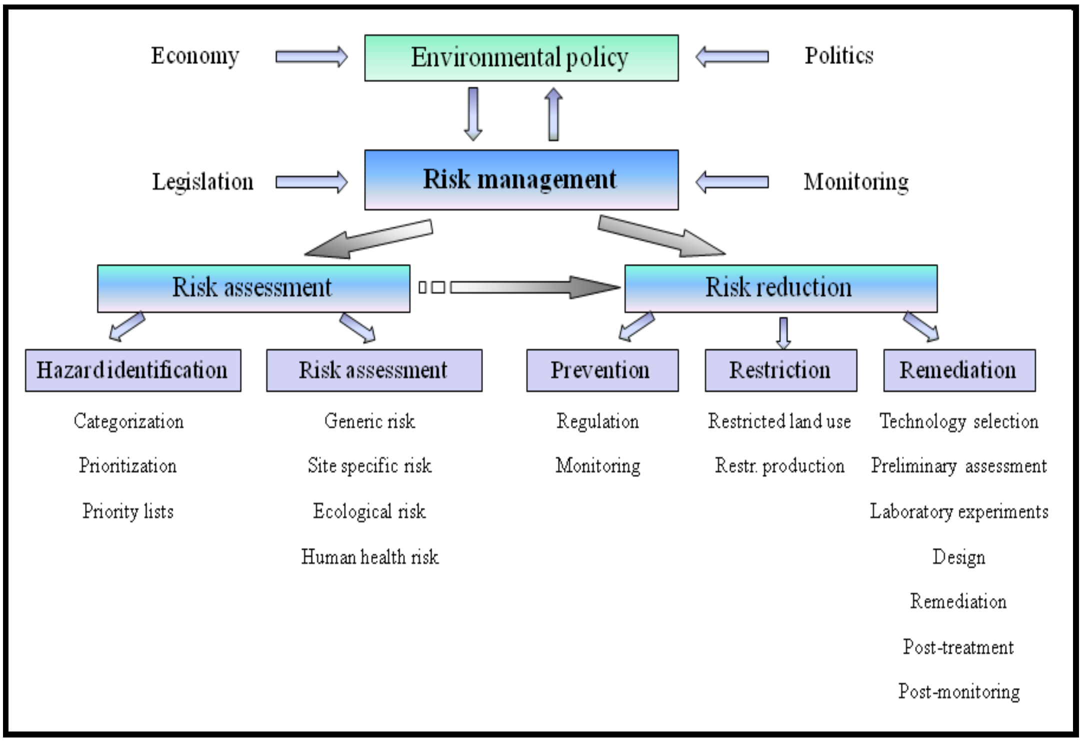

Figure1.1- Risk management

The heavy metal toxicity of the salt water environment has long been seen as a serious environmental concern (Balkas *et al.*, 1982)(Tariq *et al.*, 1991).For this reason, it is important to figure out the chemical quality of the marine organisms, specifically the measure of heavy metals, in order to estimate the possible risk, to human health, of fish ingestion (Cid *et al.*, 2001). Metals such as iron, copper, zinc and manganese, are important metals since they play an effective role in biological systems, whereas mercury, lead and cadmium are non-essential metals, as they are toxic, even in smaller quantity (Schroeder, 1973)(Somer, 1974).

Research on heavy metals in lakes, rivers, fish and sediments (Özmen *et al.*, 2004)(Fernandes *et al.*, 2008)(Öztürk *et al.*, 2008)(Pote *et al.*, 2008) and (Praveena *et al.*, 2008) have been the main environmental focal point specifically during the last decade. Sediments are essential sinks for diverse pollutants like pesticides and heavy metals and also play a major part in the remobilization of pollutants in aquatic environment under favorable conditions and in interactions between water and sediment level. Fish samples can be seen as one of the most astounding indicators in freshwater environment for the determination of metallic pollution (Rashed, 2001).

Research has been used to estimate the concentrations of heavy metals (Pb, Cd, Fe, Cu, Mn and Zn) in fish samples by using methodology involved in graphite furnace atomic absorption spectrometry after dry ashing and wet ashing. Recoveries were quantitative for all elements studied ($\geq$95%). The relative standard deviations were lower than 7% for all elements. It was found that the level of heavy metals in the fish samples was lower compared to the Public Health Regulation in Turkey (Tüzen, 2003).

Pervious study aimed to describe the heavy metal contamination of soil in north Cyprus showing that seawater was seriously contaminated by chromium, nickel and copper within the area of the smelting facility. Copper and iron levels greatly increased after rainfall (wet period), indicating the contribution of tailings to marine pollution, the researchers called for an urgent need for remediation treatment for the studied sites (Yukselen, 2002).

Research also proved that some heavy metals (Cd, Cr, Cu, Fe, Ni and Pb) were occasionally estimated in water, sediment and some tissues of *Cyprinus carpio* from Avsar Dam Lake, which is a significant water source for irrigation and drinking in Turkey. Heavy metal concentration in water, sediment and fish samples was experimented by inductively coupled plasma spectroscopy (ICP/AES). The results obtained proved that the average values of Fe in water samples were higher than the respective reference values for fresh water. The analysis of heavy metals in sediments determined that among the six heavy metals that were analyzed, Fe was greatly accumulated, followed by Ni, Cu, Cr, Pb and

Cd. But in the fish samples, nickel, chromium, cadmium and lead levels exceeded the tolerable values provided by international institutions (Öztürk *et al.*, 2009).

1.2 Heavy metals

"An excellent man, like precious metal, is in every way invariable; A villain, like the beams of a balance, is always varying, upwards and down wards." John Locke.

Metals attend in a large part of the periodic table and are commonly good conductors of electricity or heat. They form cations and ionic bonds with non-metals. Metals cannot be produced or destroyed, but can alter form, which changes their biological availability and toxicity. Heavy metals are commonly related to as those metals which have a specific density of more than 5 g/cm3 and some of them negatively change the environment and living organisms (Jarup, 2003).Some of these metals are nutritionally important or essential to preserve different physiological functions and biochemical in living organisms when in low concentrations, the toxicity of these metals comes from either nutritional deficiency or excess exposure. As widespread of heavy metal is increasing in the all side of the life. So their toxicity is a serious problem for ecological, evolutionary, nutritional and environmental reasons and this toxicity need a lot of increasing importance as an environmental contaminants (Jaishankar *et al.*, 2013) (Nagajyoti *et al.*, 2010).

Essential nutrientsare reported these metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn). Less qunantiy for supply of these micro-nutrients results in a variety of deficiency diseases or syndromes (Levander & Whanger, 1996).The heavy metalsclassifed as essential heavy metals exert fundamental biological functions inliving organisms, their oxidation-reduction properties and chemical coordination sometimes have given them additional benefit so that they can escape control mechanisms such as homeostasis, transport and binding to required cell constituents such as cell membrane, mitochondrial, lysosome, endoplasmic reticulum, nuclei, and some enzymes used in metabolism, detoxification, and damage repair. Preceding study has confirmed that oxidative stress of biological macromolecules is mainly due to binding of heavy metals to the DNA and nuclear proteins (Flora *et al.*, 2008).

The environment pollution caused by heavy metals occur via wide range of processes, during atmospheric emssion, metal corrosion, soil erosion of metal ions and leaching of heavy metals, sediment re-suspension and metal evaporation from water resources to soil and ground water. The great concern in terms of human health come to be atmospheric emissions, because of the amounts involved and the prevalent dispersion and potential for exposure that often result. Lead discharges are basically identified with man-made activites and consequently distributed in environment. Cadmium emissions are principally related with fuel combustion, non-ferrous metallurgy and cigarette smoking whereas the spatial distribution of anthropogenic mercury emissions reflects primarily the level of coal utilization in various areas and process such as agriculture, local wastewater discharges, mining, discharges of industrial wastewater. Individuals might be exposed to possibly harmful substance, physical and biological agents in air, food, water or soil. However, exposure does not result only from the presence of a harmful agent in the environment. The key word in the definition of exposure is contact (Berglund *et al*., 2001). There must be contact in the main routs of absorption to human body, the airway, the skin or the mouth. Exposure defined as a function of concentration and time: “an incident that occur when there is contact at a boundary between a human and the environment with a contaminant of a specific concentration for an interval of time” (Lioy, 1991).

1.2.1 Arsenic

Arsenic is important heavy metals cause imbalance from both individual health point of views and ecological (Hughes *et al.*, 1988). It has a semi metallic property, is considerably toxic and carcinogenic, and is commonly available in the form of oxides or sulfides or as a salt of iron, sodium, calcium, copper, *etc.* (Singh *et al.*,2007).Its present in inorganic forms such as arsenite and arsenate compounds are fatal to the environment and living creatures. Humans may exposure to arsenic by natural means, industrial source, or from unintentional source. Drinking water contaminated by utilization of arsenical pesticides, inappropriate transfer of arsenical chemicals or normal mineral stores. Deliberate taking of arsenicin case of suicidal attempts or accidental consumption by children may also result in cases of acute poisoning of arsenic (Mazumder, 2008)(Saha *et al.*, 1999).

1.2.2 Lead

Lead is naturally occurring in the environment as an extremely dangerous metal whose has created broad environmental contamination and medical issues in many parts of the world. Lead is bluish-gray metal in a dry atmosphere. It begins to tarnish on contact with air, thereby forming a complex mixture of compounds, depending on the surrounding conditions. Lead sources include mostly industrial process, food and smoking, drinking water and domestic sources. Lead source were gasoline and painting, which has been extended to lead bullets, plumbing pipes, pewter pitchers, storage batteries, toys and faucets (Thürmer *et al.*, 2002). It has been reported that 100 to 200,000 tons of lead per year is being released from vehicle exhausts in the USA. Some is taken up by plants, fixation to soil and stream into water bodies, consequently human introduction of lead in the all-inclusive community is either due to drinking water or food (Goyer, 1990).

1.2.3 Mercury

Mercury is very toxic and highly bioaccumulative. Mercury is in nature occurring heavy metal which is a shiny silver-white, odorless liquid and becomes colorless and odorless gas when heated. Its attendance negatively affects the aquatic environment and so that many studies are confirmed the distribution of mercury in water environment. The contamination sources of mercury include man-made activities such as domestic wastewater discharges, agriculture, discharges of manufacturing wastewater mining and incineration (Chen *et al.*, 2012).

Mercury also occurs in three forms: metallic elements, organic compounds and inorganic salts, each of which have different bioavailability and toxicity. The three forms of mercury are distributed in water resources such as lakes, rivers and oceans where causing major disturbance to aquatic lives through mercury get transformed into methyl mercury within algae and bacteria. Utilization of this infected aquatic animal is the major route of human exposure to methyl mercury (Trasande *et al.*, 2005). Methyl mercury treansfer through the food chain into fish, shellfish, and finally into humans.Utilization of mercury nowadays it is in thermometers, barometers, pyrometers, hydrometers, mercury arc lamps, fluorescent lamps and as a catalyst. Furthermore it is used in paper industries and pulp, as a component of batteries and in dental amalgams.

Elemental mercury (Hg0) and methyl mercury (MeHg) are highly absorbed by the species. Dental amalgam composed over half of contents from elemental mercury (Zahir *et al.*, 2005).The lipophilicity of elemental vapor is important for absorption through the lungs and tissues lining the mouth. Then after Hg0 enters the blood, it quickly passes through cell membranes, which include both the blood-brain barrier and the placental barrier (Guzzi *et al*., 2008) after it enter into the cell, Hg0 is oxidized and turn to highly reactive Hg2+. Once mercury is absorbed it has a very low excretion rate. A major amount of what is absorbed accumulates in the kidneys, neurological tissue and the liver. All forms of mercury are toxic and their effects include gastrointestinal toxicity, neurotoxicity, and nephrotoxicity (Tchounwou *et al*., 2003). According to the EPA and FDA, the level of mercury in drinking water should not exceed 2 ppb, and maximum permissible level of methyl mercury in seafood is1 ppm.

1.2.4 Cadmium

Cadmium may be a substantial metal about ecological what's more word related vitality. It will be characteristically conveyed in the earth outside toward a normal fixation about something like 0.1 mg/kg. The most astounding level from claiming cadmium mixes in the earth will be gathered to sedimentary rocks, and marine phosphates hold numerous around 15 mg cadmium/kg (Caspers, 1985).The main use of it in rechargeable batteries is for special alloys production and also it can be obtained in tobacco smoke. Cadmium constitutes an electrode component in alkaline battery production; the remaining part is used in coatings, pigments and plating and as a plastic stabilizer. People can come in contact with cadmium either through the process of inhalation and ingestion and suffer from chronic intoxication. The presence of a high concentration of cadmium in food can increase its toxicity in the human bodies. Cadmium can be identified in the liver, mushrooms, shellfish, mussels, dried seaweed and cocoa powder.

Cadmium exposure can be determined by measuring cadmium levels in blood or urine. The concentration of cadmium in blood reflects recent cadmium exposure (from smoking, for example). The presence of cadmium in urine is usually adjusted for dilution by calculating the cadmium percentage for creatinine ratio which can indicate accumulation of cadmium in kidney burden (Wittman R & Hu H, 2002) (Järup L *et al.*, 1998). Cadmium is a very toxic nonessential heavy metal that is well known for its adverse effects on the enzymatic systems of cells, oxidative stress and for promoting nutritional deficiency in plants (Irfan *et al.*, 2013).

1.2.5 Chromium

Chromium is a naturally occurring element found on earth crust as the 7th most abundant element (Mohanty & Kumar Patra, 2013). The existence of Chromium at different oxidative states in the environment ranges from Cr2+ to Cr6+ (Rodriguez *et al.*, 2007). Some of the most toxic chromium substances that can be highly toxic to animals, humans and plants forms of Cr are trivalent Cr+3 and hexavalent Cr+6 (Mohanty& Kumar Patra, 2013). Chromium are also used in the burning of oil and coal, petroleum from ferrocromate refractory material, pigment oxidants, catalyst, chromium steel, fertilizers, oil well drilling and metal plating tanneries. Chromium can be released into the environment through sewage and fertilizers (Ghani, 2011).In its reduced form, Cr (III) is immobile and is insoluble in water whereas in its oxidized state, Cr (VI) is highly soluble in water and thus mobile (Wolińska *et al.*, 2013). Metal speciation is very important in order to determine the activities of the metal ions in the environment, whereas in case of chromium the oxidative form of Cr (III) is not a significant contaminant of the ground water but Cr(VI) has been discovered to show toxicity to humans (Gürkan *et al.*, 2012). The presence of Cr(III) resides in the organic matter of soil and aquatic environment in the form of oxides, hydroxides and sulphates (Cervantes *et al.*, 2001). In industrial and agricultural practices, the wide usage of chromium increases the toxicity level of chromium in the environment causing problematic concern as regards pollution. The greatest concerns in last year's, is the pollution of the environment by hexavalent chromium, (Zayed &Terry, 2003). It has been discovered that Tanneries released numerous polluting heavy metals and compounds into the water streams (Nath *et al.*, 2008). Cr (III) is oxidized to Cr (VI) due to the presence of excess oxygen in the environment, which is highly soluble in water and very toxic (Cervantes *et al.*, 2001). The discharge of industrial wastes and ground water contaminants has highly increased the concentration of chromium in soil (Bielicka *et al.*, 2005). Cr residues and waste water irrigation create a serious Cr pollution to agriculture during manufacturing of chromate.

Intake food contaminated with a high concentration of chromium can lead to stomach upsets, ulcers, convulsions, and finally death (Scheuhammer, 1987).In drinking water, EPA maximum permissible level of chromium (III) and chromium (IV) is 10 μg/m3. Dietary intake of chromium (III) should be between 50-200 μg/day according to the National Research Council (NRC).

2. TOXIC EFFETS AND MECHANISMS HEAVY METALS

In the environment and diet, some heavy metals can commonly be found. In little quantities they are needed to maintain a good health for the human population, but in larger quantities they tend to highly toxic and harmful. Heavy metal toxicity can reduce the energy levels and damage the healthy function of the brain, lungs, kidney, liver, blood composition and other significant organs. Chronic exposure can result in the progressive advanced physical, muscular, and neurological degenerative diseases. Long-term re-exposure of some metals and their compounds may even lead to cancer (Jarup, 2003).

The bio-toxic effects of heavy metals can be defined as the adverse effects of heavy metals to the body when ingested above the bio-acclaimed limits. Each metals although show some signs of their toxicity, the following are general signs such as vomiting and convulsion, gastrointestinal (GI) disorders, diarrhea, stomatitis, tremor, hemoglobinuria causing a rust–red color to stool, ataxia, paralysis, depression, and pneumonia when volatile vapors and fumes are inhaled, this has been reported in a good number of studies (McCluggage, 1991). This, related to the nature of its effects could show toxicity, in neurotoxicity, carcinogenicity, mutagenicity or teratogenicity.

2.1 Mechanism of Cadmium toxicity

The mechanism of cadmium toxicity is not clear to understand but its changes on cells are identified (Patrick, 2003). The concentration of cadmium is increased to three thousand fold when it binds to cystein-rich protein such as metallothionein. Hepatotoxicity in the liver due to the cystein-metallothionein complex and then it gets accumulated and causes nephrotoxicity in the renal tissue when it circulates to the kidney. Cadmium can also lead to the deficiency of iron (Castagnetto *et al.*, 2002). Cadmium and zinc have the same oxidation states and thus cadmium can substitute zinc present in metallothionein.

Many in vitro studies show that cytotoxic effects at the concentrations 0.1 to 10 mM and free radical-dependent DNA damage is incited by cadmium (Sugiyama *et al.*, 1993)(Mukherjee & Das,2002). Studies have shown that cadmium stimulates male reproduction in mice model at a concentration of 1 mg/kg body weight in vivo. However in comparison to carcinogenic metals, cadmium is a weak mutagen when compared to others (Smith *et al.*, 1989). According to previous reports, cadmium affects signal transduction pathways; inducing inositol polyphosphate formation, increasing cytosolic free calcium levels in various cell types (Thevenod & Jones., 1992), and blocking calcium channels (Suszkiw *et al*., 1984)(Dally & Hartwig, 1997).

Cadmium compounds can be as human carcinogens by many regulatory agencies. According to the U.S. National Toxicology Program and International Agency for Research on Cancer (Loprieno N, 1975), it has been concluded that there is adequate proof that cadmium is a human carcinogen. The lung is the major site for human carcinogenesis from cadmium exposed into the environment. Animal studies have confirmed the reproductive and teratogenic effects of cadmium.

2.2. Mechanisms of Lead toxicity

One of the most important mechanisms of lead toxicity in living cells that exert toxic effect on lead is oxidative stress. Several studies have demonstrated that oxidative stress in living cells is brought about by the imbalance between the generation of antioxidants and production of free radicals to eliminate the toxicity of reactive intermediates or to repair the resulting damage. The attack of heavy metals on a cell and the balance between reactive oxygen species (ROS) production and the next defense are introduced by antioxidants. Antioxidants such as glutathione, present in the cell protect it from free radicals that include H2O2. , The level of the ROS increases and the level of antioxidants decrease in the case of lead. The oxidized form (GSSG) accounts for 10% under normal conditions and the reduced form (GSH) of glutathione accounts for 90% of the total glutathione content. The concentration of GSSG exceeds the concentration of GSH under the condition of oxidative stress. Another biomarker for oxidative stress is lipid peroxidation, since the free radical accumulates electron from lipid molecules that is present inside the cell membrane, which eventually brings about lipid peroxidation (Wadhwa *et al.*, 2012)(Flora *et al.*, 2012).

2.3 Mechanism of Arsenic toxicity

Toxic inorganic arsenic compounds get methylated by bacteria, algae, fungi and humans to give a total of metabolites monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA) in arsenic biotransformation. Inorganic arsenic species (iAs) are changed enzymatically to methylated arsenicals which are the final metabolites and the biomarker of chronic arsenic exposure in biotransformation process.

iAs (V) → iAs (III) → MMA (V) → MMA (III) → DMA (V)

The process of detoxification in biomethylation to get a final products, are methylated inorganic arsenic which includes MMA (V) and DMA (V), excreted through urine indicating inorganic arsenic exposure. However, MMA (III) isn’t excreted and remains within the cell as an intermediate product. The intermediate product Monomethylarsenic acid (MMA III) is found to be highly toxic in comparison to other arsenicals which is potentially responsible for arsenic-induced carcinogenesis (Singh *et al.*, 2007).

2.4 Mechanism of Chromium Toxicity

The major factors play role in the toxicity of chromium compounds in oxidation state and solubility. Cr(VI) compounds are shown to be highly toxic compared to Cr(III) compounds because of its powerful oxidizing agents and solubility (Connett &Wetterhahn, 1983)(De Flora *et al*., 1990). However, the mechanisms of biological interaction are unknown, the difference in toxic levels may be related to Cr(VI) which can pass through cell membranes and its subsequent intracellular reduction to reactive intermediates. It can be absorbed by the lung and gastrointestinal tract, reaching a certain level by intact skin while Cr(III) is poorly absorbed by any pathway, so the toxicity of chromium is mainly related to the Cr(VI) form.. The reduction of Cr(VI) is important when it undergoes a process of detoxification that occurs at a distance from the site of action for toxic or genotoxic effect while reduction of Cr(VI) may serve to activate chromium toxicity if it happens in or close to cell nucleus of target organs(Dayan & Paine., 2001). The balance occurring between extracellular Cr(VI) and intracellular Cr(III) suggests the amount and rate at which Cr(VI) penetrates cells and induces its toxic effects (Cohen *et al*., 1993). Cr(VI) penetrates several types of cells and under physiological conditions can result in a reduction by hydrogen peroxide (H2O2), ascorbic acid, glutathione (GSH) reductase and GSH to produce reactive intermediates, including Cr(V), Cr(IV), thiylradicals, hydroxyl radicals, and ultimately, Cr(III). These species could attack proteins, membrane lipids and DNA, thereby interrupting cellular integrity and functions (Mattia *et al*., 2004) (O’Brien *et al.,* 2003). Research carried out with animal models has also reported many toxic effects of Cr (VI) on mammals.

Carcinogenicity is shown to be associated with inhalation of the less soluble or non-soluble Cr(VI) compounds. Epidemiological evidence strongly points to Cr(VI) as an agent in carcinogenesis. Solubility and other characteristics of chromium, which includes size, surface charge, crystal modification and the ability to be phagocytozed, may be significant in determining cancer risk (Norseth T, 1981).

2.5 Mechanism of Mercury toxicity

Through oxidative stress mercury indicates that the mechanisms of sulfhydryl reactivity actually enters the cell of both Hg2+ and MeHg forming covalent bonds with cysteine residues of proteins thereby reducing cellular antioxidants. In eukaryotic organisms the major site for the production of reactive oxygen species (ROS) takes place in the mitochondria via normal metabolism (Shenker *et al.,* 2000). Studies in Inorganic mercury have been discovered to enhance the production of these ROS by developing deformities in oxidative phosphorylation and electron transport at the ubiquinone-cytochrome b5 step (Palmeira & Madeira, 1997). Oxidative stress has an effect on calcium homeostasis. Both organic and inorganic mercury have been discovered to modify calcium homeostasis but through several mechanisms. Organic mercury compounds (MeHg) are known to increase intracellular calcium by quickening the influx of calcium from the extracellular medium and mobilizing intracellular stores, while inorganic mercury (Hg2+) compounds bring about a growth in intracellular calcium stores only via the influx of calcium from the extracellular medium (Kim *et al*., 2010) . Mercury compounds have also been discovered to cause increased levels of malondialdehyde (MDA) in both the livers, testes, kidneys and lungs of rats treated with HgCl2 (Lash *et al*., 2007). This growth in the concentration was discovered to conform with the severity of hepatotoxicity and nephrotoxicity (Lund *et al*., 1991).

Epidemiological studies have shown that enzymatic activity was modified in populations that are prone to mercury exposure, resulting in genotoxic transformation, and proposing that both chronic and low level mercury exposures might prevent enzyme activity and cause oxidative stress in the cells (Rana SVS, 2008). The correlation between exposed mercury and carcinogenesis is highly controversial. Although, *in-vitro* studies suggests that the sensitivity to the damage of DNA exist because of cellular exposure to mercury. This also indicates that carcinogenicity and induced mercury toxicity might be cell to organ to and/or species to specific.

3. FOOD CHAIN AND BIOMAGNIFICATION

Food chains may take place in aquatic environments with aquatic pollutants, or in terrestrial organisms with soil, water, airborne or food borne pollutants, or a combination of these. The significant part of any food chain is the scope for biomagnification of the substance as it migrates up through the food chain. The most significant characteristics of a substance that enters a food chain are its lipid solubility and its metabolic stability in biological systems. Polar and ionized Hydrophilic compounds may be raised up by organisms but at the same time are readily excreted. Absorbed Lipophilic pollutants are increasingly metabolized to polar metabolites and tend to be eventually excreted and hence will not remain in the organism or be transferred to the predator.

The most common sources of heavy metal exposure for humans are food and water, frequently resulting from crops grown on heavy metal-contaminated agricultural soils (Gimeno-García *et al*., 1996) (Luo *et al*., 2009). Common sources of heavy metals in agriculture include atmospheric deposition, phosphate-based fertilizers, livestock manures, wastewater irrigation, metallo-pesticides, and long-term applications of both treated and untreated sewage sludge (Nicholson *et al*., 2003)(Cai *et al*., 2009)(Chary *et al*., 2008)(Luo *et al*., 2009) (Neilson & Rajakaruna, 2014).

A pitiable event took place in Japan in the 1950s; in 1956 a new factory on the shores of Minamata Bay in Japan began producing vinyl chloride and acetaldehyde. Mercuric chloride was used as a catalyst, and thereafter was released into the bay with the rest of the effluent from the factory. In a shortness of time, illness had appeared among the local fishermen and their families which was the Minamata disease. Their pet cats were also affected and showed similar symptoms. It was pointed out that the disease occurred as a result of contaminated seafood and mercury was suspected in 1959. Methyl mercury was identified in seafood in 1960 and in residue gotten from the factory in 1961. The methyl mercury was discovered to be present in seafood which was eaten by the local population. It became clear that the inorganic mercury that released into rivers, lakes or the sea was not inert but could be biomethylated to methylmercury by micro-organisms. This occurred specifically under anaerobic conditions, such as in the effluent sludge which was collected at the bottom layer of Minamata Bay. The pollution at Minamata resulted to 700 cases of poisoning and over 70 deaths were reported.

4. TREATMENT AND ANTIDOTES FOR HEAVY METAL POISONING

Metal toxicity exposure may result due to; excessive extrinsic exposure to heavy metals from several sources or genetic disorder in important metal excess likes Wilson disease. Most metals have the ability to form covalent bonds with carbon, leading to metal-organic compounds. Metals and metal compounds interfere with the proper functioning of several organ systems such as the central nervous system (CNS), the hematopoietic system, liver, kidneys etc. Studies on the presence of heavy metals, and then decreasing the body's load of certain substances, should be an essential part of the overall treatment procedure for persons with a contamination to metal showing symptoms or a known exposure to these substances (Flora & Pachauri, 2010).

Metal toxicity after its occurrence may be acute, sub-acute or chronic. Basic principles of metal toxicity management involve the following steps:

-Prevention of an additional metal absorption into the system

-Elimination of metal from the systemic circulation

-Inactivation of metal bioavailability in the system

Chelating agents were once used as antidotes for metal contamination in humans since the Second World War. The most first applied chelators was British Anti-Lewisite (BAL), a chelating drug produced during the Second World War in England as an antidote for the arsenic composed of a warfare agent (lewisite) (Taylor *et al*.,1995). Calcium disodium ethylenediaminetetraacetate (CaNa2EDTA), D-penicillamine and deferoxamine were antidotes developed in clinical use as well.

4.1 Dimercaprol (BAL)

Dimercaprol is 2,3-dimercapto-1-propanol or British-Anti-Lewisite (BAL) . It is a lipophilic drug, which can penetrate the cells and be evenly distributed both intracellularly and extracellularly (Aposhian *et al*., 1995). It composed of two sulfhydryl groups forming a balanced, relatively nontoxic five-chained heterocyclic chelate ring with heavy metals. The most stable complexes are composed of metals; including gold, arsenic and mercury.BAL is more active when administered immediately after exposure because it mostly prevents the inhibition of sulfhydryl enzymes than reactivates them(Flora &

Pachauri, 2010) (Trümpler *et al*., 2009). It is metabolized to an oxidized form of BAL, which is an active metabolite identifiable in the urine (Aposhian *et al*., 1995).

4.2 meso-2,3-Dimercaptosuccinic Acid (SUCCIMER, meso-DMSA)

Succimer, *meso*-2,3-dimercaptosuccinic acid (*meso*-DMSA), is an orally active and low toxic analogue of BAL (Rivera *et al*., 1989)(Aposhian, H. V., & Aposhian, M. M, 1990).*Meso*-DMSA is an productive chelator used in the treatment of lead intoxication both in neonate and adults (Aposhian & Aposhian., 1990) (Friedheim *et al*., 1978) (Counter *et al*., 2003). It has also been productively used for elemental, antimony, copper chelation, inorganic and organic mercury, and arsenic in humans((Rivera *et al*., 1989)(Aposhian, H. V., & Aposhian, M. M., 1990) (Fournier *et al*., 1988)(Cullen*et al*., 1995). One of the importance of *meso*-DMSA is that it does not form a toxic compound with iron like BAL, which brings about the chance for iron intake during the treatment of chelates (Haust *et al*., 1989). This is specifically essential for anemic and malnourished patients.

4.3 Dimercaptopropane-1-Sulphonic Acid (DMPS)

The derivatives of BAL is DMPS, sodium salt of 2,3-dimercaptopropane-1-sulphonic acid which is orally active chelating agent. It is distributed extracellularly and, to a lower extent, intracellularly (Aposhian *et al*., 1995)(Wildenauer *et al*., 1982). It has been comfirmed that DMPS enters the intracellular layer through the organic anion transport route (Wildenauer *et al*., 1982).DMPS has been positively used for the treatment of arsenic poisoning (GuhaMazumder *et al*., 2001)(Moore *et al*., 1994)], bismuth (Slikkerveer *et al*.,1998), copper (Walshe, 1985),(Torres-Alanís *et al*., 2000), lead (Bulman, 1987) and mercurial compounds (Clarkson *et al*., 1981) (Vasken Aposhian *et al*., 1992)(Campbell *et al*.,1986)(Gonzalez-Ramirez *et al*., 1998). Research carried out by Guha Mazumder and his coworkers (Guha Mazumder, 2003), proved that chronic arsenic poisoning DMPS is superior to *meso*-DMSA. DMPS is also used as a provocative (challenge) test for arsenic(Le, X. C., 2001)(Aposhian, H.V *et al.,* 2003) or mercury (Aposhian H. V, 1998) exposure. DMPS is authorized for the treatment of arsenic intoxication in the People's Republic of China, and for mercury and lead poisoning in Germany.

4.4 D-Penicillamine (DPA) and N-Acetyl-D-Penicillamine (NAPA)

These drugs are degradation products of penicillin. They are administered orally, and D-penicillamine (DPA) can also be taking intravenously (Andersen, O, 1999). Thiol group seems to be the most significant functional group for chelation of metal atoms (Netter *et al*., 1987). DPA is aslo used in treatment of Wilson's disease (Shimizu *et al*., 1999) (Brewer, G. J, 1995) and heavy metal poisoning, since it is an efficient chelator of copper (Austen &Winslow, 1984) (El-Youssef, 2003), lead (Goyer *et al*., 1995), gold (Davis, 1969), mercury (Clarkson *et al*., 1981)(Snodgrass *et al.*, 1981),and zinc(Van Caillie-Bertrand *et al*., 1985). DPA was discovered to be useful in arsenic poisoning(Andersen, 1999)(Blanusa *et al*., 2005)(Watson *et al*., 1981). It is also used in cystinuria (Stephens,1989)and patients suffering from rheumatoid arthritis (Pisetsky & Clair 2001).
NAPA is also known to be effective in the treatment of mercury poisoning(Clarkson *et al*., 1981)(Markowitz & Schaumburg, 1980). In the Iraq outbreak of methyl mercury poisoning in the winter of 1971-1972, due to fungicide-treated wheat, NAPA was shown to be very effective as DPA, although DMPS was the most effective of the used chelating agents, according to half-life of mercury in the blood (Clarkson *et al*., 1981). Its mercury chelating properties have been approved in animal analysis of inorganic and methyl mercury intoxication, although with lesser efficacy than those of *meso*-DMSA or DMPS (Nielsen & Andersen,1991)(Aaseth & Friedheim, 1978).

4.5 Ethylenediaminetetraacetic Acid (EDTA) andDiethylenetriaminepentaacetic Acid (DTPA)

Calcium disodium ethylenediaminetetraacetate (CaNa2EDTA, calcium edetate) and calcium trisodium or zinc trisodiumdiethylenetriaminepentaacetate (CaNa3DTPA and ZnNa3DTPA, respectively) are parenterally administered chelating agents as they have a low gastro intestinal absorption. Since EDTA has high compatibility for calcium, it may cause tetany as a result of rapid reduction in serum calcium. Therefore, it is continuously applied as calcium salt CaNa2EDTA. Both CaNa2EDTA and calcium or zinc salt of DTPA are dispersed mainly in extracellular fluid (Andersen, 1999).Animal studies recommend that CaNa2EDTA is an important chelator in cobalt contamination (Kasprzak *et al*., 1994)(Hilmy *et al*., 1990).

5. DETERMINATION TECHNIQUES AND ANALYSISOF HEAVY METALS IN ENVIRONMENTAL SAMPLES

The determination of heavy metals in environmental samples realized by analytical instrument and techniques procedure must be applied to obtain good result, there are many inorganic techniques such as FAAS, ETAAS, ICP-OES, ICP-MS as well as anodic stripping and recently laser induce breakdown spectroscopy (LIBS).

Actually all the steps involved in an analysis, namely (i) specimen sampling, (ii) to prevent analyte loss e.g. its sorption on vessel wall, (iii) contamination from the environment, chemicals added to the sample, (iv) transfer the sample to the lab, (v) treatment of sample prior to analysis (leaching, extraction, pre-concentration/separation of the analytes, (vi) choose of the method considering its limitations, (vii) calibration of the vessels, instrument etc, (viii) preparation of sample, all solutions, standards correctly and appropriately, (ix) to test the accuracy of the method using Certified Reference Materials (CRM), (x) evaluation of results statistically and reporting are all the rings of a chain. Each step is significant and potential source of error if not applied conveniently.

In order to lower interferences, organic matrix of the sample should be eliminated by digestion as well as metal containing compounds should be disintegrated to get a free metal ions which can be estimated by atomic absorption spectrometry (AAS) or inductively coupled plasma (ICP) more conveniently. After choosing the effective sample preparation procedure, the major techniques are applied.

5.1 Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Inductively coupled plasma mass spectrometry (ICP-MS) is a multi-element procedure as shown in figure 5.1 and figure 5.2 which uses plasma source to atomize the sample, and then ions are identified by mass spectrometer. Mass spectrometer separate ions according to their mass to charge ratio. This procedure has an excellent detection limits, in PPT range. Samples introduced as an aerosol, liquid or solid. Solid samples are dissolved prior to analysis or by a laser solid samples are converted directly to aerosol. All elements can be experimented on within minutes, simultaneously. But it needs high skilled operator, because method development is moderately difficult from other procedure. There are different types of ICP-MS instruments; HRICP- MS (high resolution inductively coupled plasma mass spectrometry and MC-ICP-MS (multi collector inductively coupled plasma mass spectrometry). HR-ICP-MS has both magnetic sector and electric sector to separate and focus ions. By these instruments elimination of the effect of interferences due to mass overlap is accomplished but operation cost, time and complexity will increase. MC-ICP-MS are designed to perform high-precision isotope ratio analysis. They have multiple detectors to collect every isotope of a single element but the major disadvantage of the system is that all the isotopes should be in a narrow mass range which eliminates these instruments from routine analysis.

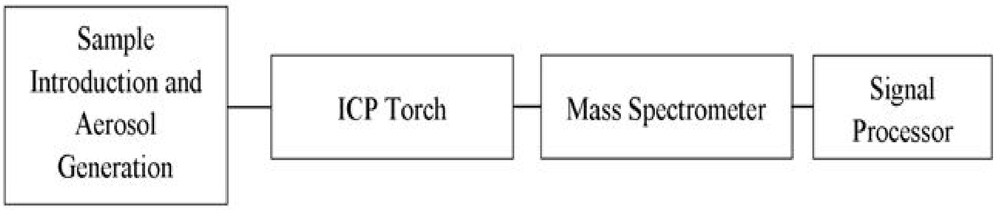

Figure 5.1-Block diagram of ICP-MS instrument

Figure5.2- Inductively Coupled Plasma Mass Spectrometer instrument (ICP-MS)

5.2 Ion Chromatography (IC)

Ion chromatography is a type of liquid chromatography used for water chemistry analyses, to measure concentrations of major anions such as fluorides, chlorides, nitrates, and sulfates. It can also be used to measure concentrations of major cations such as lithium, sodium, ammonium, potassium, and magnesium ions in part per billion ranges.

In ion chromatography, concentrations of ionic species are measured by separating them based on their interaction with a resin. Ions separate differently depending on type and size. Sample solution passes through a pressurized chromatographic column where ions are absorbed by column constituents. As an ion extraction liquid known as eluent runs through the column, the absorbed ions begin separating from the column. The retention time for different species determines the ionic concentration in the sample. The column packing for ion chromatography consists of ion exchange resins bonded to inert polymeric particles. For cation separation, the cation exchange resin is usually a sulfonic or carboxylic acid, and for anion separation, anion exchange resin is a quaternary ammonium group.

6. MATERIALS AND METHOD

6.1 Instrumentation

For the analysis of water cation and anion, the IC (Ion Chromatography) System model (Dionex 3000, USA) has been used.

Microwave model CEM Mars 5 (USA).

The samples were analyzed using the Inductively Coupled Plasma–Mass Spectrometer manufactured by an Agilent 7500ce ICP-MS (Agilent Technologies, Tokyo, Japan).

Table 6.1 - Optimal ICP-MS operating conditions for analysis of studied samples

Instrument parameter	**Conditions**
Purity of argon gas	99.998 %
RF Power	1500 W
Plasma gas	15L/min
Carrier gas	0.9 L/min
Nebulizer pump	0.1rps
S/C Temp	2degC
Mod	Nogas mod
Integration Time	0.6(sec)
Rep	3
Interference Correction	ON

Table 6.1 present the ICP-MS parameter and it operating conditions for analysis the samples study. Before the measurement, calibration of ICP-MS spectrometer using multi-elemental mixture of metal standards (Agilent Technologies, Japan) was carried out.

6.2 Data Treatment and Statistics

Concentrations of heavy metals in fish (*Cyprinus Carpio*)muscle and gills were determined by Kruskal-Wallis Test, Mann-Whitney U Test for (Pb, Cu, Ni, Fe and Cr) and student T-Test for (As and Cd) and Pearson correlation coefficient to determine the relationship between concentration of heavy metals in muscles and gills and all data was expressed by Mean ± SD.

All calculation was carried out on a Microsoft EXCEL program for win-2016 and SPSS (statistical Package for the Social Sciences) version 20.0 statistical calculation program. The chosen level of significance is $p < 0.05$.

6.3 Preparation of Standard Solutions

For all determinations an internal standard mix (^{6}Li, ^{45}Sc, ^{72}Ge, ^{115}In and^{209}Bi) in 2% HNO_3matrix has been used for the external standard calibration method. NIST single-element reference standards were used to construct ten-point calibration curves.

6.4 Sampling locations

Selection of sampling stations for sediment and water samples considered the outlets for drain water from other areas into the lake. Sampling stations in table 6.2 were selected to provide information on the impact of natural and anthropogenic inputs of heavy metals into Gönyle Lake. For convenience purposes, the 4 sampling sites were categorized into 4 sites closed to stream water within the city.

Table 6.2- Location of study collection samples

Sample ID	Latitude	Longitude
Site 1	35.2322	33.3005
Site 2	35.2491	33.1432
Site 3	35.2487	33.3052
Site 4	35.2320	33.3002

6.5 Sampling procedure

Sediments and water samples were collected from two different sites, located in the north and east side of the laketo provide information on the impact of natural and anthropogenic inputs of heavy metals in the Gonyeli Lake in the Turkish Republic of Northern Cyprus.

An instrument (Scoop) was used to collect **sediment samples**. It was properly washed after each collection from the different sites to avoid contamination. For metals analysis, 250g of sediment samples were stored in labeled polyethylene bags and transported to the laboratory within 2 hours of collection and all the samples were stored at 4˚C until taking for analysis.

Surface **water samples** were collected also, 500 ml filled on plastic deionized bottles. Then the samples were carried to laboratory to store in dark at 4˚C to be ready for analysis.

Fish samples (*Cyprinus Carpio*) were caught from the location, fish samples were kept at -20°C until analysis. Sampling procedures are carried out according to Ohio EPA. (Ohio, E. P. A. 2001)

6.6 Sample treatment

Prior to testing, the sediment samples were dried in the air then thoroughly homogenized and sieved in analytical sieve shakers through a 2.0-mm mesh screen. The reason for using the sieve process is to remove large materials such as rocks, shells, debris, and wood > 2mm which could affect analysis. Preparing of the fish samples for analysis started with removing the muscle tissue of fish and chopped into pieces with the stainless steel knife. The chopped fish samples were air dried and oven dried and the finally, the dried samples were ground, sieved.

The digestion procedure for the soil and fish samples has been done by (800W) microwave oven, before the digestion polytetrafluoroethylene (PTFE) vessels were cleaned with 10mL 65% HNO_3 heated for 10min at 180°C and rinsed with ultra –pure water.

0.1 g of sediment sample was weighed. 6 ml HCl, 2ml HNO_3 and 1ml H_2O_2 were added to the vessels. All samples were digested using the same microwave conditions (a 15-min gradual increase in temperature to 180°C, a 15-min step, at 180°C, 800W).

7. RESULTS

Heavy metal concentrations in sediment obtained from four different sampling area of Gönyeli Dam Lake, were given in Table 7.1.

Table 7.1-Heavy metal concentrations in sediment for the study area

Heavy metals mg/kg	Site 1	Site 2	Site3	Site 4	Mean± SD
Cu	61.62	56.23	65.64	61.80	61.32±3.86
Ni	201.76	196.11	228.16	225.27	212.82±16.24
Cd	1.62	1.64	1.38	1.64	1.57±0.12
Pb	30.67	28.00	33.78	37.94	32.59±4.27
As	31.69	29.02	25.69	24.03	27.60±3.42
Cr	378.28	403.26	406.52	404.16	398.05±13.25
Co	38.58	30.28	33.21	31.86	33.48±3.60

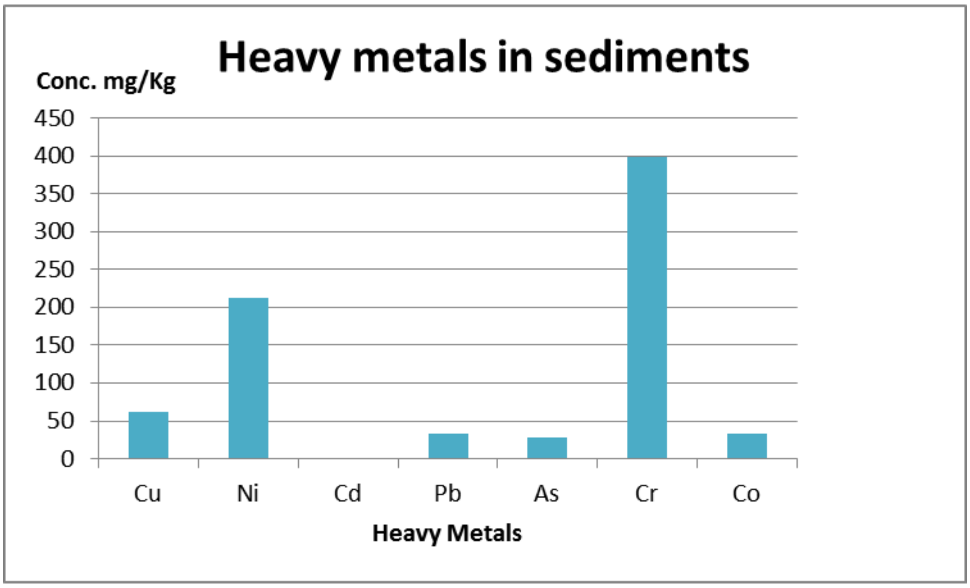

Figure 7.1- Heavy metals concentration in sediments

Assessment according to contamination factor

The contamination factor (CF) or Enrichment ratio (ER) and the degree of contamination (Cd) are used to detect the contamination status of sediments in present study determined following equation according to (Thomilson *et al.*, 1980) (Table 2. 2.). The level of contamination by metals was established by applying the CF that can be calculated as following equation:

CF = Cm sample / Cm background.

The average abundances of metals in the earth crust such as 44.71 for Ni, 25 Cu, 17 Pb and 69 Cr according to (Taylor & Mclennan, 1985) and to (Yuan-Hui Li, 2000).

Table 7.2- Classified grades of CF indices, after (Thomilson *et a*l., 1980) and (Boszke *et al*., 2004) in (Rabee *et al*., 2011)

Contamination factor CF	
<1	Low contamination (Class 1)
$1 \leq CF < 3$	Moderate contamination (Class 2)
$3 \leq CF \leq 6$	Considerable contamination (Class3)
> 6	Very high contamination (Class 4)

Table7.3 – Contamination factor and degree of contamination for heavy metals

Metals	Site 1	Site 2	Site 3	Site4
Cu	2.46	2.24	2.62	2.47
Ni	4.58	4.45	5.18	5.11
Pb	1.8	1.64	1.98	2.23
Cr	5.48	5.84	5.89	5.85

Table 7.3 present the contamination factor for the elements, Ni and Cr come in class 3 the considerable contamination so that Cr was appeared as maximum contamination factor in site3. Cu and Pb in class 2 moderate contaminations. On the basis of contamination factor, sediments are enriched for metals in the following order Cr> Ni>Cu>Pb.

Table 7.4- Comparison limits value for metal concentration in soil with US EPA, TSPCR

Heavy metal	Study samples mean±SD(mg/kg) (n=4, mean ±SD)	Polluted soil* (mg/kg)	USEPA guidelines for sediment (1998) (Moderately polluted)
Pb	32.59±4.27	150	40-60
Cd	1.57±0.12	5	-
Cr	398.05±13.25	250	25-75
Ni	212.82±16.24	100	-
Cu	61.32±3.86	100	25-50

* According to Turkish Soil Pollution Control Regulations (TSPCR 2000).

Table 7.4 shows the mean values for each element of the toxic heavy metals in soil samples investigated under the limits of polluted soil according to the TSCR2000 when the mean concentration were taken in the determination of contamination in the study area in the soil. But in US EPA the concentration of Cr and Cu shows that more than moderately polluted values.

Table 7.5-Heavy metals in the water samples

Metals	Concentrations (µg/l)				
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Mean ±SD**
Cd	1.082	0.9506	0.9496	0.9729	0.99 ±0.063
As	68.6	55.93	50.68	51.69	56.72±8.236
Pb	1.014	0.7982	0.6634	1.089	0.89±0.195
Cr	19.37	20.93	21.59	21.29	20.80±0.987
Ni	18.5	19.38	21.89	18.97	19.70±1.513
Co	1.347	1.224	1.432	1.217	1.30±0.103
Cu	28.6	27.85	29.38	29.29	28.78±0.711

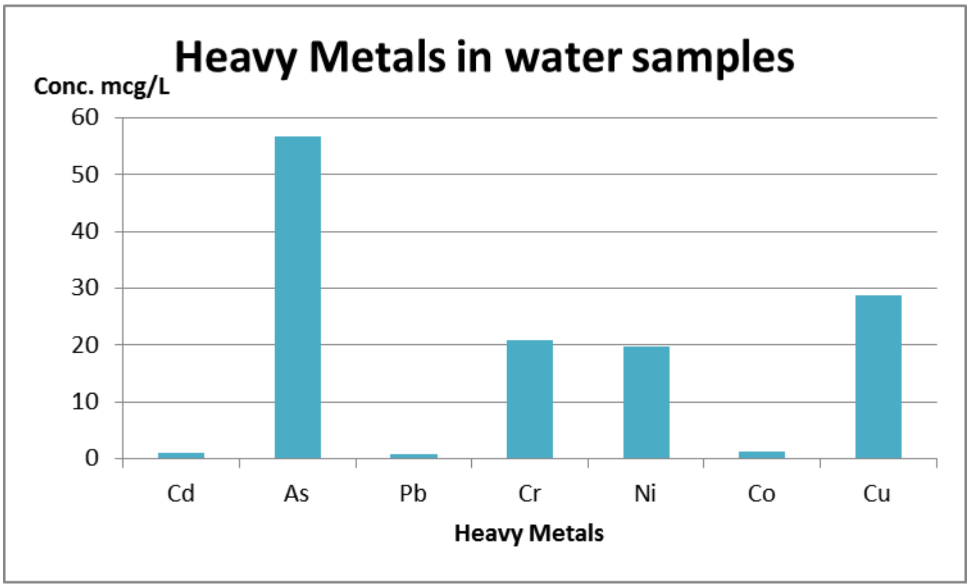

Figure 7.2- Heavy metals concentration in water samples

Table 7.6- Comparison between heavy metals concentration in water and international standard

Metals	**Concentrations (µg/l)**			
	Study sample values (n=4, mean ±SD)	**WHO standard guideline for heavy metals in drinking water (2004)**	**USEPA 2008**	**EU 1998**
Cd	0.99±0.06	3	5	5
As	56.72±8.23	10	10	10
Pb	0.89±0.19	10	15	10
Ni	19.68±1.51	70	100	20
Cr	20.79±0.98	50	100	50
Cu	28.78±0.71	2000	1300	2000

Table 7.6 shows that heavy metals mean±SD µg/l concentration in water samples increased more than international standard in arsenic but other elements below limits.

Table 7.7- Concentration of heavy metals in tissues muscle of the lake fish samples

Fish samples	Metals (mg/kg)						
	As	Pb	Cd	Cu	Ni	Fe	Cr
M1	0.35	2.6572	0.020	5.14	4.12	22.23	0.73
M2	0.30	0.1842	0.007	1.24	1.09	25.12	0.85
M3	0.50	0.4639	0.013	2.22	3.34	48.74	3.19
M4	0.41	0.0003	0.016	0.37	0.85	23.76	0.24
M5	0.24	0.0006	0.016	0.77	0.52	24.76	0.07
M6	0.43	0.0001	0.010	1.71	0.63	40.85	0.24
M7	0.43	0.0662	0.006	0.13	0.58	11.61	0.74
M8	0.65	0.2436	0.016	1.84	2.26	63.83	0.53
M9	0.47	0.0004	0.007	0.54	0.67	16.01	1.23
M10	0.35	0.0003	0.006	1.07	0.64	19.12	0.04
Mean± SD	0.41± 0.114	0.36± 0.820	0.01± 0.0051	1.50± 1.44	1.47± 1.308	29.60± 16.379	0.79± 0.925

Overall 10 samples of tissues muscle for the fish were collected from the lake, heavy metals concentration was found in these values Table 7.7 shows the mean concentration is increased for the elements in order to Fe>Cu>Ni>Cr>As>Pb>Cd. The heavy metal concentrations detected in the gill samples tested are shown in Table 7.8, where the Ni and Cu concentrations higher in fish muscle samples (Table 7.9).

Table7.8- Heavy metals in the tissue gills of the fish

Fish Samples	Metals (mg/kg)						
	As	Pb	Cd	Cu	Ni	Fe	Cr
G1	0.28	0.13	0.016	2.48	3.47	138.67	0.46
G2	0.35	0.08	0.015	2.34	6.16	233.05	0.26
G3	0.46	0.18	0.033	3.01	8.61	403.56	0.83
G4	0.68	1.44	0.034	3.73	10.38	672.92	1.83
G5	0.21	0.10	0.025	2.40	6.65	237.25	0.28
G6	0.52	0.08	0.041	2.69	5.96	172.87	0.37
G7	0.33	0.25	0.014	1.99	8.34	251.19	0.35
G8	0.47	0.06	0.010	1.27	5.74	261.56	0.29
G9	0.44	0.15	0.031	2.87	7.87	394.92	0.71
G10	0.45	0.07	0.011	1.86	5.43	236.91	0.27
Mean ± SD	0.42± 0.13	0.26± 0.42	0.02± 0.011	2.46± 0.67	6.86± 1.96	300.29± 155.3	0.57± 0.48

Table 7.9-Heavy metals concentration in fish tissues (muscles and gills) samples

Sample (n=10)	**Heavy metals (mg/kg) (mean ±SD)**						
	As	Pb	Cd	Cu	Ni	Fe	Cr
Muscle	0.413± 0.114	0.361± 0.820	0.0117± 0.0051	1.50± 1.44	1.47± 1.308	29.60± 16.37	0.78± 0.92
Gill	0.419± 0.133	0.257± 0.422	0.023± 0.011	2.46± 0.67	6.86± 1.96	300.29± 155.36	0.56± 0.48

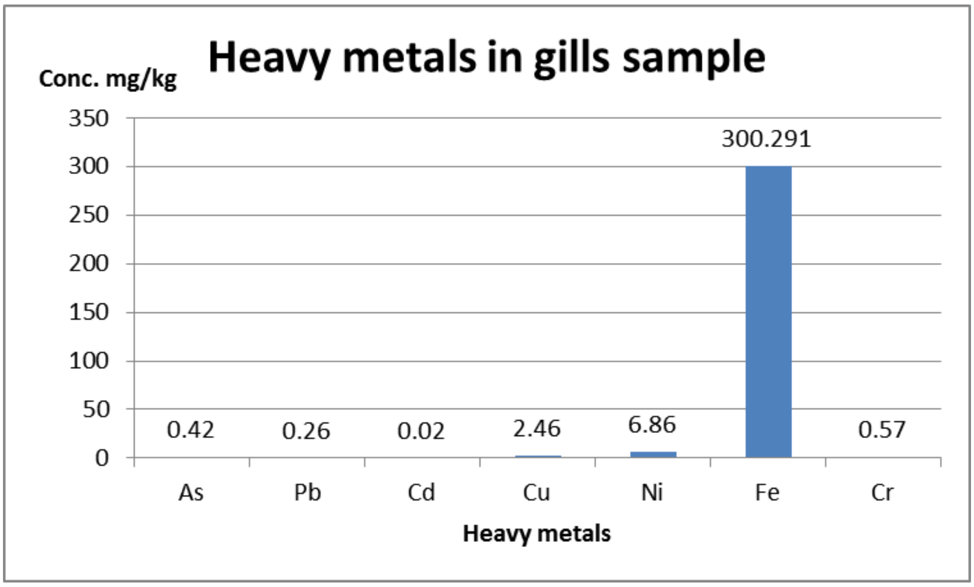

Figure 7.3-Heavy metals concentration in fish (gills) samples

Table 7.10- Comparative account of heavy metals concentration in fish with standard guidelines

Metals (ppm)	**Average concentration in study**	**Permissible limits of heavy metals in fish (ppm)**
Fe	164.94	100 (FAO/WHO 1989)
Ni	4.16	70-80 (USFDA 1993b)
Cu	1.98	3 (FAO/WHO 1983)
As	0.41	0.1 (FAO/WHO 1983)
Pb	0.3	0.2 (FAO/WHO 1983)
Cd	0.02	0.05 (FAO/WHO 1983)
Cr	0.68	0.15 (FAO/WHO 1996)

Values of heavy metal content in the present study are given as Mean ±SD. In this present study the heavy metals concentration in fish samples estimated that As, Pb, Cr and Fe with toxic levels when compare with international guidelines for heavy metals (Table 7.10).

Table7.11-Pearson correlation between metals in fish samples

Muscles / Gills	Ni	Cd	As	Pb	Cu	Fe	Cr
Ni	-0.368						
Cd		0.77					
As			0.491				
Pb				-0.141			
Cu					-0.83		
Fe						-0.39	
Cr							0.153

Correlation between metals in the different fish (*Cyprinus Carpio*) parts (muscles and gills) samples examined was determined using Pearson's correlation coefficient. A strong positive correlation exists between Cd in muscles and Cd in gills, r= (0.77) as shown in Table 7.11. Metals with strong positive correlations are related linearly, an increase in concentration of one metal leads to increase in concentration of the other and vice versa.

Table7.12-Statistical analysis between 20 samples in fish (Muscles and gills)

Fish Sample	Metals and p values						
	Pb	Cr	Ni	Cd	As	Cu	Fe
Muscle Gills	0.698	0.673	0.027*	0.833	0.149	0.819	0.914

*There is a statistically significant difference ($p < 0.05$) between two groups (muscle and gills)

8. DISCUSSION

Because of risk assessment is an important for hazard identification and risk management, to estimating health or environmental outcomes. It is the expected value of undesirable consequences on hazard. This study established to the risk management in TRNC and presently, one of the most concerning pollutants around the world is heavy metals toxicity.

As we know no national standard related to heavy metal pollution is available, so international reference values have been used to assess the risk. In this current study the heavy metals mean concentrations in the results obtained were compared with the international guidelines for heavy metals such as United States Environmental Protection Agency (U.S.EPA), Turkish Soil Pollution Control Regulations (TSPCR 2000), WHO,FDA and European Commission (EC).

Different studies have been done to asses for heavy metals contamination in the environment due to anthropogenic activities, so heavy metal concentrations in the sediments are not only appropriate indicator of pollution (De Luca *et al*., 2004) (Cukrov *et al*., 2011) but physical movement and chemical interactions within the sediment can control the transport and storage of toxic metals consequently the degree of risk they appear to the environment and people ingest sea food. Heavy metal contamination in sediment can change the water quality and the bioaccumulation of metals in marine life, which cause potential long-term consequence on human health and environment.

Table1 present the heavy metal concentration in four samples from varied sites. (Cu, Ni, Cd, As, Cr, Pb, Co) were detected in all sites, the highest metal concentration was found in site 3 (406.52 mg Cr kg^{-1}) and the lowest concentration was also in site 3 (1.38 mg Cd kg^{-1}). Generally, heavy metals concentrations in the sediments were decreased Cr>Ni>Cu>Co>Pb>As>Cd respectively. The comparison of mean concentration of heavy metals with USEPA standard in table 4 demonstrated all of the elements exceeded the moderately polluted values except Pb. The sites contained high concentration of Ni and Cr, but lower concentration of Cd, Cu, As and Pb when compared to TSPCR standard. Metals were founded in northern Cyprus due to geochemical structure of the region and old center of copper mining activities. These elevated results indicated that Ni and Cr originated from parent rock weathering. Obtained data showed that sediments were moderately contaminated by metals. The contamination levels of Cu and Ni levels were defined as moderately polluted at all sampling stations indicating Cu mining disposal effects at western part of Northern Cyprus.

The concentrations of Cd, As, Pb, Cr, Ni, Co and Cu were determined in the surface water of the lake, the mean concentrations of the selected metals and the standard deviations presented in Table 7.5 and Table 7.6.The Cd, Pb, Cr, Ni and Cu concentration in lake water lower than WHO, EPA and EC-1998 standards, while the As concentrations higher than international standards. High arsenic concentrations are also found in some alkaline lakes as a result of extreme evaporation and/or geothermal inputs.

Assessment of heavy metal contamination and spatial distribution in surface and subsurface sediment layers in the northern part of Lake Babrukas by Raulinaitis, M *et al.*, 2012 the detected level of heavy metals As from 6.14 to 24.59 mg/kg, Cd from 10.75 to 31.79 mg/kg, Cr from 16.38 to 76.97 mg/kg, Cu from 17.18 to 32.41 mg/kg, Hg from 0 to 10.25 mg/kg, Ni from 0 to 67.35 mg/kg, Pb from 0 to 7.25 mg/kg. Detected levels of chromium (Cr), copper (Cu) and nickel (Ni) exceeded background concentrations in Lithuanian soils and lake sediments up to 7.25 times and show evidence of the effects of anthropogenic activity. When compare with current study the concetrations of Cr, Ni and Cu , (398.05mg/kg, 212.82 mg/kg and 61.32 mg/kg) respectivley exceeded the values of the Lake Babrukas study but Hg not detcted in current study.

Concentrations of some heavy metals in water, sediment and fish species from the Ataturk Dam Lake (Euphrates) in Turkey by Hulya Karadede and Erhan Ünlü, 1999. The concentration of Ni, Cu and Fe in water (0.011-0.0154ppm, 0.025-0.22 ppm and 0.062 ppm) respectivley and in sediment (43.69-139.69 ppm, 14.57-22.7 ppm and 12587-19265 ppm) respectivley. Heavy metals in fish only (*Cyprinus Carpio*) muscle part Cu and Fe (2.23 ppm and 11.51 ppm) respectivley. The concentration of Cu and Ni in sediment and water for current study exceeded the concentration of this study and in fish Cu value 1.5 ppm higher than curent study but Fe is lower than this study.

Monitoring of environmental heavy metals in fish from Nasser lake by (Rashed, 2001) investigated the mean concentration and standard deviation of elements in fish(*Tilapia mossambica*) parts (gills and muscles), the lowest concentration of heavy metals in muscles 0.078 µg/g mean concentration of Cr in muscle, 0.216 µg/g in gill. 0.260 µg/g Cu in muscle and 0.338 µg/g of Cu in gill, 0.062 µg/g Ni in muscle and 0.132 µg/g Ni in gill. When compared these results with examined current results, it observed this study lower than values of current study. The mean concentration (ppm) of Copper (Cu), Nickel (Ni) and Chromium (Cr) were determined and the levels of these heavy metals concentration were measured in the fish (*Tilapia mossambica*) organs (gill and muscle) by Khillare *et al.,* 2015; the results of analysis presented as the highest mean concentration of Copper is 0. 46 ppm in gill and 0.32 ppm in muscle, the mean concentration of Ni in gills (0.73-0.52 ppm) and in muscle (0.15-0.18 ppm), the highest concentration of Cr in gills (4.84 ppm) and in muscle (4.23 ppm), only the Cr mean concentration of this study exceeded the Cr concentration in examined study

9. CONCLUSION

In this current study, it can conclude that, the concentration of Chromium, Nickel, Lead, Arsenic, Cadmium and Copper are noticeable in fish, sediment and water samples of the lake. Because heavy metals are non-degradable and tend to bio-accumulate, their levels may increase over time resulting in elevated concentrations in the organisms. The values reported in this study may provide as baseline data to observe future anthropogenic activities in the area. Although this study established that there is a presence of heavy metals in and around Gönyeli Lake and that these contaminants accumulate in the resident organisms through the process of biomagnification, further studies are necessary to better assess the potential hazards of heavy metals in these organisms. Heavy metals are known to be neurotoxic and genotoxic. The assessment of these effects through DNA damage detection techniques, such as Alkaline Comet Assay or Cytokinesis-blocked Micronucleus Assay needs to be conducted to determine genotoxic risks. These assays will enable to better assess the dangers to genetic integrity of all exposed persons. Moreover, regular close monitoring and regulation of such highly contaminated places as Gönyeli Lake in the future for heavy metal levels will help reduce the risks to the population to a minimum. Heavy metals are associated with genetic malfunctions (DNA damage or otherwise) at relatively minute quantities and their concentration must be kept at as low as possible, and sources of heavy metal pollution eliminated, to minimize potential risks for genetic diseases or cancer.

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11. APPENDIX

Figure 11.1- Gonyeli Lake

Figure 11.2- Sampling area from the Gonyeli Lake

Figure 11.3- Water sample from the Gonyeli Lake

Figure 11.4- Sediment sample from Gonyeli Lake

Figure 11.5- Fish samples from Gonyeli Lake