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CHARACTERIZATION OF METALS AND NON-METALS IN THE INDIAN OIL SARDINE (SARDINELLA LONGICEPS) IN THE NORTHERN UNITED ARAB EMIRATES

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United Arab Emirates University

College of Science

Department of Biology

CHARACTERIZATION OF METALS AND NON-METALS IN THE INDIAN OIL SARDINE (*SARDINELLA LONGICEPS*) IN THE NORTHERN UNITED ARAB EMIRATES

Shaima Malik

This thesis is submitted in partial fulfilment of the requirements for the degree of
Master of Science in Environmental Sciences

Under the Supervision of Professor Sabir Bin Muzaffar

June 2020

Declaration of Original Work

I, Shaima Malik, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*Characterization of Metals in the Indian Oil Sardine (Sardinella longiceps) in the Northern United Arab Emirates*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Professor Sabir Bin Muzaffar, in the College of Science at UAEU. This work has not previously been presented or published or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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Abstract

The marine ecosystems of the world are especially susceptible to pollution arising from anthropogenic sources. The Arabian Gulf ecosystem is a partially enclosed hypersaline system with increasing levels of pollution arising from ongoing development in the region. Marine biota are expected to be influenced by pollutants and levels of trace elements in marine species could be indicative of increasing pollution. Bioaccumulation of 19 elements (As, Ca, Cd, Co, Cr, Cu, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sr, V, Zn) in 120 specimens of Indian oil sardines (*Sardinella longiceps*) purchased from local fish markets of Sharjah, Ajman and Umm Al Quwain in the United Arab Emirates were studied. The fish samples were dissected to obtain liver, gastrointestinal tract and muscle tissue resulting in a total of 360 samples. The Varian 720-ES (ICP-OES) system was used for determining metals and non-metals (As, Ca, Cd, Co, Cr, Cu, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sr, V, and Zn) and the Varian SpectrAA 220 FS was used to determine Mercury (Hg) concentration in the liver, gastrointestinal tract and muscle of *Sardinella longiceps*. Discriminant analysis showed that some elements were useful in discriminating between the three sampling areas. Cadmium, chromium, and copper were high in concentration in the liver and gastrointestinal tract compared to the internationally acceptable limits. In addition, cadmium and chromium in the muscle samples had concentrations above or equal to permissible levels. Pollutants in muscle are indicative of high levels in the environment and is of great concern to marine food webs due to their potential for biomagnification. High levels in muscles raises health concern with respect to human consumption. Thus, there is an urgent need to monitor pollutants in fish and other marine organisms and link them with specific types of industries. Initiatives need to be taken for managing, protecting, and monitoring the marine environment.

Keywords: Potential toxic element, Bioaccumulation, Arabian Gulf, *Sardinella longiceps*, Spectrometer.

Title and Abstract (in Arabic)

تحديد خصائص المعادن والفلزات في زيت السردين الهندي (سردينيلا الرئة) في شمال الإمارات العربية المتحدة

الملخص

النظم البيئية البحرية في العالم عرضة بشكل خاص للتلوث الناجم عن المصادر البشرية. تمت دراسة التراكم الحيوي لتسع عشرة عنصراً من المعادن الثقيلة (الزرنيخ، الكالسيوم، الكادميوم، الكوبالت، الكروم، النحاس، الزئبق، البوتاسيوم، المغنيسيوم، المنجنيز، الموليبدنوم، الصوديوم، النيكل، الفوسفور، الرصاص، الكبريت، السترونشيوم، الفاناديوم والخارصين) في أجسام مئة وعشرين سمكة من أسماك سردين الزيت الهندي، والتي تم شراؤها من الأسواق المحلية في إمارات الشارقة وعجمان وأم القيوين التابعة لدولة الإمارات العربية المتحدة. تم تشريح عينات الأسماك للحصول على الكبد والقناة الهضمية وأنسجة العضلات ليصل مجموع العينات إلى ثلاثمئة وستون عينة. تم استخدام نظام (Varian 720-ES (ICP-OES)) للكشف عن معادن الزرنيخ والكالسيوم والكادميوم والكوبالت والكروم والنحاس والبوتاسيوم والمغنيسيوم والمنجنيز والموليبدنوم والصوديوم والنيكل والفسفور والرصاص والكبريت والسترونشيوم والفاناديوم والخارصين في الكبد والقناة الهضمية وعضلات الأسماك بينما تم استخدام نظام (Varian SpectrAA 220 FS) لتحديد تركيز الزئبق. تظهر التحليلات أن بعض المعادن مهمة للتمييز بين مناطق جمع العينات الثلاثة. مقارنةً مع المعادن الثقيلة الأخرى الموجودة في أسماك سردين الزيت الهندي؛ كان تركيز الكادميوم والكروم والنحاس في الكبد والقناة الهضمية مرتفعاً عن المستوى المقبول من قبل التوصيات الدولية. بالإضافة إلى ذلك، كان تركيز الكادميوم والكروم في عينات العضلات أعلى من أو يساوي المستويات المسموح بها. يشير التلوث في العضلات إلى المستويات العالية في البيئة ويعتبر مصدر قلق كبير للشبكات الغذائية البحرية لاحتمالية تضخمها الحيوي بالإضافة إلى أن المستويات العالية في العضلات قد تسبب مشكلات صحية للمستهلكين من البشر وبالتالي هناك ضرورة ملحة للإسراع في رصد الملوثات في الأسماك والكائنات البحرية الأخرى وربطها بأنواع محددة من الصناعات. كما أن هناك ضرورة لاتخاذ مبادرات لإدارة البيئة البحرية وحمايتها ومراقبتها.

مفاهيم البحث الرئيسية: عنصر سام محتمل، التراكم الحيوي، الخليج العربي، سردين الزيت الهندي (*Sardinella longiceps*)، المطياف الضوئي.

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Dedication

To my beloved parents and brother

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List of Abbreviations

AJ	Ajman
Al	Aluminium
As	Arsenic
Ca	Calcium
CCD	Charged Coupled Detector
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
FAO	Food and Agriculture Organization
Fe	Iron
GI	Gastrointestinal tract
ICP- OES	Inductivity Coupled Plasma Optical Emission Spectrometers
Hg	Mercury
K	Potassium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
NOAA	National Oceanic and Atmospheric Administration
Nm	Nanometre
Ni	Nickel
P	Phosphorus
Pb	Lead

PCB	Polychlorinated biphenyls
Ppb	Parts per billion
Ppm	Parts per million
S	Sulphur
SHJ	Sharjah
SPECTR AA	Atomic Absorption Spectrometer
Sr	Strontium
UAQ	Umm Al Quwain
US EPA	United States Environmental Protection Agency
UNEP	United Nation Environment Program
UN EPA	United Nations Environmental Protection Action
V	Vanadium
WHO	World Health Organization
WWF	World Wildlife Fund
Zn	Zinc

Chapter 1: Introduction

1.1 Overview

Nutrient cycles are an integral part of the marine ecosystems nitrogen, phosphorus and silicon are especially important (Cunningham & Cunningham, 2010). There are also several trace elements and organic compounds that can be considered as nutrients because of their high concentration in water, example sodium, potassium and calcium (Cunningham & Cunningham, 2010). The input of these nutrients into the marine ecosystem is through glaciers, volcanic activity and riverine discharge (Cunningham & Cunningham, 2010). Even though there is certain amount of nutrients released into the waterbodies these nutrients are not in the same concentration throughout the marine waters (Cunningham & Cunningham, 2010). Nutrients may either become assimilated by phytoplankton and enter into food webs, accumulate in sediments or removed by adsorption on to solid particles (Cunningham & Cunningham, 2010). Increase in the number of industries with developed technologies is directly proportional to the increase in the amount of pollutants released in the marine ecosystem (Kumar et al., 2013). In order to maintain a standard level of food with respect to safety in consuming them, there has been a keen interest to study the contamination level in the marine food, especially fish (Ashraf, 2005). The marine environments are monitored occasionally and the main reason for monitoring the marine ecosystem is to track the contamination level, as the concentration of the metals and non-metals is increasing steadily in recent years (Ashraf, 2005). Metals and non-metals are either essential macronutrients or micronutrients that are required in small quantities (Ashraf, 2005). These metals and non-metals occur naturally or at times are the product of the anthropogenic activities (UNEP, 2004; Adal & Tarabar, 2013). Once they enter the ecosystems, they travel through food webs by accumulating in the tissues of the aquatic animals resulting in bioaccumulation (Kalay et al., 1999). These levels can be used to study the contamination level and apply useful methods to overcome the level of contamination (Kalay et al., 1999).

During the 1991 Gulf war about 460 million gallons of oil was released into the Arabian Gulf, causing major pollution and direct mortality of fish, seabirds and marine mammals (Issa & Vempatti, 2018). At present the amount of pollution contributed by United Arab Emirates is increasing due to the following anthropogenic activities: presence of industries that are close to coastlines, sewage effluents, dredging and reclamation, waste disposal and hypersaline water discharges from desalination plants. The concentration of the metals and non-metals in the marine organisms present in the Arabian Gulf have gradually increased (Al-Ghais, 1995; Kalay et al., 1999; Kureishy, 1993; Naser, 2013; Sadiq & Zaidi, 1985; Sheppard et al., 2010).

In this study, Indian oil sardine was examined (*Sardinella longiceps*), a small forage fish species, collected from local fish markets from Sharjah, Ajman and Umm Al Quwain. Indian oil sardines are widely consumed by people and used as bait fish. Three tissues for metals and non-metals namely Arsenic (As), Calcium (Ca), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Mercury (Hg), Potassium (K), Magnesium (Mg), Manganese (Mn), Molybdenum (Mo), Sodium (Na), Nickel (Ni), Phosphorus (P), Lead (Pb), Sulfur (S), Strontium (Sr), Vanadium (V) and Zinc (Zn) were tested. The aims for this study were to:

1. Quantify metals and non-metals contamination in the fish tissues (liver, gastrointestinal tract and muscle).

2. Compare the variation in metals and non-metals with respect to the sampling sites.
3. Assess the obtained metal and non- metal levels in relation to international guidelines.

1.2 Statement of the Problem

The Arabian Gulf has unique oceanographic characteristics with a semi-enclosed structure making it vulnerable to pollution (Fowler et al., 1993; Naser, 2013). Salinity in seawater usually ranges from 30 - 35 parts per thousand (g/kg) but due to high evaporation rate in the Arabian Gulf, the salinity could reach up to 40 g/kg, especially in the northwestern regions (Fowler et al., 1993). In the shallow intertidal lagoons of the Arabian Gulf the salinity can exceed 70 g/kg (Fowler et al., 1993). High salinity imposes environmental stress on the marine species making the respective species more susceptible to the effects of pollution (Fowler et al., 1993). In the Arabian Gulf turnover rate ranges from 3 to 5.5 years, during this period contaminants including a variety of organic pollutants, metals and non-metals circulate within the Arabian Gulf (Krupp et al., 1997; Naser, 2013). These circulating pollutants may bioaccumulate in marine organisms and magnify along the marine trophic levels and they also reside in the Arabian Gulf for considerable period (Krupp et al., 1997; Naser, 2013).

Discharge of metals and non-metals constitute a serious threat to the marine ecosystem of the Arabian Gulf from industrial effluents, sewage, coastal modifications, brine discharge and oil pollution (Naser, 2013). Fish are important components of marine food webs that accumulate varying levels of pollutants, including metal and non-metal particles, at different trophic levels.

1.3 Relevant Literature

The total length of the coastlines around the world is 1.6 million km, covering about 123 countries (UNEP, 2015) and the amount of economic benefits obtained from the oceans is about US $ 2.5 trillion per year (WWF, 2019). Thus, numerous resources and benefits are obtained from the marine environment. Various anthropogenic activities are either reducing or decreasing the amount of marine resources (UNEP, 2015). These anthropogenic activities come in different forms like overexploitation, pollution, dumping waste, sewage and invasive species (Naser et al., 2008; Sheppard et al., 2010). The sources of pollution can be differentiated into two types, namely, (i) point source pollution, where the source of the pollution can be identified based on the contaminants present; and (ii) non-point source pollution, in which the pollution is caused by various polluters over a wide area and it is difficult to track the polluter (Cunningham & Cunningham, 2010; Schreiber & Burger, 2001). Synthetic organic compounds, plastics, metals, non-metals, polycyclic aromatic hydrocarbons (PAH), oil or hydrocarbon, radionuclides and sewage are the prominent contaminants present in the marine environment albeit origin of these contaminants is usually land-based (Hassan & Karim, 2018). About 80% of the pollution found in the marine environment is due to the runoff from the land to the nearby waterbodies composed primarily of agricultural waste pesticides and fertilizers (NOAA, 2018). Such runoff from land are a huge risk to the marine environment as they have the ability to contain a range of pollutants that are often toxic, persistent, and have the ability to bioaccumulate in food webs (Hassan & Karim, 2018). Involvement of humans with the marine environment has intensified the rate of pollution (Vikas & Dwarakish, 2015). Marine pollution can be defined as ‘the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects such as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities’ (Irving et al., 2019).

Marine contaminants cause disease and mortality in marine organisms, as observed in Southern Brazil with sea turtles between the year 1997 to 1998 where many sea turtles (green turtle- *Chelonia mydas*, loggerhead turtle- *Caretta caretta* and leatherback turtle- *Dermochelys coriacea*) had ingested plastic debris resulting into death (Bugoni et al., 2001). About 8 million tons of plastic waste ends up in the ocean every year (UNEP, 2019). Metal and non-metal pollution have also featured prominently in the marine ecosystem due to increase in industrial waste and urban development (Buccolieri et al., 2006). Sediments can be used to understand metal and non-metal pollution in the marine environment since the presence of an industry near the coastline is often linked to water and sediment quality (Buccolieri et al., 2006). Measuring metals and non-metals in surface sediments is beneficial, as sediments absorb a variety of elements when exposed (Buccolieri et al., 2006). Sediment evaluation was conducted in Taranto Gulf, Southern Italy around year 2004 where borderline presence of heavy metal was recorded (Buccolieri et al., 2006). Another study was conducted in Al- Jubail area of Saudi Arabia in the Arabian Gulf where arsenic, cadmium, copper, mercury, nickel and vanadium levels were higher in the sediments compared to the average concentration (El-Sorogy et al., 2018). The reasons for the contaminants deposition in the area was due to sewage effluents, landfills, petroleum industries, coastal infrastructure and desalination plants (El-Sorogy et al., 2018). Distribution and accumulation of metals in the sediments is due to human activities causing change in the mineral composition, texture, adsorption, oxidation and reduction state, deposition and physical transport (Buccolieri et al., 2006). Usually the sediments absorb metals and non-metals from the water column through fine surface particles and this influence and brings about different changes in the ecosystem by bioaccumulation and biomagnification. This could lead to an increase in the metal and non-metal concentration that may cause introduction of toxins and affect the marine environment through the process of assimilation where the phytoplankton has the ability to absorb, accumulate and transfer the same to the higher trophic level organisms (Buccolieri et al., 2006; Xu et al., 2001).

Accumulation of the organic compounds or metals can have adverse effects on the marine organisms and hamper the marine ecosystem (Mackay et al., 2018). For example, Hg is one of the most toxic metals that can bio magnify in the marine trophic levels (Bełdowska & Falkowska, 2016; Mackay et al., 2018). Thus, the process of accumulation of contaminants begins with the contaminants are assimilated into the body of the organisms. Contaminants may pass through the bodies of organisms to become stored in different tissues by a process called bioaccumulation (Mackay et al., 2018). Biomagnification occurs when the contaminants magnify as pollutants transfer from one organism to another across the entire food chain or food web due to feeding interactions, affecting the organisms belonging to different trophic levels (Mackay et al., 2018). The process of biomagnification is illustrated in Figure 1 where polychlorinated biphenyls (PCB- one of the highly toxic industrial compounds) pass from the phytoplankton and increase successively while moving upwards in the food chain passing from small fish to large fish, seabirds and other marine mammals (Naser et al., 2008; Jitar et al., 2015). Phytoplankton is the primary link of a marine food chains or food webs that interact with the environment through chemical and biological processes by excretion, bioaccumulation, production of organic matter and decomposition (Jitar et al., 2015). Thus, the accumulation of metal and non-metal contaminants depends on interaction and consumption by the algae and ultimately accumulating in the fish and other marine organisms (Jitar et al., 2015).

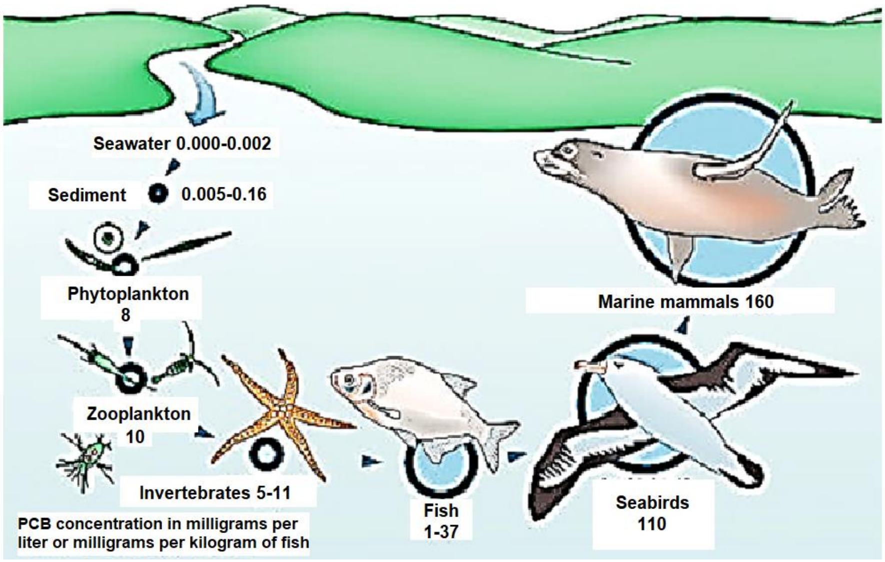

Figure 1: Biomagnification of PCB in a marine food web. Concentrations (mg/l) increase moving from lower to upper trophic levels in the food web.

Source: (World Ocean Review, 2010).

1.3.1 Metal and Non-Metal Accumulation and Effects on Fish

The aquatic system consists of numerous habitats namely lakes, rivers, springs, wetlands, estuaries, reefs, coastal habitats and sea (Nelson et al., 2016; Jennings et al., 2008). Fish contributes a huge standing biomass in the aquatic system (Jennings et al., 2008) and more than 30,000 species are known (Craig., 2016; Hughes, 2015; Nelson et al., 2016). The fishery industry is considered one of the largest industries that serves as an important part of the economy of many countries (Craig., 2016; Hughes, 2015). Currently increase in the pollution (Dudgeon et al., 2006) due to toxic discharge in the lakes and rivers has killed many fish (Kangur et al., 2013). Similarly, freshwater pollution and eutrophication in Europe has caused the death of eight out of thirteen species as a result of suffocation and lack of nutrients (Freyhof & Brooks, 2011).

Fish are vulnerable to pollutants and some species are sensitive to toxicants (Zaki et al., 2014) making them suitable to study alterations occurring in marine ecosystems due to chemical, physical, or biological changes (Khoshnood, 2017). The early detection of the toxic effect of pollutants can be observed at a cellular or a tissue level, while chronic effects can be identified much later in the behavior or the external features of the fish (Mary et al., 2014; Harley & Glover, 2014). International standards for contaminant levels in fish have been established (Mary et al., 2014; Harley & Glover, 2014). As transfer of the toxic compounds in the trophic level can lead to serious issues, especially to the marine environment where the organisms may suffer behavioral changes, endocrine disruption, metabolic and physical alterations (Mary et al., 2014; Harley & Glover, 2014). Maintaining the internal ion level above the ions present in the surroundings is one of the functions performed by the fish continuously for survival (the active uptakes by the fish are Na^+, Cl^-) (Harley & Glover, 2014). Gills are one of the flexible sites for uptake of ions that can also consist of dissolved metal ions entering the body through absorption. Disruption in the uptake of ion can lead to the death of the fish (Harley & Glover, 2014). Other routes for the contaminants to enter the body of fish is ingestion of contaminated food through the alimentary canal or by skin absorption. Toxic contaminants present inside the body may be transported in the blood to different organs ultimately accumulating in the tissues (Adeyemo et al., 2010; Fazio et al., 2014). The fish gets affected the most during the embryonic or larval stage of its life cycle (Khoshnood, 2017). The response to the stressors experienced by the fish is divided into three: (i) effects on neuroendocrine function where there is disfunction observed in osmoregulation, maintaining saltwater balance, mating and laying eggs (Nascimento et al., 2012); (ii) changes in the plasma and tissue ion and metabolic levels and hematological features that relate to physiological adjustments in metabolism, respiration, acid- base status, hydro- mineral balance, immune function and cellular responses (Nascimento et al., 2012); and (iii) effects of whole animal performance such as changes in the growth condition, overall resistance to disease, metabolic scope for activity, behavior and ultimately survival (Nascimento et al., 2012).

Metals and non-metals either occur naturally or by anthropogenic means and they belong to the group of metals and metalloids having an atomic density of 4 to 5 g/cm or more compared to water (UNEP, 2004; Adal & Tarabar, 2013; Ozparlak et al., 2016). Metals are a metallic element with high density (Ozparlak et al., 2016), non-biodegradable and persistent but can cause deleterious effects (Javed & Usmani, 2016) as it is toxic even at low concentration (Ozparlak et al., 2016). Irrespective of a prolonged or an acute exposure there will be minute effects of metals seen on the respective organism (Javed & Usmani, 2016).

Some of metals and non-metals are described below based on their occurrence and their effects on fish.

Aluminum (Al)- After oxygen and silicon, Al is the most abundant and common metal found (Authman, 2011). Aluminum concentration is inversely proportional to pH and it is soluble in water having pH below 6 (Authman, 2011).

Aluminum used at its lowest concentration of 0.52 mg/l causes reduction in growth of fish, and could cause cardiovascular problems (Laitinen & Valtonen, 1995), hematological issues (Barcarolli & Martinez, 2004), difficulty in respiration and damage of gills (Peuranen et al., 1993), reproduction (Vuorinen et al., 2003), endocrine (Waring et al., 1996) and metabolic problems (Brodeur et al., 2001).

Arsenic (As)- Naturally As occurs in air, soil, rock and water (Järup, 2003; Liao et al., 2004). Inorganic and organic arsenic are found in groundwater and fish respectively (Järup, 2003). The anthropogenic reasons for the presence of As is smelting activities causing water and atmospheric pollution (Järup, 2003). Arsenic has the ability to accumulate in the sediments and aquatic organisms (Järup, 2003; Liao et al., 2004). Accumulation of arsenic is usually in the liver, kidney or retina of the fish and when exposed to the metal the effect is seen on the immune system and only a short term exposure of non- lethal arsenic can make them susceptible to infections (Liao et al., 2004).

Cadmium (Cd), Copper (Cu), Lead (Pb), Zinc (Zn) – Cadmium occurs naturally in ores with Pb, Zn and Cu (Järup, 2003). Cadmium is a nonessential trace metal (Liao et al., 2011). Copper is an essential trace metal and a micronutrient in living organisms for cellular metabolism (Monteiro et al., 2009). Even though Pb is a naturally occurring metal, human activities have influenced and increased the amount by manufacturing batteries, metal mining, the use of lead-based gasoline and paints (Authman, 2011). Zinc is one of the important micronutrients in the living organisms as it is the second most abundant trace element found (Sfakianakis et al., 2015). Cadmium accumulates and causes oxidative stress whereas increase in Cd, Cu and Pb concentration leads to mortality or deformities in embryonic and larval stages and may weaken the immune system making the fish more susceptible to infections (Low & Higgs, 2015). Copper also disturbs the reproduction, life span, physical appearance and behavioral changes of the fish (Farag et al., 2006; Yacoub & Gad, 2012).

Iron (Fe)- Industries and mining effluents are the reason for presence of Fe in the aquatic ecosystem and ferric iron is considered more toxic than ferrous iron with respect to fish (Authman, 2011) as they can bioconcentrate in fish tissues like liver, brain, heart and muscle, affect the respiratory system by damaging the gills causing suffocation in fish (Authman, 2011). Precipitation of iron compounds on the fish eggs surface can cause death due to lack of oxygen (Authman, 2011).

Chromium (Cr)- Chromium is required for carbohydrates metabolism and is an essential nutrient (Farag et al., 2006). The anthropogenic sources in the aquatic ecosystem is through textile, leather industry, electroplating, mining, metal finishing, dyeing, ceramic, printing industries, pharmaceutical industries and photographic (Arunkumar et al., 2000). Increase in concentration leads to toxic effects causing histological and morphological, hematological, growth reduction and impaired immune system (Reid, 2011).

Mercury (Hg)- Methylmercury is considered most toxic because this organometallic compound has been derived from inorganic mercury and is highly lipophilic having the ability to cross the blood brain barrier (Authman, 2011) causing immunotoxicity, neurotoxicity, nephrotoxicity and mutagenicity (Bełdowska & Falkowska, 2016). The classic case related to mercury toxicity is of Minamata Bay, Japan where methylmercury had been dumped in the Bay and the effect was seen on the marine food chain affecting not only large fish but other marine organism like seabirds (Reynolds, 1996; Moffett et al., 2015). Many fish did not survive mercury poisoning and the seabirds that consumed contaminated fish showed neurological dysfunctionality (Reynolds, 1996).

The principle by which the metals and non-metals can affect not only the fish, but other organisms is the exposure and dose of the substance (Moffett et al., 2015). The metals and non-metals present in the effluents of industries are been reported to be toxic (Mary et al., 2014). The toxin can be termed as toxic depending on two factors that is the duration of exposure and the dose of the toxin (Moffett et al., 2015). Considering the example of Cu being an essential metal for most of the living organisms, but if high in concentration it can affect the fish internal activities, cortisol secretion and the ability to sustain stressful situations (Nascimento et al., 2012). The exposure is the duration an organism is exposed to the toxins. For example, fish may be exposed to numerous chemicals and different forms of pollution through breathing, ingestion of food and water (Campbell & Cohall, 2017). The exposure of the toxic substances that are readily bioavailable can then enter into the organism's body and affect different organ systems by absorption and distribution through the blood stream (Campbell & Cohall, 2017; Schreiber & Burger, 2001). The effect of the toxin can be acute where the impact ends after a short period of time and no accumulation takes place. In contrast, in the chronic stage, accumulation takes place in the organism's body (Campbell & Cohall, 2017; Schreiber & Burger, 2001). Effects of the pollutant can be restricted to few individuals or go to an extend by affecting the entire population of a species (Schreiber & Burger, 2001).

Forage fish are mainly small to medium pelagic fish (Alder et al., 2008). Figure 2 describes forage fish with their advantages as they have both ecological and economic benefits and the prominent forage fish are anchovies, sardines and herrings (Alder et al., 2008; Essington et al., 2015; Hilborn et al., 2017).

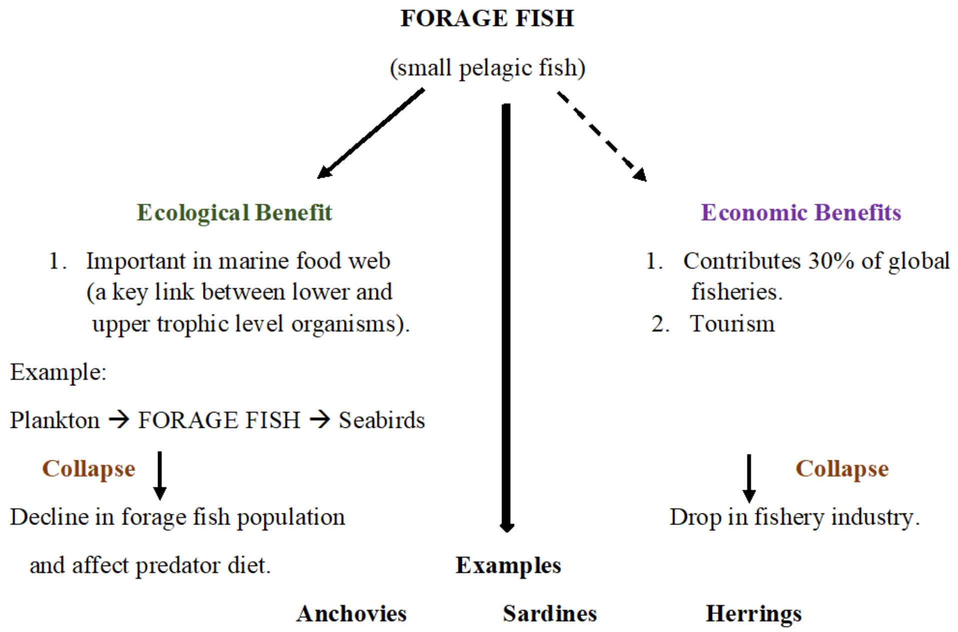

Figure 2: The contribution of forage fish towards ecological and economic benefits. Sources: (Alder et al., 2008; Essington et al., 2015; Hilborn et al., 2017).

1.3.2 Arabian Gulf: Sardines and Sources of Metals and Non-metals

The Arabian Gulf is a northern extension of the tropical Indian Ocean with shallow sea and its depth does not exceed 120 meters (Krupp et al., 1997). During Pleistocene glaciation (started about 2.6 million years ago and lasted for about 11,711 years ago) the entire world sea level had dropped, and the Arabian Gulf consisted of a dried-up basin with loss of marine life (Krupp et al., 1997). In the Indo-Pacific origin, recolonization had started by plants and animals about 17,000 years ago (Krupp et al., 1997). In geological term this recolonization is considered as a recent incident (Krupp et al., 1997). Indian Ocean and the Arabian Gulf is connected by a narrow Strait of Hormuz and there is restriction with exchange of water masses (Krupp et al., 1997). The restriction according to the estimated calculation stays for 3 to 5.5 years and during this period the water and the pollutants in the water remains and circulates inside the Gulf (Krupp et al., 1997). The climate here is arid with scarce amount of rainfall but high evaporation rate causing high salinity (Krupp et al., 1997). The maximum temperature observed during summer is more than 40°C whereas during winter the temperature drops to 11°C approximately (Krupp et al., 1997).

The life history of sardines consists of a brief pelagic egg stage, hatching, yolk-sac larvae, feeding larvae, metamorphosis, juveniles and mature adults (Checkley et al., 2017). They have large reproductive potential, allowing rapid population growth (Checkley et al., 2017). Sardines are considered forage fish (Alder et al., 2008; Essington et al., 2015; Hilborn et al., 2017). Sardines (*Sardinella longiceps*), are a highly migratory and schooling species and commonly known as Indian oil sardine whereas in the Arabian Gulf it is known as Uomah or Umah (FAO, 1985; Froese, 2009). Sardines are pelagic species (Froese, 2009), found at depths of 20- 200 meter of the photic zone (FAO, 1985). According to different studies it has been found out that Indian oil sardines are found throughout the Arabian Gulf and are native to this region however, the maps do not specify the same (Ali et al., 2018; Al-Faisal & Mutlak, 2018). There are many species of fish including *S. longiceps* that are found in extreme northern regions of Arabian Gulf that is Iraq and sardines are found to be residing in the waters of Iraq (Al-Faisal & Mutlak, 2018). The geographical distribution extends from the coasts of Djibouti, Egypt, Somalia, Mombasa, Seychelles, Bahrain, India, Iran, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, Sri Lanka, United Arab Emirates, Yemen, Andaman Island, Java, Bali Straits and recently in Bangladesh (Rohit et al., 2018; Salarpouri et al., 2018). The main source of food for sardines are phytoplankton especially diatoms although they sometimes feed on zooplankton mostly the copepods (FAO, 1985; IUCN, 2010). *S. longiceps* breeds once a year on the west coast of India. During the monsoon season in India the temperature and salinity of the water is low hence, the fish prefers to breed in the southwest parts of India (FAO, 1985; IUCN, 2010). Sardines spawning season begins in August up to September but at times the sardines arrive early at the coast around June or July with respect to the spawning ground the exact site has not been located (FAO, 1985; IUCN, 2010; Froese, 2009). However, it is still not confirmed whether Indian oil sardines from the Arabian gulf migrate to other regions (to the Indian coastlines) as it is possible that they are not migrating in and out of the Arabian Gulf as there are few studies stating the same (Burt et al., 2011).

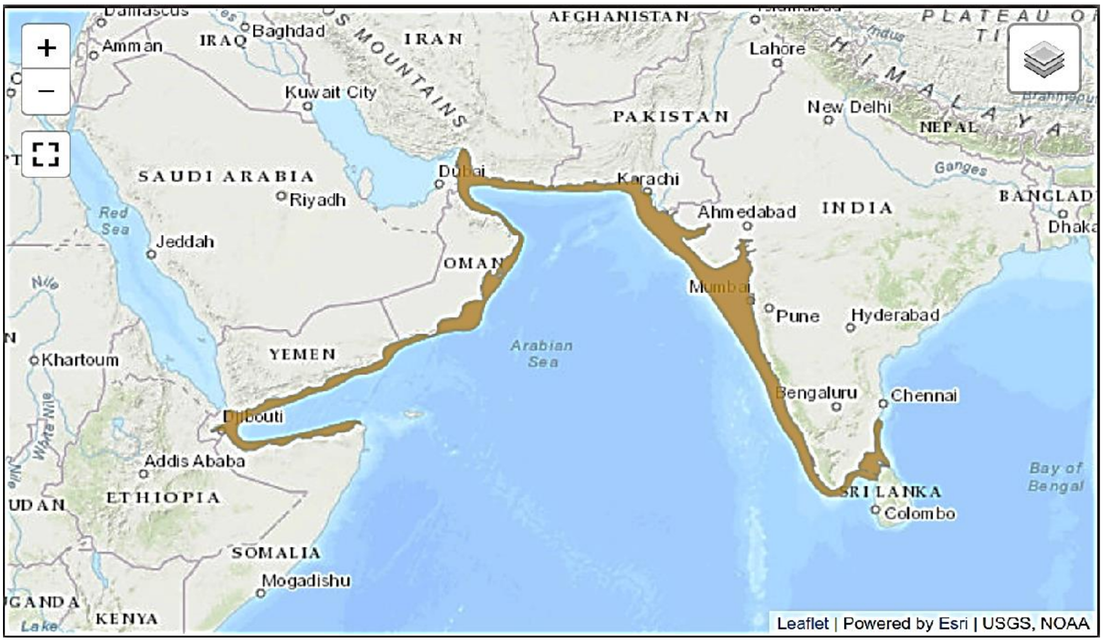

Figure 3: The habitat location and distribution of Indian oil sardines showing their distribution in the Gulf of Oman and in the Arabian sea. Extensive fish landings data indicate that the species also occurs throughout coastal areas in the Arabian Gulf (not shown in map).

Sources: (Froese, 2009).

A continuous supply of nitrogen is essential in the habitats of sardines (Checkley et al., 2017). The new source of nitrogen is provided in their habitat by deep mixing and upwellings (Checkley et al., 2017). The need for nitrogen is important because the phytoplankton mainly absorbs nitrogen as source of food for itself whereas, sardines feed on phytoplankton (Rabalais, 2002). Therefore, requirement of nitrogen is important to the growth and development of sardines (Rabalais, 2002). Winds cause upwelling and deep mixing, of gulfs and oceans helping to circulate nitrogen and other nutrients (Checkley et al., 2017). In deep mixing, surface water gets cooled by the dry cold winter winds and convection mixes the cold water deep inside the water column bringing the nitrate rich water to the surface, Figure 3 (Checkley et al., 2017) . The levels of nitrate do get low in the habitats of sardines due to fishing or overfishing (Checkley et al., 2017). The upwellings and deep mixing are represented in Figure 4 where Japanese sardine- *Sardinella zunasi* is considered as an example, but these mechanisms are seen in the habitats of another sardine species too (Checkley et al., 2017).

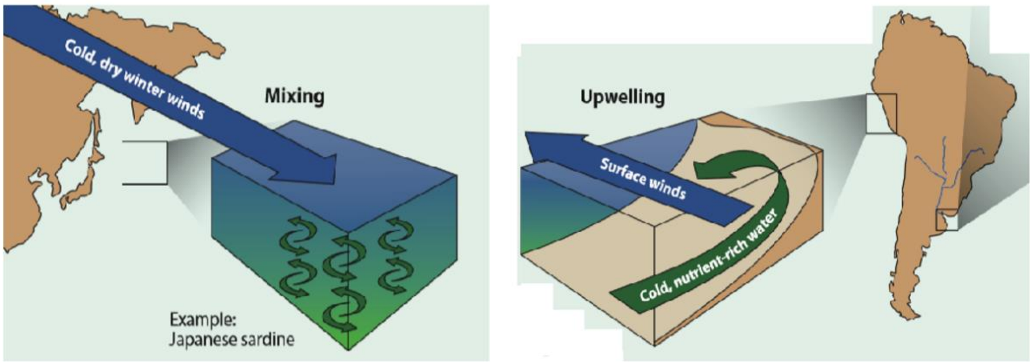

Figure 4: Representation of nutrient supply in the habitat of sardines by the methods of deep mixing and upwellings.

Source: (Checkley et al., 2017).

It has been established that metal and non-metal contamination is a serious issue in the coastal and marine environment (Naser, 2013; Ruilian et al., 2008). The sources of such contaminants in the Arabian Gulf is through reclamation and degradation, industrial effluents, sewage discharges, oil pollution and desalination plants (Naser, 2013). There has been a rapid increase in the coastal construction for recreational and economic purposes as currently about 40% of the coast has been developed (Naser, 2013). The contaminants released from the construction are causing physical and chemical alterations, decreasing the richness, biomass and abundance of the marine biodiversity (Smith & Rule, 2001). Besides the coastal development Arabian Gulf countries are witnessing a rapid growth in the industrial sector and these industries discharge wastewater that contains chemicals which may contain metals like zinc, copper, iron, nickel etc. (Wake, 2005). Moreover, Arabian Gulf is seen as a hotspot for high concentration of metals (Naser, 2013).

Coastal and marine environments are at the receiving end of sewage water that contains high suspended solid load of nutrients like ammonia, phosphate and nitrate originating from the chemical and biological waste resulting into degradation of the marine ecosystem (Naser, 2013; Sheppard et al., 2010; Singh et al., 2004).

Oil pollution is one of the highlighted pollution where the oil is either illegally poured in the water or gets spilled by mistake or there are leakages in the oil wells, underwater pipelines or military activities and there is no hidden secret that Arabian Gulf is the largest reserve for oil in the world (Naser, 2013; Sale et al., 2011). In 1991 Gulf war had taken place where many marine organisms had lost their lives (Naser, 2013) and it was been reported that metal contamination had occurred due to this major oil spill (Naser, 2013).

To understand accumulation and measure the concentration or the amount of metals and non-metals or their effects in the marine food webs of United Arab Emirates Indian oil sardines (*Sardinella longiceps*) were chosen for analyzing the metal and non-metal contamination as they are considered an important forage fish. The tissue samples selected for this study were gastrointestinal tract (GI tract), liver and muscle of sardines. The GI tract is the first system inside the fish that comes in contact with metals and non-metals (or other contaminants) through ingestion of food and water. The GI tract performs the function of absorbing the required nutrients and eliminating what is not required (Cardoso et al., 2019). If contaminants are high in concentration in the food and water, then the GI tract is likely to have high levels as well when analyzed. One of the functions of the liver includes the detoxification of hazardous materials including organic molecules, metals or non-metals. Digested materials, including contaminants from the GI tract, are transferred to the liver via the hepatic portal vein. The liver detoxifies some of these materials or stores them as less toxic materials (Cardoso et al., 2019). Thus, analysis of liver tissues for metals and non-metals could indicate high levels of absorption in the GI tract. Lastly presence of metals or non-metals in the muscles could indicate high levels being consumed and absorbed, resulting in excesses (that are not removed by the liver) that are eventually accumulated in muscle or other tissue. Detection of metals and non-metals in muscle also raises concerns regarding the health of humans as fish consumption involves primarily the consumption of muscle tissue, that could directly impact consumers (Cardoso et al., 2019).

1.4 Potential Contributions and Limitations of the Study

The metal and non-metal contamination study in the marine food web of the Arabian Gulf has the potential and opens pathways for further research in the field of contaminants present in the waterbodies. The method used in this field of research was to quantitatively assesses impact of metal and non-metal contamination on fish. It has been established that Arabian Gulf is a good site for socio-economic and environmental purposes.

The main aim of this study was to characterize and gain information regarding the metals and non-metals contamination in Arabian Gulf, its limit against the permissible level, by using fish as source of information.

The limitation was lack of data as there are data available for sediments and water contamination but deficient information regarding marine organism contamination. Another limitation was not encountered in the current study but can be a drawback in the coming future because there is always an annual fluctuation in the population of sardines moreover, they are a commercial fish meaning sardines suffer intense fishing pressure and coinciding of both the scenario can lead to low population size.

Chapter 2: Methods

2.1 Study Area

Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates are the eight countries that surround the Arabian Gulf (Krupp et al., 1997). To understand the effects of metals and non-metals contamination forage fish were chosen to assess the levels of 19 elements. The fish were collected from fish markets in Umm Al Quwain (25.564° N, 55.553° E), Ajman (25.400°N, 55.453° E) and Sharjah (25.3495° N, 55.379° E), Figure 5.

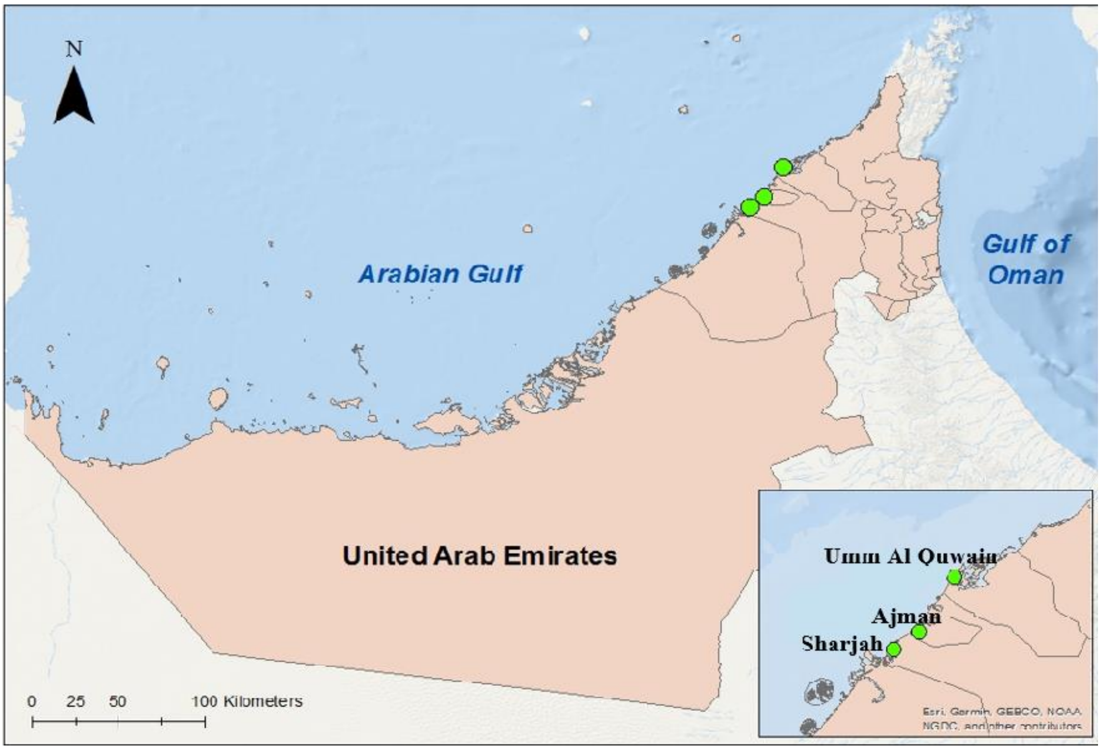

Figure 5: Map showing sample collection area and stations (Sharjah, Ajman and Umm Al Quwain) in the northern United Arab Emirates.

Source: Alizada et al., 2020.

2.2 Sample Collection

Indian oil sardine (*Sardinella longiceps*) were collected from fish markets from three sites and were identified using Fish Base (Froese, 2009). One hundred and twenty fish specimens were collected from those three stations, namely Ajman, Umm Al Quwain and Sharjah, Table 1. The fish were collected in the month of November 2018. The collected samples were packed with ice, labelled and immediately brought to the UAEU Entomology and Animal Ecology Laboratory in Biology Department, College of Science. All the fish were stored in the refrigerator at -18℃. They were later defrosted, and measurements of the entire fish sample was conducted to obtain their standard length (measured from the tip of the mouth to the base of the tail,(Froese, 2009) that varied from 16-20 cm in length.

The aim of the experiment was to detect presence of metals and non-metals in the fish samples of three tissues: muscle, gastrointestinal tract (GI) and liver, respectively. These three tissue types were chosen due to their functions in absorption, assimilation and storage of metals and non-metals. The dissection of fish was performed using stainless steel equipment. The samples were placed in aluminum foil, labelled and frozen at -18℃.

Table 1: Indian oil sardine (*Sardinella longiceps*) sampling locations with their coordinates, date of sample collection and sample size.

Location	GPS Coordinates	Legend of abbreviations	Date	Sample size
Umm Al Quwain	25.564° N, 55.553° E	UAQ	20.11.2018	40
Ajman	25.400° N, 55.453° E	AJ	20.11.2018	40
Sharjah	25.3495° N,55.379° E	SHJ	20.11.2018	40

2.3 Analytic Procedure

The analytic procedure was carried out in the Animal Nutrition Laboratory, College of Food and Agriculture UAEU. The chemicals mentioned in the procedure were according to UAEU procurement guidelines. The plastic tubes used, were washed thoroughly with deionized water. Calibration of the instruments and preparation of the standard solutions were according to the standard values. The standard solutions were prepared from commercially available materials and all the reagents were of analytical grade with low concentration of trace metals. Argon gas at high purity level was the inert gas of choice.

2.3.1 Digestion of Fish Samples

All samples were weighed by the analytical balance in grams with the minimum weight required of the fish tissue for preparing the solution for digestion was 0.5 g. The principle is to treat the fish samples with acids to destroy the organic matter and obtain the recoverable elements that has been solubilized by heating (CEM Microwave Sample Preparation Notes Mars 5, 2017). The procedure of preparing the solution before digesting the samples belonging to all three categories (US EPA, 1998) are mentioned below. The liver samples were in wet condition during the procedure. After weighing the sample, they were transferred into the plastic vessel having volume of 75 ml, further 10 ml of nitric acid with concentration of 65% to 70% was been added. The samples were placed into rotor that has the capacity of 40 samples at a time, this rotor was then placed in a heating digester called One- touch (Mars 6) as shown in Figure 6 (CEM Microwave Sample Preparation Notes Mars 5, 2017). The temperature inside the heating digester varied from 200℃ to 250℃ taking about 50 mins to digest the samples. The digester utilizes maximum power of 1600 watts heating (CEM Microwave Sample Preparation Notes Mars 5, 2017). After digestion, a clear homogenized solution was obtained, which was then transferred into a centrifuge tube and diluted with deionized water making a volume of 50 ml each. Muscle samples were analyzed with slight modification in the procedure in which 1 ml of hydrochloric acid with concentration of 65% was added. The addition was required for digesting the skin and scales that were attached to the muscle samples. The gastrointestinal tract samples were dried unlike the liver and muscle samples. The GI samples were dried overnight in the oven at 60°C, but the remaining procedure was identical to the liver and muscle samples with addition of 2 ml of hydrochloric acid, concentration of 65% for obtaining clear homogenized solution as there were presence of fat and food in the GI samples.

Figure 6: Heating digester One- touch (Mars 6) with the liver samples, was used for breaking down the tissue samples and obtain clear solutions.

2.3.2 Determination of Minerals and Trace Elements in Fish Samples

Determination of minerals and trace elements was conducted to analyze presence of metals and non-metals in the fish samples. A portion of the homogenized solution that was obtained after digesting was used for analysis. A total of 18 elements were quantified, namely: Arsenic (As), Calcium (Ca), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Potassium (K), Magnesium (Mg), Manganese (Mn), Molybdenum (Mo), Sodium (Na), Nickel (Ni), Phosphorus (P), Lead (Pb), Sulfur (S), Strontium (Sr), Vanadium (V) and Zinc (Zn). Varian Inductively Coupled Plasma Optical Emission Spectrometers (ICP- OES) model 720- ES with instrument setting, complete PC control and compatible accessories was used for analyzing the samples (Agilent technologies ICP- OES application notes, 2018) as seen in Figures 7 and 8.

Figure 7:Varian Inductivity Coupled Plasma Optical Emission Spectrometers (ICP- OES) model 720 ES was used for determining the elements through optic waves at different wavelength.

The principle of using IPS- OES is to obtain calibration curve of each metal which is derived by atomized elements that emits characteristic spectral lines separated by optical spectrometer simultaneously (Agilent technologies ICP- OES application notes, 2018). In the ICP- OES there is a nebulizer through which the homogenized solution passes resulting into aerosol (Agilent technologies ICP- OES application notes, 2018). This aerosol is then transported to the plasma torch where excitation of the elements occurs (Agilent technologies ICP- OES application notes, 2018). Due to radio frequency inductivity coupled plasma, spectra of the respective element with their specific emission frequency is produced (Agilent technologies ICP- OES application notes, 2018). Grating spectrometer function is to disperse the spectra and intensity of the line spectra belonging to the respective element was monitored at specific wavelengths by charged coupled detector (Agilent technologies ICP- OES application notes, 2018). Megapixel CCD detector is an innovative feature designed mainly for IPS- OES that provides complete wavelength coverage of 177- 785 nanometer (nm) (Agilent technologies ICP- OES application notes, 2018). The matrix effect and blank signal errors are corrected by background correctors which are fitted inside the machine (Agilent technologies ICP- OES application notes, 2018). In line broadening background correction is not required because the background correction measurement will degrade the analytical results (Agilent technologies ICP- OES application notes, 2018) Figure 8 gives an insight of the ICP- OES mechanism.

Figure 8: Mechanism of ICP- OES where the samples were allowed to run through the nebulizer for further detection process.

2.3.3 Determining Mercury Content in Fish Samples

The homogenized solution samples were also used for detecting mercury (Hg). The machine used for detection was Varian Spectr AA- Atomic Absorption Spectrometer 220 FS, Figure 9.

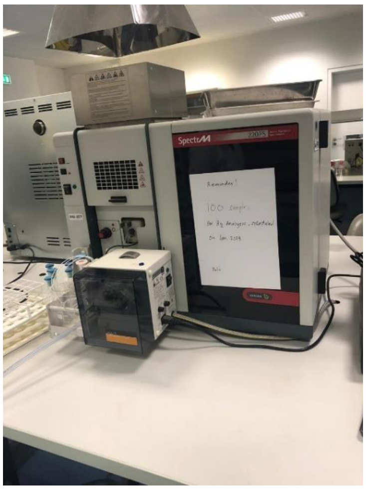

Figure 9: Varian Spectr AA- Absorption Spectrometer 220 FS used for determining mercury in the tissue samples.

The principle is to reduce the Hg present in the homogenized solution to an elemental state by adding stannous chloride and detecting the presence of Hg by cold vapor atomic absorption spectrometry when placed in the light path of the spectrometer. Varian Spectr AA 220 FS provides full PC control, automated operation that includes programmable gas control and automatic lamp selection (Varian booklet, 1997). There are four lamps positioned with automated wavelength, the sample is placed in the light path of the spectrometer that monitors and detects the wavelength of the element resulting into a calibration curve. Background correctors are also fixed inside the spectrometer (Varian booklet, 1997).

2.4 Statistical Analysis

SPSS software (version 25) all for statistical analyses. To examine existence of significant differences among the groups of predictor variables (metals and non-metals) and to determine the predictor variables that contributed the most in the inter-group differences discriminant analysis was performed (Alizada et al., 2020) (Arbuckle, 2010; Savinov et al., 2003). Regarding the three sampling sites (SHJ, AJ, and UAQ) their significant contribution from each parameter was assessed using stepwise multivariate discriminant analysis (Sokal & Rohlf, 2012). There were three separate discriminant analysis generated. The first analysis included metals and non-metals related variables for liver samples between the three sampling sites. Second analysis included metals and non-metals related variables for GI samples between the three sampling sites and lastly in the third analysis metals and non-metals related variables for liver samples between the three sampling sites was performed (Alizada et al., 2020).

Further post- hoc MANOVA test was performed for each significant variable (metals and non-metals) and their effect sizes were calculated (Zar, 2013; Ott, 2018; Alizada et al., 2020). Indicate differences of variables between three sampling sites and present a report in a standardized metric (communicate practical significance of results), instead of presenting only statistical significance was the aim of this study (Alizada et al., 2020). Significance levels for pairwise comparison were indicated when required (Sokal & Rohlf, 2012; Alizada et al., 2020).

Chapter 3: Results

3.1 Metals and Non-metals Concentration in Tissues

The accumulation of As, Ca, Cd, Cr, Cu, Hg, K, Mg, Mn, Na, P, S, Sr and Zn are shown in Table 2. Nickel and V in all three stations were low in liver samples and were absent in GI and muscle samples. Similarly, Co was detected in muscle samples but absent in the liver and GI samples. Lead and Mo were below the detection limits for all the three samples belonging to the three stations therefore, no calculation was conducted. The concentrations of elements were compared with international guidelines, Table 2. The organizations chosen for comparison were European Union Commission (EU, 2001), World Health Organization (WHO, 2007) and FAO (FAO, 1983). These three organization were considered for comparing the current study as they have a long history in studying and providing permissible limits for various types of environmental pollutants in different species including the fish. Furthermore, regionally, the countries usually have their own standards that are not widely publicized, that are similar to the international levels. Cadmium and Cr were higher than permissible standards in samples from all three stations. Cadmium, Cr and Cu were high in liver and GI tract samples in most sites. Values in asterisk (*) represent elements exceeding the maximum permissible limits.

Table 2: Metal and non-metal concentrations (mg/kg; ppm) in the liver, GI tract and muscle samples of *Sardinella longiceps* compared with international organizations EC, WHO and FAO.

Element	Location	Tissue Metal Concentration			Reference		
		Sardinella longiceps			Maximum permissible limit in fish		
		Liver	GI	Muscle	EU, (2001)	WHO, (2007)	(FAO, 1983)
As (ppm)	SHJ	2.89±0.28	6.54±0.42	4.62±0.25	-	-	-
	AJ	2.64±0.25	6.55±0.18	4.78±0.19			
	UAQ	2.41±0.25	6.92+0.42	3.31±0.21			
Ca (ppm)	SHJ	2704.3±1003.22	18409.58±1366.97	9068.32±589.93	-	-	-
	AJ	903.53±254.13	6164.32±689.04	1007.45±708.06			
	UAQ	262.58±29.81	3204.84±376.69	8430.58±939.28			
Cd (ppm)	SHJ	1.06±0.32*	5.31±0.37*	0.19±0.03*	0.10	-	0.05
	AJ	1.68±0.38*	4.85±0.33*	0.23±0.04*			
	UAQ	0.63±0.11*	3.6±0.4*	0.1±0.001*			
Cr (ppm)	SHJ	1.15±0.31*	7.89±0.67*	0.33±0.08*	1.0	0.15	1.0
	AJ	0.85±0.16*	2.24±0.32*	0.26±0.02*			
	UAQ	0.13±0.01	0.32±0.03*	0.21±0.01*			
Cu (ppm)	SHJ	1.43±0.34*	5.62±0.44*	0.34±0.04	1.0	3.0	-
	AJ	2.00±0.25*	4.27±0.3*	0.38±0.03			
	UAQ	1.23+0.12*	3.99±0.34*	0.97±0.13			
Hg (ppm)	SHJ	0.03±0.00	0.05±0.00	0.02±0.00	500	500	500
	AJ	0.07±0.00	0.08±0.00	0.03±0.00			
	UAQ	0.1+0.01	0.06±0.00	0.03±0.00			
K (ppm)	SHJ	1428.91±214.86	4968.63±270.11	1729.42±59.39	-	-	-
	AJ	1431.53±194.3	4179.92±146.17	1962.79±85.03			
	UAQ	1144.63±161.82	4609.09±267.36	2411.04±142.96			

Table 2: Metal and non-metal concentrations (mg/kg; ppm) in the liver, GI tract and muscle samples of *Sardinella longiceps* compared with international organizations EC, WHO and FAO (Continued).

Element	Location	Tissue Metal Concentration				Reference	
		Sardinella longiceps			Maximum permissible limit in fish		
		Liver	GI	Muscle	EC, (2001)	WHO, (2007)	(FAO, 1983)
Mg (ppm)	SHJ	731.27±216.7	4970.76±395.61	427.46±19.15			
	AJ	365.7±83.57	1714.99±173.5	386.33±20.14	-	-	-
	UAQ	123.3±15.18	1145.65±96.06	421.12±24.19			
Mn (ppm)	SHJ	2.73±0.84	20.19±1.67	2.14±0.13			
	AJ	1.2±0.32	5.67±0.73	2.16±0.31	-	-	-
	UAQ	0.1±0.01	1.16±0.1	1.9±0.28			
Na (ppm)	SHJ	1309.86±223.76	4564.18±233.21	1644.3±76.17			
	AJ	969.55±146.36	3022.8±105.15	1179.8±59.32	-	-	-
	UAQ	691.5±116.75	2831.2±189.29	1310.22±65.72			
P (ppm)	SHJ	1990.68±269.59	5450.52±383.62	7004.74±300.13			
	AJ	1886.75±174.62	5019.99±267.33	7491.45±351.89	-	-	-
	UAQ	1934.2±270.9	6525.51±449.37	6779.53±568.74			
S (ppm)	SHJ	1898.48±108.39	4519.59±280.87	1900.16±35.27			
	AJ	2334.01±163.84	4521.28±149.35	1904.54±52.86	-	-	-
	UAQ	1873.91±91.71	5209.28±344.62	2312.92±132.9			
Sr (ppm)	SHJ	10.02±3.31	61.28±4.51	24.18±1.85			
	AJ	3.26±0.93	17.45±1.93	24.77±1.97	-	-	-
	UAQ	1.25±0.14	11.56±1.31	23.2±3.12			
Zn (ppm)	SHJ	14.44±2.54	69.87±5.98*	20.93±1.44			
	AJ	16.64±2.36	63.27±2.83*	21.87±1.35	-	-	40.0
	UAQ	10.73±0.85	80.93±7.03*	22.6±2.37			

A comparison study was performed between different sardine species belonging to Tanzania, Algeria and India (Mehouel et al., 2019; Thiyagarajan et al., 2012) (Table 3).

Table 3: Comparison of the concentration of metals and non-metals (ppm) between the current study and sardines from different regions.

Species	Location	Ca	Cd	Cu	Cr	Hg	Pb	Zn
Sardines	**Tanzania**	37981.9±5558.2	-	3.5±0.1	-	-	-	130.9±0.5
European pilchard	**Algeria**	-	0.55±0.44	-		0.62±0.61	2013±1.12	-
Indian oil sardine	**India**	-	0.43±0.28	-	1.12±0.32	-	0.17±0.04	-

Source: (Mehouel et al., 2019; Thiyagarajan et al., 2012).

A similar study was conducted with Indian anchovies (*Stolephorus indicus*) in UAE (Alizada et al., 2020) with same stations and methodology. The results of both the studies showed similar metal accumulation (Cd, Cr, Cu and Zn) in the fish and all the four metals were exceeding the maximum permissible limits recommended by international guidelines, Table 4.

Table 4: Comparison of the concentration of metals and non-metals (ppm) in three tissues of *Stolephorus indicus* (Indian anchovies) and *Sardinella longiceps* (Indian oil sardines) sampled from fish in the northern Emirates of UAE.

Elements	Location	Tissue Metal Concentrations					
		Stolephorus indicus (Alizada et al., 2019)			*Sardinella longiceps* (Current study, 2020)		
		Muscle	GI	Liver	Muscle	GI	Liver
Cd(ppm)	AJ SH UAQ	0.12±0.08 0.08±0.05 0.12±0.08	6.4±4.8 1.6±1.8 3.3±2.4	3.99±2.04 4.86±6.05 7.99±3.05	0.23±0.04 0.19±0.03 0.1±0.001	4.85±0.33 5.31±0.37 3.6±0.4	1.68±0.38 1.06±0.32 0.63±0.11
Cr(ppm)	AJ SH UAQ	0.36±0.5 0.18±0.25 0.13±0.68	3.7±7.8 5.5±18.8 9.8±6.3	20±38 24±36 4.6±5.2	0.26±0.02 0.33±0.08 0.21±0.01	2.24±0.32 7.89±0.67 0.32±0.03	0.85±0.16 1.15±0.31 0.13±0.01
Cu(ppm)	AJ SH UAQ	1.7±0.86 1.2±0.71 1.7±0.94	22±16.7 10.1±7.1 18.8±12	17±6.7 12.6±5.9 24±13	0.38±0.03 0.34±0.04 0.97±0.13	4.27±0.3 5.62±0.44 3.99±0.34	2.00±0.25 1.43±0.34 1.23±0.12
Zn(ppm)	AJ SH UAQ	9.3±2.7 7.1±2.5 10.4±3.7	108±69 56±35 128±81	139±58 126±53 247±85	21.87±1.35 20.93±1.44 22.6±2.37	63.27±2.83 69.87±5.98 80.93±7.03	16.64±2.36 14.44±2.54 10.73±0.85

3.2 Metal and Non-metal Analysis in Gastrointestinal Tract

Stepwise discriminant analysis on the elements in GI tract samples indicated that Mn, Mg, Na, K, Sr, S and Hg ($p \leq 0.001$) were the significant variables that discriminated the sampling sites (Sokal & Rohlf, 2012; George & Mallery, 2016. The remaining elements As, Ca, Cd, Co, Cr, Cu, Ni, P, V and Zn were removed from the analysis as these elements did not improve the model's ability to discriminate the sampling sites. Mn had the highest F ratio in the GI samples (Lachenbruch & Goldstein, 1979).

For each predictor univariate ANOVA was carried, Table 5 that provided a strong evidence that there was a significant difference seen for all the metals and non-metals in all the sampling sites. The univariate ANOVA showed that Ca, Co, Cr, Mg, Mn, Na, Ni, Sr and V had the highest F ratio (George & Mallery, 2016). In the Pooled Within- Group low correlation was observed between the predictors (variables-metals), except a correlation has been observed between Ca, Sr; Cr, Mg; Cr, Mn; Cr, V; Mn, V and Mg, V ($r > 0.95$).

Table 5: Test of equality of group means for the GI tract samples, univariate ANOVA was carried out for determining significant difference for all the metals and non-metals in relation to the three sampling sites.

	Wilks' Lambda	F	df1	df2	Sig.
As	0.994	0.350	2	112	0.706
Ca	0.430	74.262	2	112	0.000
Cd	0.909	5.581	2	112	0.005
Co	0.453	67.578	2	112	0.000
Cr	0.412	79.868	2	112	0.000
Cu	0.911	5.448	2	112	0.006
Hg	0.917	5.064	2	112	0.008
K	0.950	2.925	2	112	0.058
Mg	0.476	61.698	2	112	0.000
Mn	0.404	82.555	2	112	0.000
Na	0.676	26.885	2	112	0.000
Ni	0.448	68.862	2	112	0.000
P	0.930	4.240	2	112	0.017
S	0.963	2.149	2	112	0.121
Sr	0.408	81.276	2	112	0.000
V	0.411	80.274	2	112	0.000
Zn	0.956	2.554	2	112	0.082

In the Box’s M test showed that the sampling sites differed significantly from one another ($F=5.759$, Box’s $M = 461.830$, $p < 0.001$), Tables 6 and 7.

Table 6: Log determinants table of the GI tract samples showing the significance of differences between sampling sites.

Location	Rank	Log Determinant
Sharjah	8	49.440
Ajman	8	46.859
Umm Al Quwain	8	44.529
Pooled within-groups	8	51.153

Table 7: Box M result test for GI tract samples showing covariance matrices relative to sampling sites.

Box's M		461.830
F	Approx.	5.759
	df1	72
	df2	34412.612
	Sig.	0.000

The eigenvalue for Function 1 was 7.582 and for Function 2 was 0.647 (Table 16). The correlation of Function 1 and Function 2 were 0.940 and 0.627 respectively where Function 1 was high as 1.000. Square of the correlations were 0.8836 and 0.3931 respectively, indicating that 94.0% of the variance in the sampling sites was explained by Function 1 and 62.7% of the variance was explained by Function 2 model (Ott, 2018; Sachs, 2012), Table 8.

Table 8: Canonical discriminant function and their associated eigenvalues for Function 1 and Function 2 for the samples from GI tract.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	7.582	92.1	92.1	0.940
2	0.647	7.9	100.0	0.627

There was a significant discrimination between the three sampling sites based on Function 1 and Function 2, Table 9.

Table 9: Canonical discriminant function; Wilk's Lambda between the sampling sites for samples from GI tract.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	0.071	287.363	16	<0.001
2	0.607	54.120	7	<0.001

Calcium, Mn, V, Sr, Cr, Co, Mg, Ni, Na and Cu were associated with Function 1 and the rest of the variables were associated with Function 2, Table 10.

Table 10: Structure matrix determining the association between each element with Function 1 and Function 2 for the GI tract samples.

	Function 1	Function 2
Ca	0.446^{*}	-0.204
Mn	0.440^{*}	-0.100
V	0.438^{*}	-0.090
Sr	0.430^{*}	-0.275
Cr	0.415^{*}	-0.095
Co	0.377^{*}	-0.069
Mg	0.377^{*}	-0.202
Ni	0.319^{*}	-0.115
Na	0.247^{*}	-0.165
Cu	0.093^{*}	-0.006
Hg	-0.062	0.308^{*}
P	0.041	-0.243^{*}
K	0.055	-0.213^{*}
Zn	-0.104	-0.200*
Cd	0.101	0.186*
S	-0.051	-0.168*
As	0.052	-0.146*

Function 1 was comparatively better than Function 2 in differentiating the three sampling sites, Figure 10. Function 1 contributed 92.1% and Function 2 contributed only 7.9%. The data of Sharjah and Ajman were concentrated in the positive sides of Function 1 and Function 2 respectively but from the Function 2 was not as discriminatory as Function 1.

Ca, Mn, V, Sr, Cr, Co, Mg, Ni, Na and Cu were associated with Function 1 having a positive correlation, Table 19. Function 2 was primarily associated with Hg, P, K, Zn, Cd, S and As, Table 11.

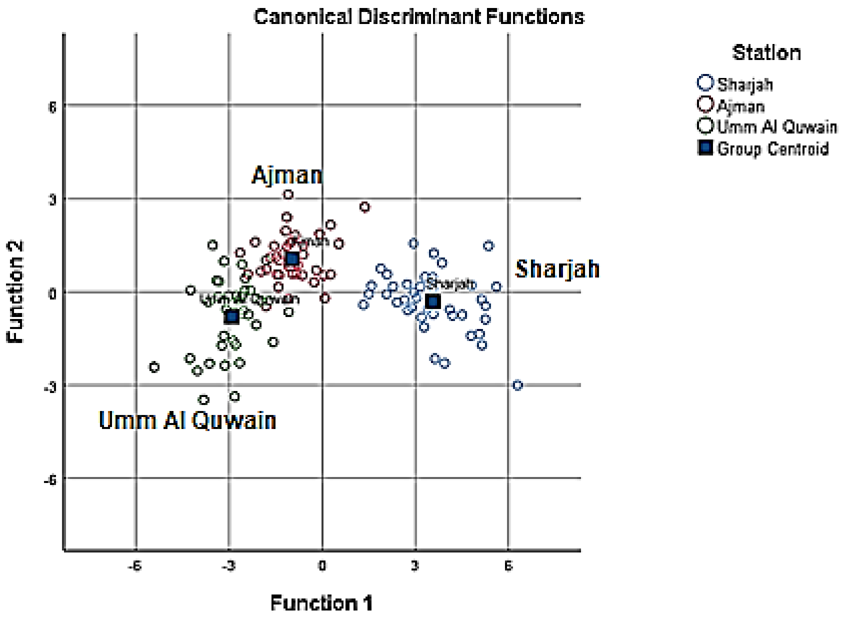

Figure 10: Canonical discriminant functions and their success in separating the three sampling areas (Sharjah- SHJ, Ajman- AJ, Umm Al Quwain- UAQ) based on concentrations of metals and non- metals in GI tract samples in UAE.

In Table 11 of Classification function coefficients individual weights of all the predictors were classified with their respective function as seen in the table, Na was correlated in Sharjah, Cd, Hg, Mg and Mn were having correlation in Ajman whereas in Umm Al Quwain K and S were having high correlation.

Table 11: Classification function coefficients using Fisher's linear function to classify individual weights of all the predictors in relation to their respective function in GI tract samples.

	Location		
	Sharjah	Ajman	Umm Al Quwain
Cd	-0.069	0.231	-.0348
Hg	3.131	12.459	-12.392
K	-0.003	0.005	0.008
Mg	-0.002	-0.005	-0.002
Mn	0.453	1.509	0.345
Na	0.010	-0.003	-0.009
S	-0.002	0.001	0.002
Sr	0.140	-0.190	-0.096
(Constant)	-13.501	-7.196	-10.726

The classification of discriminant analysis states that data belonging to Sharjah was 100.0% accurately classified whereas for the data of Ajman and Umm Al Quwain only 95.0% and 92.5% of data respectively were faultlessly classified. For the complete three sampling sites 95.8% of original grouped cases were correctly classified as seen in Table 12.

Table 12: Classification results of the discriminant model for the three location (Sharjah, Ajman and Umm Al Quwain) in UAE, where 95.8% of original grouped cases were correctly classified by the GI tract samples.

		Predicted Group Membership			
Location		Sharjah	Ajman	Umm Al Quwain	Total
%	Sharjah	100.0	0.0	0.0	100.0
	Ajman	0.0	95.0	5.0	100.0
	Umm Al Quwain	0.0	7.5	92.5	100.0

95.8% of original grouped cases correctly classified.

The post hoc test of MANOVA for pairwise group comparisons result indicated highly significant differences ($p \leq 0.05$) for Ca, Co, Sr and Hg between three sampling sites, except , Cd, Cr, Cu, K, Mg, Mn, Na, Ni, P, V and Zn which showed different conclusion when compared to discriminant analysis. There was high ability for the variance to discriminate three sampling sites when there was an increase in the value of T statistic. The pairwise group comparison table revealed Mn with the highest ability to discriminate between Sharjah and Umm Al Quwain as seen in Table 13.

Table 13: Significance of pairwise comparison between the three locations in United Arab Emirates revealed that Mn had the highest ability to discriminate between Sharjah and Umm Al Quwain (GI tract).

ELEMENTS	SHJ v/s AJ	SHJ v/s UAQ	AJ v/s UAQ
Ca (ppm)	9.34	11.36	2.19
Cd (ppm)	-	3.25	2.36
Co (ppm)	0.82	1.12	0.31
Cr (ppm)	9.19	12.02	2.99
Cu (ppm)	2.57	3.05	0.53
Hg (ppm)	3.33	-	1.9
K (ppm)	2.41	-	-
Mg (ppm)	8.83	10.16	-
Mn (ppm)	9.48	12.17	2.86
Na (ppm)	5.99	6.59	-
Ni (ppm)	8.21	11.31	3.24
P (ppm)	-	2.03	2.83
Sr (ppm)	10.36	11.51	-
V (ppm)	9.36	12.01	2.72
Zn (ppm)	-	-	2.24

3.3 Metal and Non-metal Analysis in Liver

Stepwise discriminant analysis was performed to obtain a set of predictors that helped to discriminate all the three sampling sites. Hg, Cr, Mg, Cu and Co ($p \leq 0.001$) were the significant variables in the liver samples that discriminated the sampling sites (Sokal & Rohlf, 2012; George & Mallery, 2016). The remaining elements As, Ca, Cd, K, Mn, Na, P, S, Sr and Zn were removed from the analysis as these elements did not improve the model’s ability to discriminate the sampling sites. For each predictor F ratio was calculated and the highest F ratio was selected first to include in the discriminant function only if it had a certain significance and tolerance level. The ability of predictor is higher only when the F remove ratio is higher than the discriminates the three sampling sites which were Sharjah, Ajman and Umm Al

Quwain where according to the variables in the analysis Hg was having the highest ratio in the liver samples (Lachenbruch & Goldstein, 1979).

For each predictor univariate ANOVA was carried out as shown in Table 14 that provided a strong evidence stating that there was a significant difference seen for all the metals and non-metals with respect to the means of all the three sampling sites. Univariate analysis of variance was conducted where the sampling sites were considered as categorical variables and metals, non-metals which were the predictors considered as criterion variables. The univariate ANOVA significance was supported by high value of F that indicated a significant difference between the sampling sites due to the predictor namely Hg (George & Mallery, 2016). In the Pooled Within-Group low correlation was observed between the predictors (variables- metals), correlations were recorded between Ca and Sr; Ca and Mg; Ca and Mn; Cr and Mg; Cr and Mn; K and Na; Mg and Mn; Mg and Sr; and Mn and Sr ($r > 0.95$).

Table 14: Test of equality of group means for the liver samples, univariate ANOVA was carried out for determining significant difference for all the metals and non-metals in relation to the three sampling sites.

	Wilks' Lambda	F	df1	df2	Sig.
As	0.972	0.737	2	52	0.484
Ca	0.837	5.076	2	52	0.010
Cd	0.899	2.910	2	52	0.063
Co	0.983	0.457	2	52	0.635
Cr	0.798	6.584	2	52	0.003
Cu	0.911	2.543	2	52	0.088
Hg	0.613	16.429	2	52	0.000
K	0.974	0.700	2	52	0.501
Mg	0.825	5.505	2	52	0.007
Mn	0.794	6.726	2	52	0.003
Na	0.890	3.204	2	52	0.049
P	0.998	0.051	2	52	0.951
S	0.868	3.944	2	52	0.025
Sr	0.813	5.999	2	52	0.005
Zn	0.928	2.022	2	52	0.143

In the Box's M test the null hypothesis was that the covariance matrices did not differ between the sampling sites. The log determinants were not equal (F = 5.815, Box's M = 203.815 , p < 0.001) indicating that the sampling sites differed significantly from one another (Savinov et al., 2003), Tables 15 and 16.

Table 15: Log determinants table of the liver samples showing the significance of differences between sampling sites.

Station	Rank	Log Determinant
Sharjah	5	-7.090
Ajman	5	-3.816
Umm Al Quwain	5	-11.610
Pooled within-groups	5	-3.239

Table 16: Box M test for liver samples showing covariance matrices relative to sampling sites.

Box's M		203.815
F	Approx.	5.815
	df1	30
	df2	7442.964
	Sig.	0.000

Two discriminant functions were estimated because there were three sampling sites (Savino et al., 2003). Table 17 explains variance in Function 1 and Function 2 where the eigenvalue for Function 1 was 1.769 and for Function 2 was 0.829. The proportion of variances were indicated by eigenvalues and large eigenvalue represents an association with strong function. Function 1 was been considered superior. A high canonical correlation specifies a function that can discriminate effectively and as seen in Table 8, the correlation of Function 1 and Function 2 were 0.799 and 0.673 respectively where Function 1 was as high as 1.000. Square of the correlations are $(0.799)^2$ and $(0.673)^2$ that equated to 0.6384 and 0.4529 respectively. These values indicated that 79.9% of the variance in the dependent variables that is the sampling sites are explained by Function 1 model and 67.3% of the variance in the dependent variable were explained by Function 2 model (Savinov et al., 2003).

Table 17: Canonical discriminant function and their associated eigenvalues for Function 1 and Function 2 for the samples from liver.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.769	68.1	68.1	0.799
2	0.828	31.9	100.0	0.673

Wilk’s Lambda was estimated based on chi-square transformation, indicated that there was significant discrimination between the three sampling sites based on Function 1 and Function 2 (Ott, 2018; Sachs, 2012), Table 18.

Table 18: Canonical discriminant function; Wilk's Lambda between the sampling sites for samples from liver.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	0.198	81.086	10	<0.001
2	0.547	30.170	4	<0.001

Many researchers prefer structure matrix correlations for more accurate results compared to the standard canonical discriminant function coefficients (Sachs, 2012). Table 19 represents the structure matrix table for Functions 1 and 2. Mercury, Mn, Cr, Mg, Sr, Ca, As, Na, K and P were associated with Function 1 and the rest of the variables were associated with Function 2 (Savinov et al., 2003). Asterisk’s (*) indicate elements that influence a given function more than the other.

Table 19: Structure matrix determining the association between each element with Function 1 and Function 2 for liver samples.

	Function 1	Function 2
Hg	0.596*	0.065
Mn	-0.368*	-0.026
Cr	-0.352*	0.204
Mg	-0.346*	-0.002
Sr	-0.342*	-0.131
Ca	-0.339*	-0.161
As	0.251*	0.044
Na	-0.197*	0.025
K	-0.150*	0.092
P	-0.132*	-0.052
Cu	-0.028	0.341*
S	-0.021	0.285*
Cd	0.010	0.158*
Co	-0.023	0.142*
Zn	0.031	0.058*

The contributions of Function 1 and 2 to the model are shown in Fig 11. Function 1 was comparatively better than Function 2 in differentiating the three sampling sites. The data of Umm Al Quwain and Ajman were concentrated in the positive sides of Function 1 and Function 2 respectively, but Function 2 was not as good at discriminating between sites. Thus, Function 1 was better than Function 2 for this model where Function 1 contributed 68.1% and Function 2 contributed only 31.9% of the variance in the data, Figure 11).

Hg, Mn, Cr, Mg, Sr, Ca, As, Na, K and P were associated with Function 1 while Function 2 it was primarily associated with Cu, S, Cd, Co and Zn (Savinov et al., 2003; Zar, 2013).

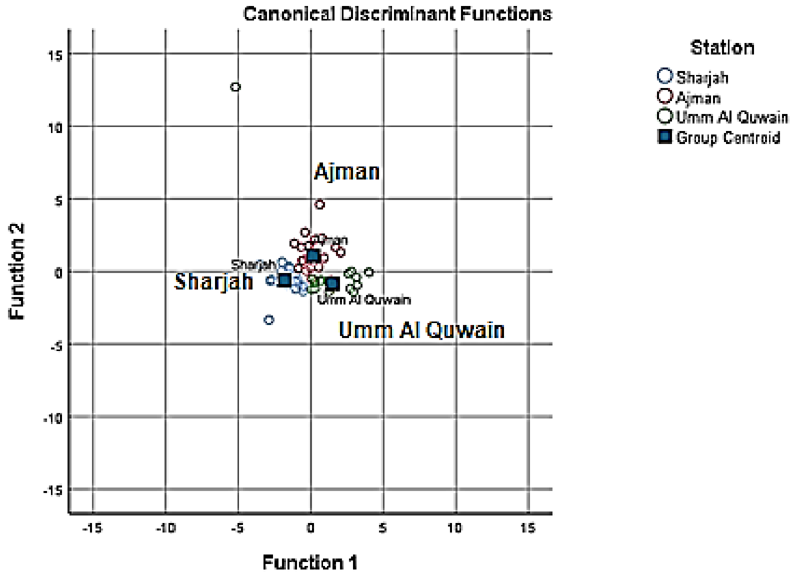

Figure 11: Canonical discriminant functions and their success in separating the three sampling areas (Sharjah- SHJ, Ajman- AJ, Umm Al Quwain- UAQ) based on concentrations of metals and non-metals in liver samples in UAE.

In the Table 20 of classification function coefficients individual weights of all the predictors were classified with their respective function as seen in the table, Co had correlation in Sharjah, Cr and Cu had correlations in Ajman whereas in Umm Al Quwain Hg and Mg had high correlation.

Table 20: Classification Function Coefficients using Fisher's linear function to classify individual weights of all the predictors in relation to their respective function in liver samples.

	Location		
	Sharjah	Ajman	Umm Al Quwain
Co	10.985	0.602	-12.651
Cr	0.353	4.041	-5.254
Cu	0.408	3.175	2.459
Hg	4.172	53.743	110.450
Mg	0.001	-0.010	0.004
(Constant)	-2.678	-6.195	-7.361

The classification of discriminant analysis showed that data belonging to Sharjah was 100.0% accurately classified whereas for the data of Ajman and Umm Al Quwain only 77.3% and 95.2% of data respectively were faultlessly classified. For the complete three sampling sites 90.5% of original grouped cases were correctly classified as seen in Table 21.

Table 21: Classification results of the discriminant model for the three locations (Sharjah, Ajman and Umm Al Quwain) in UAE, where 90.5% of original grouped cases were correctly classified by the liver samples.

		Predicted Group Membership			
	Location	Sharjah	Ajman	Umm Al Quwain	Total
%	Sharjah	100.0	0.0	0.0	100.0
	Ajman	9.1	77.3	13.6	100.0
	Umm Al Quwain	0.0	4.8	95.2	100.0

90.5% of original grouped cases correctly classified.

After stepwise discriminant analysis, determination of significant differences between the sampling sites was performed by the post hoc test where the independent variables were significantly different compared to one another (Sachs, 2012; Tabachnick & Fidell, 2012). The post hoc test of MANOVA for pairwise group comparisons result indicated highly significant differences ($p \leq 0.05$) for Ca, Cr, Sr and Hg between three sampling sites, except Cd, Cu, Mg, Mn, Na and S which showed different conclusion when compared to discriminant analysis. The post hoc test of MANOVA (Mean difference I-J/ Std. error) output was considered for calculating T statistic to report the p-value of the variables from pairwise group comparisons table. There was high ability for the variance to discriminate three sampling sites when there was an increase in the value of T statistic. The pairwise group comparison table revealed Mn with the highest ability to discriminate between Sharjah and Umm Al Quwain as seen in Table 22.

Table 22: Significance of pairwise comparison between the three locations in United Arab Emirates revealed that Mn had the highest ability to discriminate between Sharjah and Umm Al Quwain (liver).

ELEMENTS	SHJ v/s AJ	SHJ v/s UAQ	AJ v/s UAQ
Ca (ppm)	2.39	3.06	-
Cd (ppm)	-	-	2.37
Cr (ppm)	-	3.48	2.66
Cu (ppm)	-	-	2.13
Hg (ppm)	-3.83	-5.83	-0.2
Mg (ppm)	2.10	3.29	-
Mn (ppm)	2.24	3.65	-
Na (ppm)	-	2.52	-
S (ppm)	2.28	-	2.45
Sr (ppm)	2.69	3.29	-

3.4 Metal and Non-metal Analysis in Muscle

Cu, Na, Ca, As and Cd ($p \leq 0.001$) were the significant variables in the muscle samples that discriminated the sampling sites (Sokal & Rohlf, 2012; George & Mallery, 2016). The remaining elements Cr, Hg, Mg, Mn, Ni, P, S Sr, V and Zn were removed from the analysis as these elements did not improve the model's ability to discriminate the sampling sites. Cu had the highest F ratio in the muscle samples (Lachenbruch & Goldstein, 1979).

There was a significant difference seen for all the metals and non-metals in all the sampling sites, Table 23. The univariate ANOVA significance was supported by high value of F that indicated a significant difference between the sampling sites due to As, Cu and Na (George & Mallery, 2016). In the Pooled Within- Group low correlation has been observed between the predictors (variables- metals), except a correlation has been observed between Cr, V ($r > 0.95$).

Table 23: Test of equality of group means for the muscle samples, univariate ANOVA was carried out for determining significant difference for all the metals and non-metals in relation to the three sampling sites.

	Wilks' Lambda	F	df1	df2	Sig.
As	0.714	12.819	2	64	0.000
Ca	0.967	1.087	2	64	0.343
Cd	0.891	3.914	2	64	0.025
Cr	0.963	1.245	2	64	0.295
Cu	0.654	16.922	2	64	0.000
Hg	0.846	5.842	2	64	0.005
Mg	0.968	1.058	2	64	0.353
Mn	0.983	0.547	2	64	0.582
Na	0.717	12.661	2	64	0.000
Ni	0.971	0.941	2	64	0.396
P	0.977	0.740	2	64	0.481
S	0.802	7.908	2	64	0.001
Sr	0.995	0.148	2	64	0.863
V	0.991	0.277	2	64	0.759
Zn	0.993	0.224	2	64	0.800

The sampling sites did differ significantly from one another (F = 3.121, Box's M = 105.631, p < 0.001), Tables 24 and 25.

Table 24: Log determinants table of the muscle samples showing the significance of differences between sampling sites.

Location	Rank	Log Determinant
Sharjah	5	18.668
Ajman	5	18.931
Umm Al Quwain	5	20.168
Pooled within-groups	5	20.897

Table 25: Box M result test for muscle samples showing covariance matrices relative to sampling sites.

Box's M		105.631
F	Approx.	3.121
	df1	30
	df2	12933.254
	Sig.	0.000

The eigenvalue for Function 1 was 3.006 and for Function 2 was 0.673, Table 25. The correlation of Function 1 and Function 2 were 0.866 and 0.634 respectively where Function 1 was high as 1.000, Table 26. Square of the correlations were 0.866 and 0.673 respectively, indicating that 86.6% of the variance in the sampling sites was explained by Function 1 and 63.4% of the variance was explained by Function 2 model, Table 26 (Ott, 2018; Sachs, 2012).

Table 26: : Canonical discriminant function and their associated eigenvalues for Function 1 and Function 2 for the samples from muscle.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	3.006	81.7	81.7	0.866
2	0.673	18.3	100.0	0.634

There was a significant discrimination between the three sampling sites based on Function 1 and Function 2, Table 27.

Table 27: Canonical discriminant function; Wilk's Lambda between the sampling sites, for samples from muscle.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	0.149	117.965	10	0.000
2	0.598	31.917	4	0.000

Zinc and Hg were associated with Function 1 and the rest of the variables were associated with Function 2, Table 28.

Table 28: Structure matrix determining the association between each element with Function 1 and Function 2 for the muscle samples.

	Function 1	Function 2
Zn	0.200*	0.160
Hg	0.198*	0.191
Na	-0.263	-0.529*
As	-0.291	0.466*
Cu	0.369	-0.419*
S	0.060	-0.386*
V	-0.076	0.352*
Cd	-0.128	0.329*
Cr	-0.023	0.261*
P	0.037	0.257*
Ni	-0.023	0.241*
Mg	-0.020	-0.218*
Ca	-0.039	0.209*
Sr	0.033	0.165*
Mn	-0.031	0.156*

Function 1 was comparatively better than Function 2 in differentiating the three sampling sites, Figure 12. Function 1 contributed 81.7% and Function 2 contributed only 18.3%. The data of Sharjah and Umm Al Quwain were concentrated in the positive sides of Function 1 and Function 2 respectively but from the Function 2 was not as discriminatory as Function 1.

Zn and Hg were associated with Function 1 having a positive correlation, Table 29. Function 2 was primarily associated with Na, As, Cu, S, V, Cd, Cr, P, Ni, Mg, Ca, Sr and Mn, Table 29.

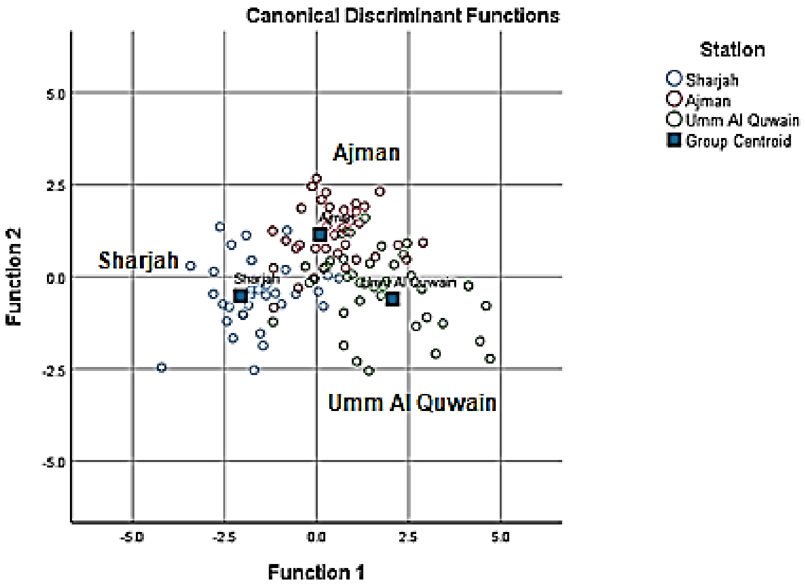

Figure 12: Canonical discriminant functions and their success in separating the three sampling areas Sharjah- SHJ, Ajman- AJ, Umm Al Quwain-UAQ) based on concentrations of metals and non- metals in muscle samples in UAE.

Arsenic, Cd and Na were correlated with Sharjah whereas, in Umm Al Quwain Ca and Cu were having high correlation, Table 29.

Table 29: Classification Function Coefficients using Fisher's linear function to classify individual weights of all the predictors in relation to their respective function in muscle samples.

		Location	
	Sharjah	Ajman	Umm Al Quwain
As (ppm)	4.381	3.938	2.240
Ca (ppm)	-0.001	0.000	0.001
Cd (ppm)	-6.988	-7.106	-17.260
Cu (ppm)	-5.929	1.248	8.881
Na (ppm)	0.023	0.009	0.007
(Constant)	-24.518	-17.042	-17.153

The classification of discriminant analysis stated that data belonging to Sharjah was 81.3% accurately classified whereas for the data of Ajman and Umm Al Quwain only 84.2% and 71.8% of data respectively were faultlessly classified. For the complete three sampling sites 78.9% of original grouped cases were correctly classified as seen in Table 30.

Table 30: Classification results of the discriminant model for the three location (Sharjah, Ajman and Umm Al Quwain) in UAE, where 78.9% of original grouped cases were correctly classified by the muscle samples.

		Predicted Group Membership			
Location		Sharjah	Ajman	Umm Al Quwain	Total
%	Sharjah	81.3	15.6	3.1	100.0
	Ajman	84.2	84.2	10.5	100.0
	Umm Al Quwain	25.6	25.6	71.8	100.0

78.9% of original grouped cases correctly classified.

The post hoc test of MANOVA for pairwise group comparisons indicated highly significant differences ($p \leq 0.05$) for As, Cu, K, Na and S between three sampling sites, except Al, Cd, Cu, Fe, Mg, Mn, Na and S which showed different conclusion when compared to discriminant analysis. There was high ability for the variance to discriminate three sampling sites when there was an increase in the value of T statistic. The pairwise group comparison table revealed Cu with the highest ability to discriminate between Sharjah and Umm Al Quwain as seen in Table 31.

Table 31: Significance of pairwise comparison between the three locations in United Arab Emirates revealed that Cu had the highest ability to discriminate between Sharjah and Umm Al Quwain (muscle).

ELEMENTS	SHJ v/s AJ	SHJ v/s UAQ	AJ v/s UAQ
As (ppm)	-	4.15	4.5
Cd (ppm)	-	-	0.27
Cu (ppm)	-	5.23	4.85
Hg (ppm)	2.86	3.03	-
K(ppm)	-	4.79	3.11
Na (ppm)	4.86	3.49	-
S (ppm)	-	3.48	3.41

Chapter 4: Discussion

The Arabian Gulf has a unique marine ecosystem with shallow and semi-enclosed structure, the extensive shallow areas have a depth of about 35 meters (Naser, 2013; Sheppard et al., 2010). United Arab Emirates is one of the Arabian Gulf countries and its shores extend up to a distance of 700 km (Al-Yousuf et al., 2000). A major development in the social, economic and industrial sector has occurred in the Arabian Gulf countries in the past few decades and the ill effects are seen on the basin of the Gulf which is surrounded by many anthropogenic activities causing huge effect on the marine ecosystem (Al-Yousuf et al., 2000; Naser, 2013).

Recently there has been a growing interest with respect to metal and non-metal contamination in the marine ecosystem, (Yasmeen et al., 2016). Additional production of metals in the environment through anthropogenic activities is a threat when it crosses the threshold level meaning exceeds beyond the tolerable limits and starts bioaccumulating or biomagnifying ultimately causing harm to the respective species (Makedonski et al., 2017).

The accumulation of metals or non-metals is evident in many fish species in different trophic levels (Alizada et al., 2020). Also, many pelagic fish belongs to lower trophic levels in marine food webs, and they themselves are an important prey for the higher trophic level organisms (Velarde et al., 2015). The age, size, species, growth development and other physiological factors play an important role, considering the larvae of fish get more affected by the contaminants compared to an adult (Alizada et al., 2020).

The contaminants may enter the body of fish through food and water passing the digestive tract (direct consumption) or through the gills and skin absorption (indirect consumption) (Rajeshkumar & Li, 2018). The gastrointestinal tract of fish develops from the larval stage to the adult, the adult fish consist an oesophagus, stomach, anterior intestine and posterior intestine (Govoni et al., 1986). The gut is an important organ that digests the food and continues the absorption process further there are intestinal barriers that prevents penetration of allergens, pathogens or any foreign contaminant (Ray & Ringo, 2014). After gastrointestinal tract, liver is considered one of the important organs as it not only restricts to the function of releasing enzymes for digestion or production of biochemicals when necessary but also detoxifies the body by storing the toxicants (Adeyemo et al., 2010; Fazio et al., 2014) and lastly the nutrients reach the muscle depositing the required nutrients through blood circulation (Adeyemo et al., 2010; Fazio et al., 2014).

This study showed that various metals and non-metals were accumulating in the three tissues of Indian oil sardines. In addition, some of the elements were measured in levels exceeding international acceptable limits, which is a cause for concern. In the greater Arabian Gulf ecosystem, this could mean that there is a chance of biomagnification along the food web. It also suggests that some of these heavy metals, are potentially entering human diets, raising concern regarding human health. In this study Cd, Cr, Cu and Zn were the metals generally exceeding internationally allowable standards of concentrations for these elements in fish used for consumption (FAO, 1983; EU, 2001; WHO, 2007). The accumulation pattern of the metals that exceeded these standards was as follows: Cd > Cr > Cu > Zn. The GI tract had high concentrations of Cd, Cu, Cr and Zn. Further in the liver, high concentrations of metals included Cr, Cu and Cd. The muscle had high levels of Cd and Cr relative to international standards. Comparisons of metal concentrations in sardine species in Tanzania showed accumulation of Cu and Zn with values 3.5±0.1 and 130.9±0.5

respectively, both of which exceeded FAO standards (FAO, 1983). The European pilchard (*Sardina pilchardus)* from Algeria showed presence of Cd (0.55±0.44) which exceeding European Commission and FAO standards (FAO, 1983, EC, 2001). However, Indian oil sardine (*Sardinella longiceps)* from India showed accumulation of Cd (0.43±0.28) and Cr (1.12±0.32) that exceeded international standards (FAO, 1983; EU, 2001; WHO, 2007). Thus, the phenomenon of bioaccumulation of various potentially harmful metals in many small fish is widespread.

The accumulation pattern for liver of metals and non-metals was as follows S > P > K > Na > Ca > Mg > Zn > Sr > Cd > As > Cr > Cu > Mn > Hg. The accumulation pattern of metals in GI tracts was as follows: S > Ca > Na > Zn > Sr > Mg > Mn > As > Cd > Cu > K > Cr > Hg. The accumulation pattern of metals and non-metals in muscles was were as follows: P > Ca > S > Na > K > Mg > Sr > Zn > As > Mn > Cu > Cr > Cd > Hg. The fish age, size, sex and species influence accumulation patterns. For example, the larvae of fish are likely be affected more when exposed to the contaminants compared to an adult fish (Alizada et al., 2020). In addition, some fish species have high resistance towards certain contaminants compared to other species (Alizada et al., 2020).

A recent study on Indian anchovy, *Stoephorus indicus* (Alizada et al., 2020) was conducted in UAE showed high concentrations of Zn, Cu, Cr and Cd exceeded international permissible limits. The sampling locations of this study were same to the current study, suggesting similar factors influenced uptake and assimilation of a range of metals and non-metals.

A large amount of Zn was found only in the GI samples of Indian oil sardines which suggests, during the initial period of digestion sardines are able to accumulate Zn inside their GI. In the Arabian Gulf through discharge of detergent industry, textile industry and oil production Zn enter into the marine ecosystem (Naser, 2013; Sarker et al., 2015).

Cadmium is considered highly toxic element and can be transported through air as fine suspended particulate matter. According to the literature it has been suggested that large fish and marine mammals and marine birds have the ability to accumulate toxins inside their liver (Sanpera et al., 2000). Presence of Cd inside their body can affect reproductive output or cause death (Sanpera et al., 2000). Regarding human’s accumulation of Cd can affect hepatic, pulmonary, adrenal, reproductive process or even cause cancer (Alizada et al., 2020). According to the results Cd was found in the liver and GI samples where they were exceeding the maximum permissible level whereas, Cd was also found in the muscle samples.

Copper enter into the marine water through boating where the paints and oils from the boats are an issue, fishing activity, electroplating and agricultural activities do contribute for releasing Cu into the water (Al Rashdi et al., 2015; Rajeshkumar & Li, 2018). Industries dealing with fossil fuels, water incineration, disposable sites, production of batteries smelting of Cu, Pb and Zn, fertilizers with phosphate directly or indirectly does contribute to increase in the availability of Cd in the marine ecosystem (Cunningham et al., 2019). Cu was found in the liver and GI samples to be exceeding the maximum permissible limits as given by international guidelines.

Chromium is a microelement and plays an important role in glucose metabolism but at the same time it is considered as a harmful pollutant (Costa & Klein, 2006). In the coastal areas of UAE Cr is found in the first 10 m of soil (Samara et al., 2016). The concentration of Cr in the emirate Sharjah found was around 15.3- 91 µg/g in the sediments (Samara et al., 2016). Similarly, in the Siniya Island of Umm Al

Quwain 135 µg/g of Cr was found in the sediments (Ksiksi et al., 2015). However, presence of Cr can be linked to its bioavailability in the bottom coastal water (Alizada et al., 2020). Sardines mostly feed on benthic organism and accumulation of Cr is understood. Regarding the Cr presence in sardines it was found in the liver, GI and muscle samples. Though the amount of accumulation in muscles was acceptable the accumulation in the liver and GI samples were exceeding the maximum permissible limits.

The emirate of Sharjah showed high amount of Cd, Cr, Cu and Zn in sardines tissue samples followed by Ajman and Umm Al Quwain. The literature does state that Indian oil sardines are found deep inside the Arabian Gulf waters and there are possibilities that they may not be migrating outside the Arabian gulf. Therefore, sardines are accumulating metals from the Gulf waters. However, there is a contradicting speculation that sardines may be migrating in and out of the Arabian Gulf and accumulating contaminants from other regions. Further studies are required for understanding migratory behavior, habitat location and contaminants presence in the Arabian gulf.

Thus, a more detailed studies needs to be conducted to understand the roles of the metals and non-metals with the marine organisms and their ecosystems in the Arabian Gulf, as there are very few studies related to bioaccumulation in the marine organisms. Currently it is a limitation as not much data is available for comparing the studies, understanding the mechanism of bioaccumulation in the Arabian Gulf but this limitation allows further studies.

Chapter 5: Conclusion

According to the study on presence of metals and non-metals in the fish biomass and the study area it can be said that Sharjah is the most polluted Emirate followed by Ajman and Umm Al Quwain. Regarding the fish gastrointestinal tract, it is consisting huge amount of different metal and non-metal constituents, even though the metal and non-metal particles exits from the fish body over the period if proper action not taken will lead to toxicity in the fish. It was noted that cadmium, chromium, copper and zinc were high in concentration specially in the GI of fish. Cadmium and chromium were also found in the muscle of fish in low concentration which is a topic of concern.

Even though humans only consume the muscle of fish other organisms in the marine ecosystem are consuming the entire fish with including liver, GI and other body parts that can cause bioaccumulation as explained in the previous chapters.

The reason for increase in the metals and non-metals in the waterbodies is due to the anthropogenic activities specially in Sharjah there are various recreational areas beside the waterbodies, presence of industries and domestic waste can also be a reason for increase in pollution. Not only Sharjah but Ajman and Umm Al Quwain has been the region for residential area and over the years the increase in population can lead to increase in the development, use of advanced technologies and these modern inventions do produce huge amount of waste.

Therefore, to protect and bring the marine ecosystem to a proper equilibrium it is necessary to understand the sources of pollution and take necessary action against it.

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Appendices

Appendix A: Metal and Non-metal Analysis in Liver

Descriptive statistic was performed for each predictor variables to check mean, standard error, standard deviation, maximum, minimum, interquartile range and skewness of the variables depending on sampling sites.

Table 32: Overview of descriptive statistic for metals and non- metals in liver.

	Station			Statistic	Std. Error
As	Sharjah	Mean		2.8938	.28407
		95% Confidence Interval for Mean	Lower Bound	2.2883	
			Upper Bound	3.4992	
		5% Trimmed Mean		2.8619	
		Median		2.9750	
		Variance		1.291	
		Std. Deviation		1.13629	
		Minimum		.92	
		Maximum		5.44	
		Range		4.52	
		Interquartile Range		1.46	
		Skewness		.156	.564
		Kurtosis		.673	1.091
	Ajman	Mean		2.6455	.25149
		95% Confidence Interval for Mean	Lower Bound	2.1224	
			Upper Bound	3.1685	
		5% Trimmed Mean		2.6135	
		Median		2.3800	
		Variance		1.391	
		Std. Deviation		1.17961	
		Minimum		.98	
		Maximum		4.87	
		Range		3.89	
		Interquartile Range		2.03	
		Skewness		.489	.491
		Kurtosis		-.870	.953
	Umm Al Quwain	Mean		2.4153	.25714
		95% Confidence Interval for Mean	Lower Bound	1.8702	
			Upper Bound	2.9604	
		5% Trimmed Mean		2.3320	
		Median		1.8800	
		Variance		1.124	
		Std. Deviation		1.06020	
		Minimum		1.39	
		Maximum		4.94	
		Range		3.55	
		Interquartile Range		1.65	
		Skewness		1.139	.550
		Kurtosis		.342	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Ca	Sharjah	Mean		2704.3063	1003.22188
		95% Confidence Interval for Mean	Lower Bound	565.9894	
			Upper Bound	4842.6231	
		5% Trimmed Mean		2175.1681	
		Median		1302.4500	
		Variance		16103266.293	
		Std. Deviation		4012.88753	
		Minimum		207.30	
		Maximum		14725.80	
		Range		14518.50	
		Interquartile Range		2246.90	
		Skewness		2.381	.564
		Kurtosis		5.436	1.091
	Ajman	Mean		903.5364	254.13166
		95% Confidence Interval for Mean	Lower Bound	375.0407	
			Upper Bound	1432.0321	
		5% Trimmed Mean		705.4955	
		Median		599.7000	
		Variance		1420823.768	
		Std. Deviation		1191.98312	
		Minimum		36.00	
		Maximum		5685.30	
		Range		5649.30	
		Interquartile Range		923.03	
		Skewness		3.316	.491
		Kurtosis		13.064	.953
	Umm Al Quwain	Mean		262.5824	29.81143
		95% Confidence Interval for Mean	Lower Bound	199.3849	
			Upper Bound	325.7798	
		5% Trimmed Mean		262.4359	
		Median		252.9000	
		Variance		15108.264	
		Std. Deviation		122.91568	
		Minimum		57.60	
		Maximum		470.20	
		Range		412.60	
		Interquartile Range		154.00	
		Skewness		-.162	.550
		Kurtosis		-.498	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Cd	Sharjah	Mean		1.0606	.32241
		95% Confidence Interval for Mean	Lower Bound	.3734	
			Upper Bound	1.7478	
		5% Trimmed Mean		.8979	
		Median		.6400	
		Variance		1.663	
		Std. Deviation		1.28966	
		Minimum		.06	
		Maximum		4.99	
		Range		4.93	
		Interquartile Range		1.32	
		Skewness		2.135	.564
		Kurtosis		5.275	1.091
	Ajman	Mean		1.6836	.38564
		95% Confidence Interval for Mean	Lower Bound	.8817	
			Upper Bound	2.4856	
		5% Trimmed Mean		1.3978	
		Median		1.0900	
		Variance		3.272	
		Std. Deviation		1.80880	
		Minimum		.30	
		Maximum		8.59	
		Range		8.29	
		Interquartile Range		.72	
		Skewness		3.026	.491
		Kurtosis		10.356	.953
	Umm Al Quwain	Mean		.6335	.11516
		95% Confidence Interval for Mean	Lower Bound	.3894	
			Upper Bound	.8776	
		5% Trimmed Mean		.6073	
		Median		.3900	
		Variance		.225	
		Std. Deviation		.47480	
		Minimum		.15	
		Maximum		1.59	
		Range		1.44	
		Interquartile Range		.72	
		Skewness		.895	.550
		Kurtosis		-.317	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Co	Sharjah	Mean		.1194	.01918
		95% Confidence Interval for Mean	Lower Bound	.0785	
			Upper Bound	.1603	
		5% Trimmed Mean		.1154	
		Median		.1000	
		Variance		.006	
		Std. Deviation		.07672	
		Minimum		.03	
		Maximum		.28	
		Range		.25	
		Interquartile Range		.12	
		Skewness		.786	.564
		Kurtosis		-.213	1.091
	Ajman	Mean		.1364	.01278
		95% Confidence Interval for Mean	Lower Bound	.1098	
			Upper Bound	.1630	
		5% Trimmed Mean		.1334	
		Median		.1250	
		Variance		.004	
		Std. Deviation		.05996	
		Minimum		.05	
		Maximum		.28	
		Range		.23	
		Interquartile Range		.10	
		Skewness		.541	.491
		Kurtosis		-.116	.953
	Umm Al Quwain	Mean		.1094	.03031
		95% Confidence Interval for Mean	Lower Bound	.0452	
			Upper Bound	.1737	
		5% Trimmed Mean		.0966	
		Median		.0400	
		Variance		.016	
		Std. Deviation		.12497	
		Minimum		.02	
		Maximum		.43	
		Range		.41	
		Interquartile Range		.09	
		Skewness		1.808	.550
		Kurtosis		2.323	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Cr	Sharjah	Mean		1.1581	.31851
		95% Confidence Interval for Mean	Lower Bound	.4792	
			Upper Bound	1.8370	
		5% Trimmed Mean		1.0485	
		Median		.7800	
		Variance		1.623	
		Std. Deviation		1.27402	
		Minimum		.09	
		Maximum		4.20	
		Range		4.11	
		Interquartile Range		1.12	
		Skewness		1.668	.564
		Kurtosis		2.091	1.091
	Ajman	Mean		.8577	.16266
		95% Confidence Interval for Mean	Lower Bound	.5194	
			Upper Bound	1.1960	
		5% Trimmed Mean		.7601	
		Median		.6200	
		Variance		.582	
		Std. Deviation		.76296	
		Minimum		.06	
		Maximum		3.54	
		Range		3.48	
		Interquartile Range		.59	
		Skewness		2.366	.491
		Kurtosis		6.833	.953
	Umm Al Quwain	Mean		.1359	.01998
		95% Confidence Interval for Mean	Lower Bound	.0935	
			Upper Bound	.1782	
		5% Trimmed Mean		.1304	
		Median		.1300	
		Variance		.007	
		Std. Deviation		.08239	
		Minimum		.03	
		Maximum		.34	
		Range		.31	
		Interquartile Range		.10	
		Skewness		1.014	.550
		Kurtosis		.978	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Cu	Sharjah	Mean		1.4306	.34402
		95% Confidence Interval for Mean	Lower Bound	.6974	
			Upper Bound	2.1639	
		5% Trimmed Mean		1.2868	
		Median		.8500	
		Variance		1.894	
		Std. Deviation		1.37609	
		Minimum		.17	
		Maximum		5.28	
		Range		5.11	
		Interquartile Range		1.80	
		Skewness		1.724	.564
		Kurtosis		3.095	1.091
	Ajman	Mean		2.0000	.25989
		95% Confidence Interval for Mean	Lower Bound	1.4595	
			Upper Bound	2.5405	
		5% Trimmed Mean		1.9119	
		Median		1.8650	
		Variance		1.486	
		Std. Deviation		1.21901	
		Minimum		.23	
		Maximum		5.48	
		Range		5.25	
		Interquartile Range		1.37	
		Skewness		1.143	.491
		Kurtosis		1.821	.953
	Umm Al Quwain	Mean		1.2353	.12405
		95% Confidence Interval for Mean	Lower Bound	.9723	
			Upper Bound	1.4983	
		5% Trimmed Mean		1.2298	
		Median		1.2300	
		Variance		.262	
		Std. Deviation		.51148	
		Minimum		.42	
		Maximum		2.15	
		Range		1.73	
		Interquartile Range		.61	
		Skewness		.474	.550
		Kurtosis		-.424	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
K	Sharjah	Mean		1428.9125	214.86675
		95% Confidence Interval for Mean	Lower Bound	970.9349	
			Upper Bound	1886.8901	
		5% Trimmed Mean		1343.7250	
		Median		1200.4000	
		Variance		738683.521	
		Std. Deviation		859.46700	
		Minimum		724.60	
		Maximum		3666.60	
		Range		2942.00	
		Interquartile Range		621.28	
		Skewness		2.071	.564
		Kurtosis		3.567	1.091
	Ajman	Mean		1431.5364	194.30121
		95% Confidence Interval for Mean	Lower Bound	1027.4649	
			Upper Bound	1835.6078	
		5% Trimmed Mean		1342.7116	
		Median		1135.4500	
		Variance		830565.096	
		Std. Deviation		911.35344	
		Minimum		531.30	
		Maximum		3915.00	
		Range		3383.70	
		Interquartile Range		524.45	
		Skewness		2.036	.491
		Kurtosis		3.717	.953
	Umm Al Quwain	Mean		1144.6353	161.82749
		95% Confidence Interval for Mean	Lower Bound	801.5763	
			Upper Bound	1487.6943	
		5% Trimmed Mean		1035.2003	
		Median		1032.6000	
		Variance		445198.339	
		Std. Deviation		667.23185	
		Minimum		603.90	
		Maximum		3655.20	
		Range		3051.30	
		Interquartile Range		226.15	
		Skewness		3.696	.550
		Kurtosis		14.664	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Mg	Sharjah	Mean		731.2750	216.70142
		95% Confidence Interval for Mean	Lower Bound	269.3869	
			Upper Bound	1193.1631	
		5% Trimmed Mean		654.6111	
		Median		413.5000	
		Variance		751352.078	
		Std. Deviation		866.80567	
		Minimum		47.00	
		Maximum		2795.50	
		Range		2748.50	
		Interquartile Range		711.38	
		Skewness		1.724	.564
		Kurtosis		2.218	1.091
	Ajman	Mean		365.7091	83.57272
		95% Confidence Interval for Mean	Lower Bound	191.9101	
			Upper Bound	539.5081	
		5% Trimmed Mean		306.9798	
		Median		266.0000	
		Variance		153656.788	
		Std. Deviation		391.99080	
		Minimum		27.40	
		Maximum		1850.60	
		Range		1823.20	
		Interquartile Range		389.83	
		Skewness		2.803	.491
		Kurtosis		9.842	.953
	Umm Al Quwain	Mean		123.3059	15.18928
		95% Confidence Interval for Mean	Lower Bound	91.1061	
			Upper Bound	155.5057	
		5% Trimmed Mean		117.7288	
		Median		111.4000	
		Variance		3922.141	
		Std. Deviation		62.62700	
		Minimum		36.50	
		Maximum		310.50	
		Range		274.00	
		Interquartile Range		59.10	
		Skewness		1.757	.550
		Kurtosis		4.492	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Mn	Sharjah	Mean		2.7313	.84575
		95% Confidence Interval for Mean	Lower Bound	.9286	
			Upper Bound	4.5339	
		5% Trimmed Mean		2.4253	
		Median		1.5850	
		Variance		11.445	
		Std. Deviation		3.38301	
		Minimum		.10	
		Maximum		10.87	
		Range		10.77	
		Interquartile Range		3.06	
		Skewness		1.714	.564
		Kurtosis		2.252	1.091
	Ajman	Mean		1.2068	.32711
		95% Confidence Interval for Mean	Lower Bound	.5265	
			Upper Bound	1.8871	
		5% Trimmed Mean		.9530	
		Median		1.0700	
		Variance		2.354	
		Std. Deviation		1.53429	
		Minimum		.02	
		Maximum		7.45	
		Range		7.43	
		Interquartile Range		1.22	
		Skewness		3.421	.491
		Kurtosis		14.013	.953
	Umm Al Quwain	Mean		.1059	.01015
		95% Confidence Interval for Mean	Lower Bound	.0844	
			Upper Bound	.1274	
		5% Trimmed Mean		.1065	
		Median		.1100	
		Variance		.002	
		Std. Deviation		.04184	
		Minimum		.02	
		Maximum		.18	
		Range		.16	
		Interquartile Range		.06	
		Skewness		-.553	.550
		Kurtosis		.227	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Na	Sharjah	Mean		1309.8625	223.76718
		95% Confidence Interval for Mean	Lower Bound	832.9140	
			Upper Bound	1786.8110	
		5% Trimmed Mean		1211.9583	
		Median		1085.3000	
		Variance		801148.009	
		Std. Deviation		895.06872	
		Minimum		576.80	
		Maximum		3805.20	
		Range		3228.40	
		Interquartile Range		463.38	
		Skewness		2.272	.564
		Kurtosis		4.509	1.091
	Ajman	Mean		969.5545	146.36324
		95% Confidence Interval for Mean	Lower Bound	665.1755	
			Upper Bound	1273.9336	
		5% Trimmed Mean		901.6657	
		Median		695.2000	
		Variance		471288.349	
		Std. Deviation		686.50444	
		Minimum		234.30	
		Maximum		2910.60	
		Range		2676.30	
		Interquartile Range		438.23	
		Skewness		2.103	.491
		Kurtosis		4.002	.953
	Umm Al Quwain	Mean		691.5000	116.75527
		95% Confidence Interval for Mean	Lower Bound	443.9899	
			Upper Bound	939.0101	
		5% Trimmed Mean		610.1167	
		Median		588.8000	
		Variance		231740.474	
		Std. Deviation		481.39430	
		Minimum		334.30	
		Maximum		2513.60	
		Range		2179.30	
		Interquartile Range		97.75	
		Skewness		3.779	.550
		Kurtosis		15.086	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
P	Sharjah	Mean		1990.6875	269.59314
		95% Confidence Interval for Mean	Lower Bound	1416.0633	
			Upper Bound	2565.3117	
		5% Trimmed Mean		1846.6972	
		Median		1692.4000	
		Variance		1162887.345	
		Std. Deviation		1078.37254	
		Minimum		1016.70	
		Maximum		5556.50	
		Range		4539.80	
		Interquartile Range		1116.30	
		Skewness		2.624	.564
		Kurtosis		8.393	1.091
	Ajman	Mean		1886.7591	174.62846
		95% Confidence Interval for Mean	Lower Bound	1523.5993	
			Upper Bound	2249.9189	
		5% Trimmed Mean		1825.3495	
		Median		1686.5000	
		Variance		670892.203	
		Std. Deviation		819.08010	
		Minimum		827.40	
		Maximum		4055.20	
		Range		3227.80	
		Interquartile Range		1077.95	
		Skewness		1.397	.491
		Kurtosis		1.717	.953
	Umm Al Quwain	Mean		1934.2000	270.90705
		95% Confidence Interval for Mean	Lower Bound	1359.9027	
			Upper Bound	2508.4973	
		5% Trimmed Mean		1780.7556	
		Median		1715.0000	
		Variance		1247640.675	
		Std. Deviation		1116.97837	
		Minimum		832.40	
		Maximum		5798.00	
		Range		4965.60	
		Interquartile Range		648.10	
		Skewness		2.793	.550
		Kurtosis		9.614	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
S	Sharjah	Mean		1898.4875	108.39554
		95% Confidence Interval for Mean	Lower Bound	1667.4479	
			Upper Bound	2129.5271	
		5% Trimmed Mean		1887.6750	
		Median		1922.4000	
		Variance		187993.484	
		Std. Deviation		433.58215	
		Minimum		1231.10	
		Maximum		2760.50	
		Range		1529.40	
		Interquartile Range		711.18	
		Skewness		.241	.564
		Kurtosis		-.646	1.091
	Ajman	Mean		2334.0182	163.84533
		95% Confidence Interval for Mean	Lower Bound	1993.2832	
			Upper Bound	2674.7532	
		5% Trimmed Mean		2284.5884	
		Median		2305.1000	
		Variance		590596.393	
		Std. Deviation		768.50270	
		Minimum		1236.00	
		Maximum		4393.40	
		Range		3157.40	
		Interquartile Range		857.25	
		Skewness		.928	.491
		Kurtosis		1.067	.953
	Umm Al Quwain	Mean		1873.9176	91.71662
		95% Confidence Interval for Mean	Lower Bound	1679.4871	
			Upper Bound	2068.3482	
		5% Trimmed Mean		1865.8252	
		Median		1951.9000	
		Variance		143002.955	
		Std. Deviation		378.15732	
		Minimum		1101.50	
		Maximum		2792.00	
		Range		1690.50	
		Interquartile Range		324.95	
		Skewness		-.041	.550
		Kurtosis		2.213	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Sr	Sharjah	Mean		10.0281	3.31077
		95% Confidence Interval for Mean	Lower Bound	2.9714	
			Upper Bound	17.0849	
		5% Trimmed Mean		8.4468	
		Median		5.2800	
		Variance		175.379	
		Std. Deviation		13.24307	
		Minimum		.74	
		Maximum		47.78	
		Range		47.04	
		Interquartile Range		9.57	
		Skewness		2.167	.564
		Kurtosis		4.342	1.091
	Ajman	Mean		3.2614	.93143
		95% Confidence Interval for Mean	Lower Bound	1.3243	
			Upper Bound	5.1984	
		5% Trimmed Mean		2.5048	
		Median		1.9600	
		Variance		19.087	
		Std. Deviation		4.36882	
		Minimum		.45	
		Maximum		20.98	
		Range		20.53	
		Interquartile Range		3.11	
		Skewness		3.445	.491
		Kurtosis		13.778	.953
	Umm Al Quwain	Mean		1.2576	.14081
		95% Confidence Interval for Mean	Lower Bound	.9591	
			Upper Bound	1.5562	
		5% Trimmed Mean		1.2329	
		Median		1.3800	
		Variance		.337	
		Std. Deviation		.58059	
		Minimum		.30	
		Maximum		2.66	
		Range		2.36	
		Interquartile Range		.51	
		Skewness		.321	.550
		Kurtosis		1.236	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Zn	Sharjah	Mean		14.4475	2.54468
		95% Confidence Interval for Mean	Lower Bound	9.0236	
			Upper Bound	19.8714	
		5% Trimmed Mean		13.1111	
		Median		11.4500	
		Variance		103.606	
		Std. Deviation		10.17871	
		Minimum		6.86	
		Maximum		46.09	
		Range		39.23	
		Interquartile Range		4.48	
		Skewness		2.561	.564
		Kurtosis		6.523	1.091
	Ajman	Mean		16.6450	2.36286
		95% Confidence Interval for Mean	Lower Bound	11.7312	
			Upper Bound	21.5588	
		5% Trimmed Mean		14.9076	
		Median		13.6500	
		Variance		122.829	
		Std. Deviation		11.08282	
		Minimum		8.00	
		Maximum		58.82	
		Range		50.82	
		Interquartile Range		6.83	
		Skewness		2.985	.491
		Kurtosis		10.273	.953
	Umm Al Quwain	Mean		10.7329	.85210
		95% Confidence Interval for Mean	Lower Bound	8.9266	
			Upper Bound	12.5393	
		5% Trimmed Mean		10.5466	
		Median		9.9200	
		Variance		12.343	
		Std. Deviation		3.51329	
		Minimum		5.53	
		Maximum		19.29	
		Range		13.76	
		Interquartile Range		4.99	
		Skewness		.846	.550
		Kurtosis		.794	1.063

Table 32: Overview of descriptive statistic for metals and non- metals in liver (Continued).

	Station			Statistic	Std. Error
Hg	Sharjah	Mean		.0301	.00402
		95% Confidence Interval for Mean	Lower Bound	.0216	
			Upper Bound	.0387	
		5% Trimmed Mean		.0304	
		Median		.0320	
		Variance		.000	
		Std. Deviation		.01607	
		Minimum		.00	
		Maximum		.05	
		Range		.05	
		Interquartile Range		.03	
		Skewness		-.271	.564
		Kurtosis		-1.009	1.091
	Ajman	Mean		.0763	.00602
		95% Confidence Interval for Mean	Lower Bound	.0638	
			Upper Bound	.0889	
		5% Trimmed Mean		.0758	
		Median		.0696	
		Variance		.001	
		Std. Deviation		.02825	
		Minimum		.04	
		Maximum		.12	
		Range		.08	
		Interquartile Range		.05	
		Skewness		.357	.491
		Kurtosis		-1.425	.953
	Umm Al Quwain	Mean		.1002	.01295
		95% Confidence Interval for Mean	Lower Bound	.0728	
			Upper Bound	.1277	
		5% Trimmed Mean		.0973	
		Median		.0820	
		Variance		.003	
		Std. Deviation		.05339	
		Minimum		.04	
		Maximum		.22	
		Range		.18	
		Interquartile Range		.09	
		Skewness		.899	.550
		Kurtosis		-.312	1.063

The boxplot was illustrated in order to see outliers for each predictor variables depending on sampling sites. Extreme outliers were pointed out with stars and potential outliers were depicted as a circle.

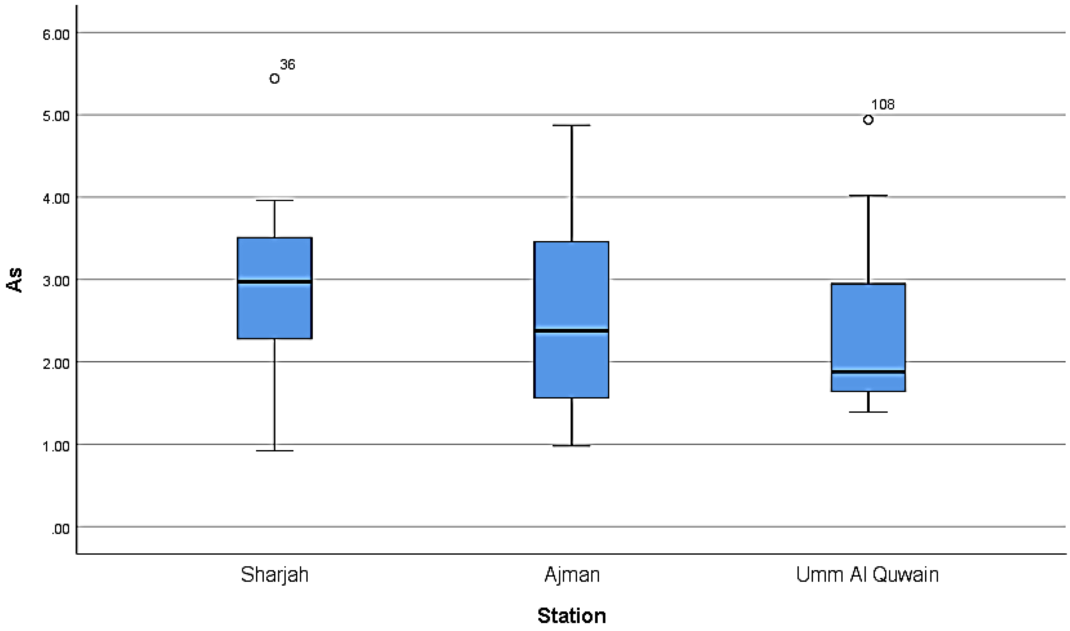

Figure 13: Representation of outliers for As in liver.

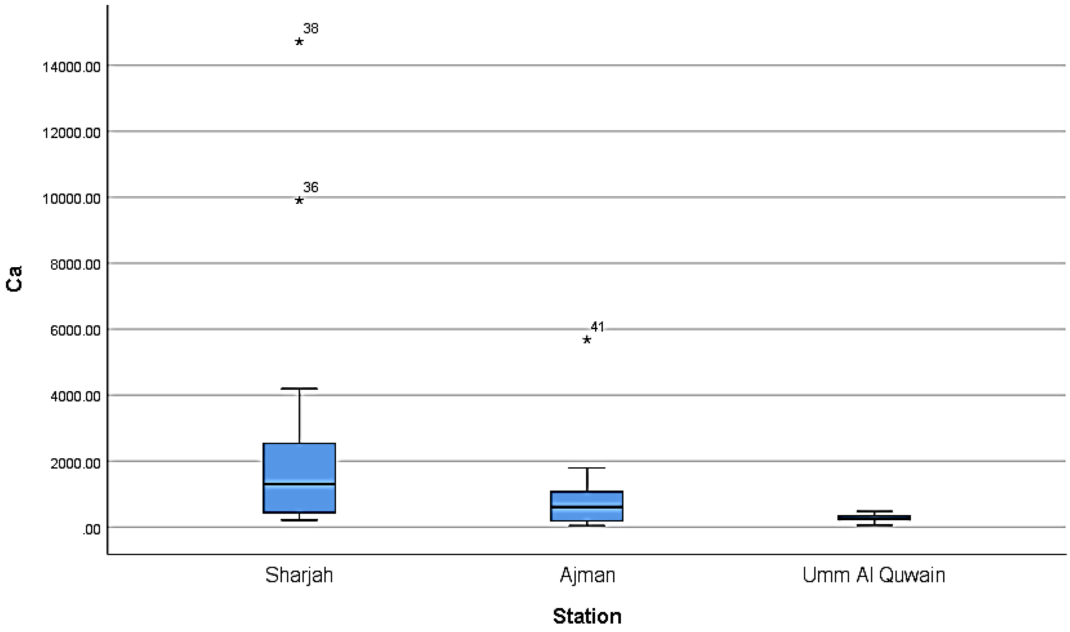

Figure 14: Representation of outliers for Ca in liver.

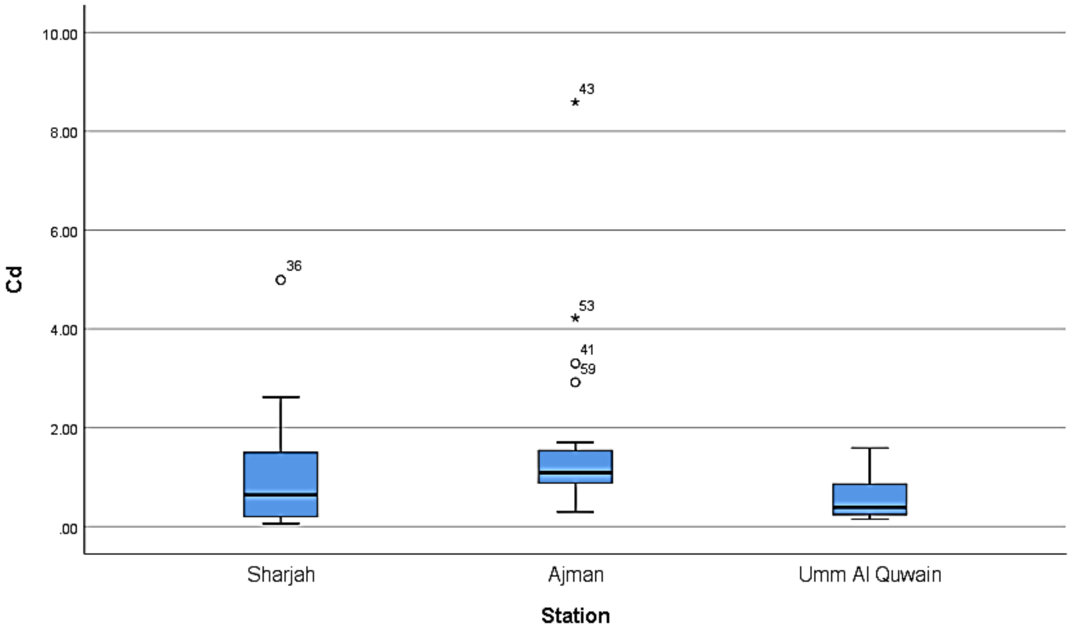

Figure 15: Representation of outliers for Cd in liver.

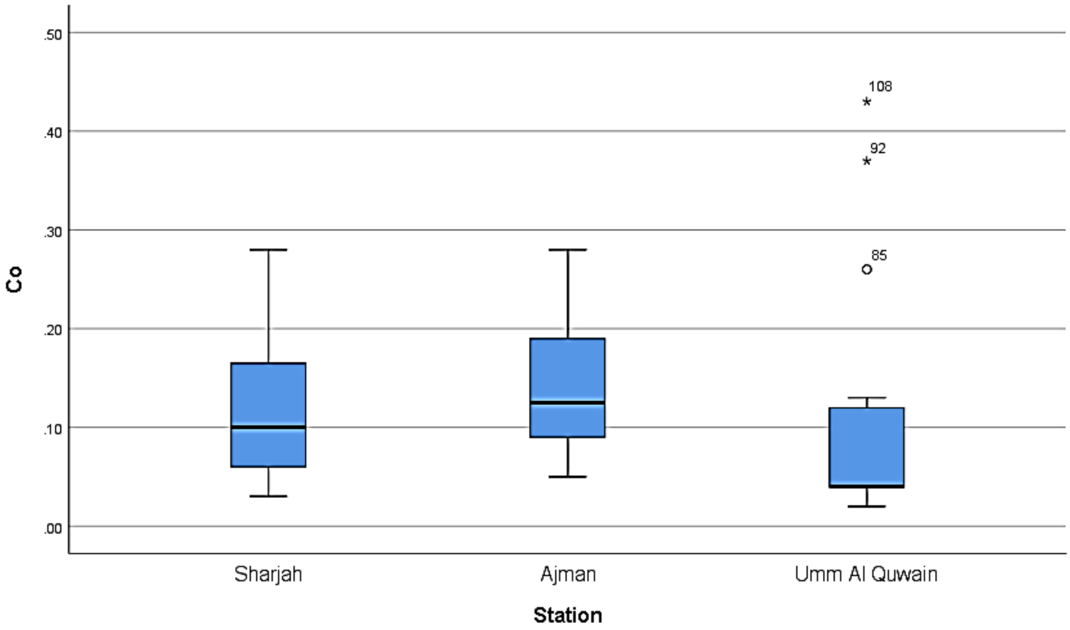

Figure 16: Representation of outliers for Co in liver.

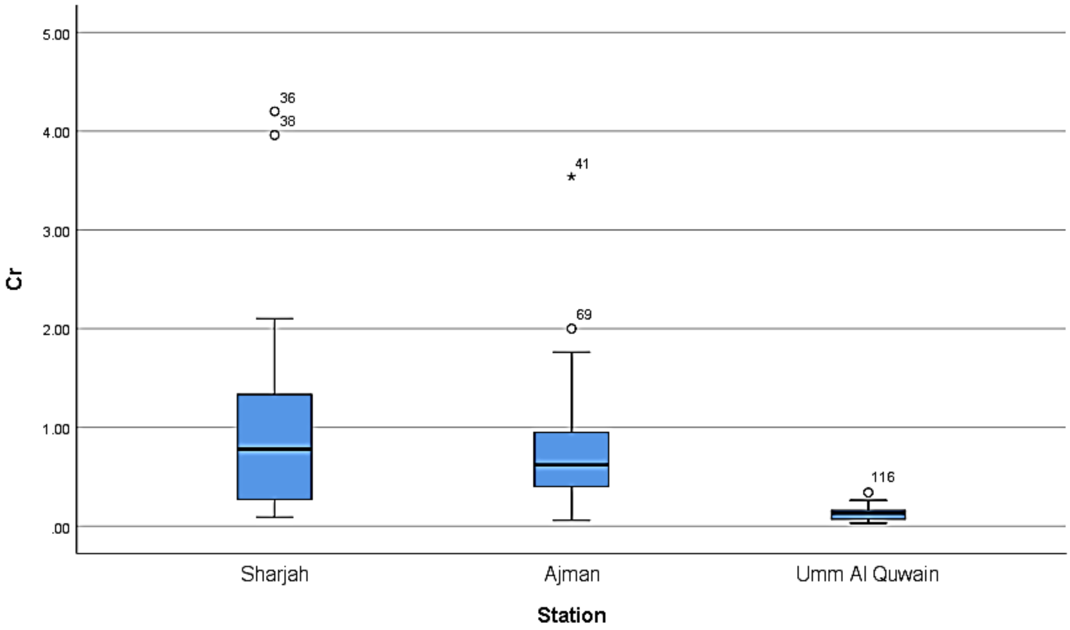

Figure 17: Representation of outliers for Cr in liver.

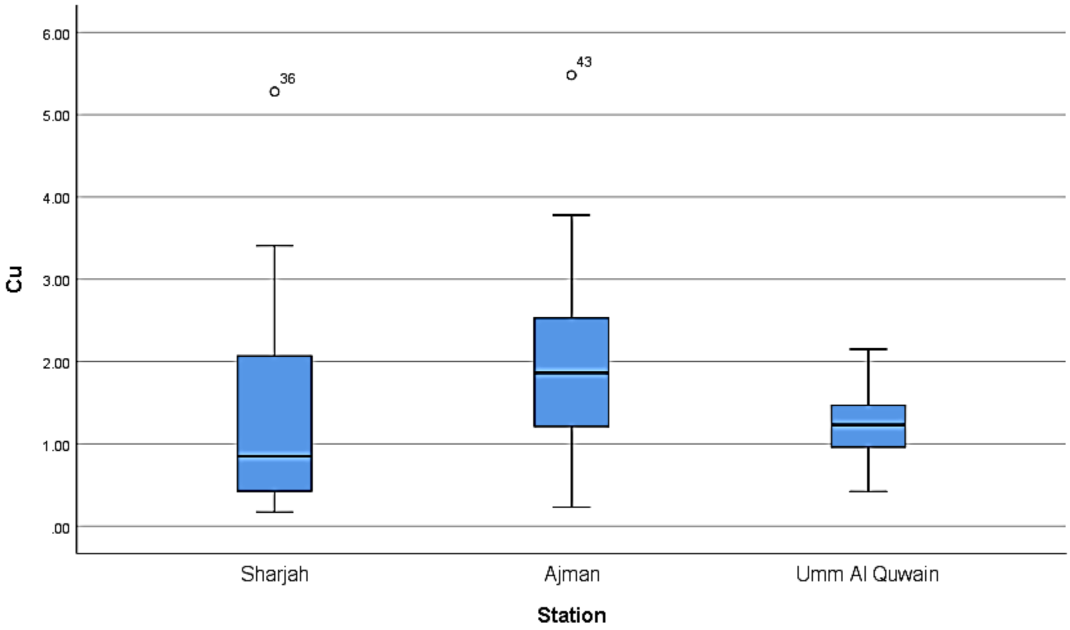

Figure 18: Representation of outliers for Cu in liver.

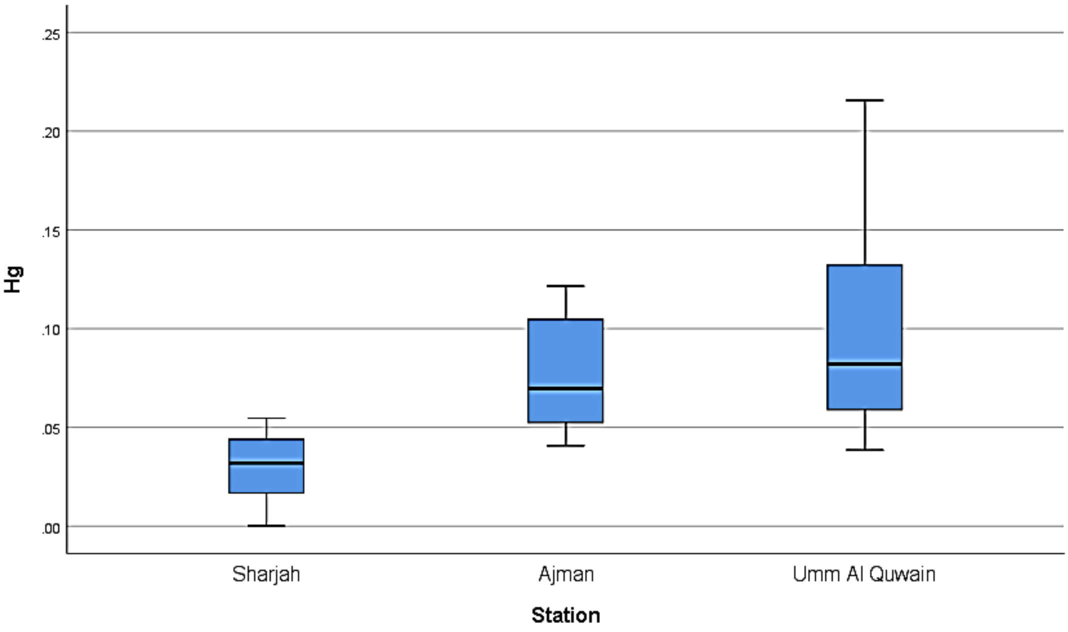

Figure 19: Representation of outliers for Hg in liver.

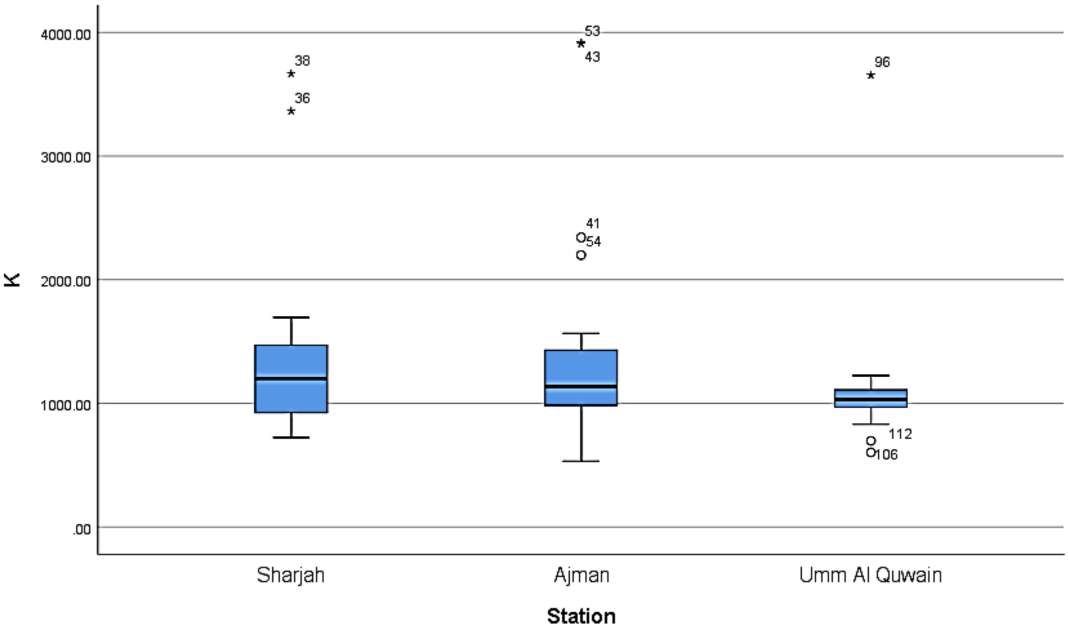

Figure 20: Representation of outliers for K in liver.

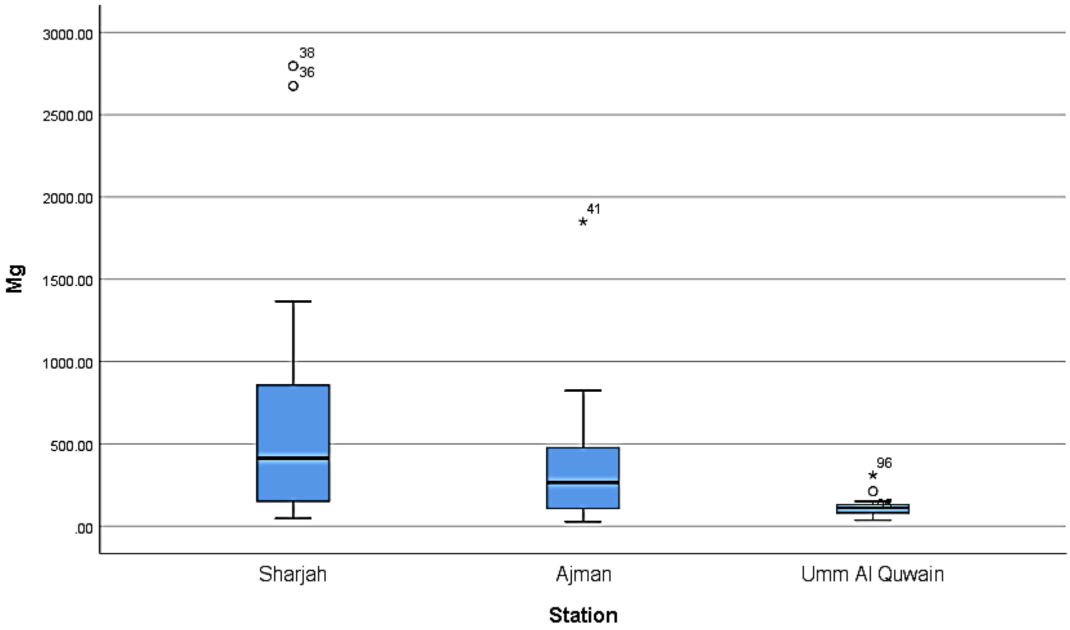

Figure 21: Representation of outliers for Mg in liver.

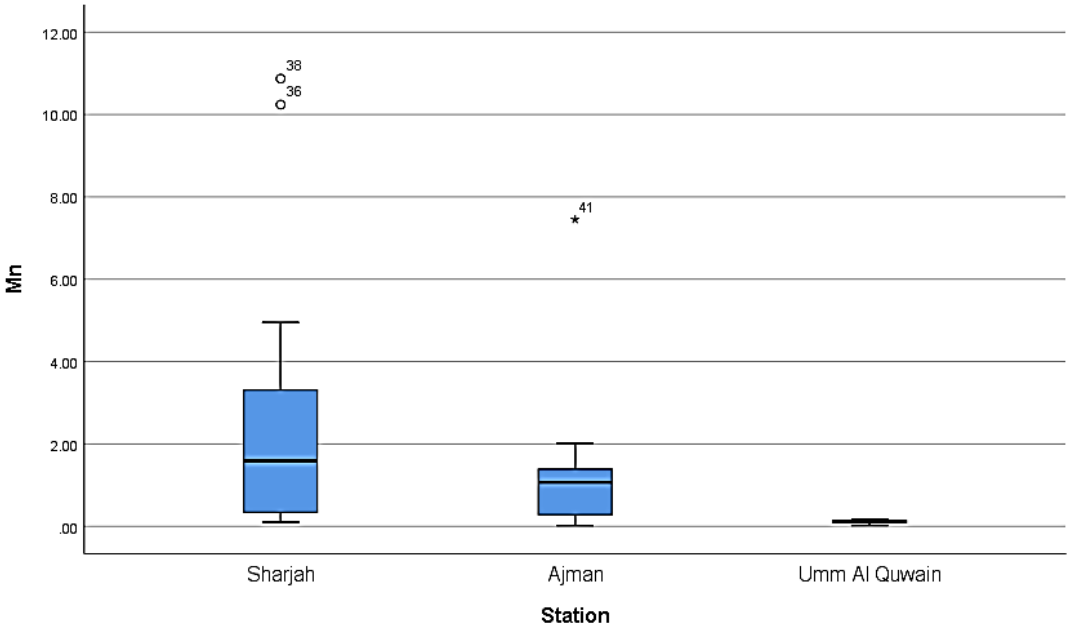

Figure 22: Representation of outliers for Mn in liver.

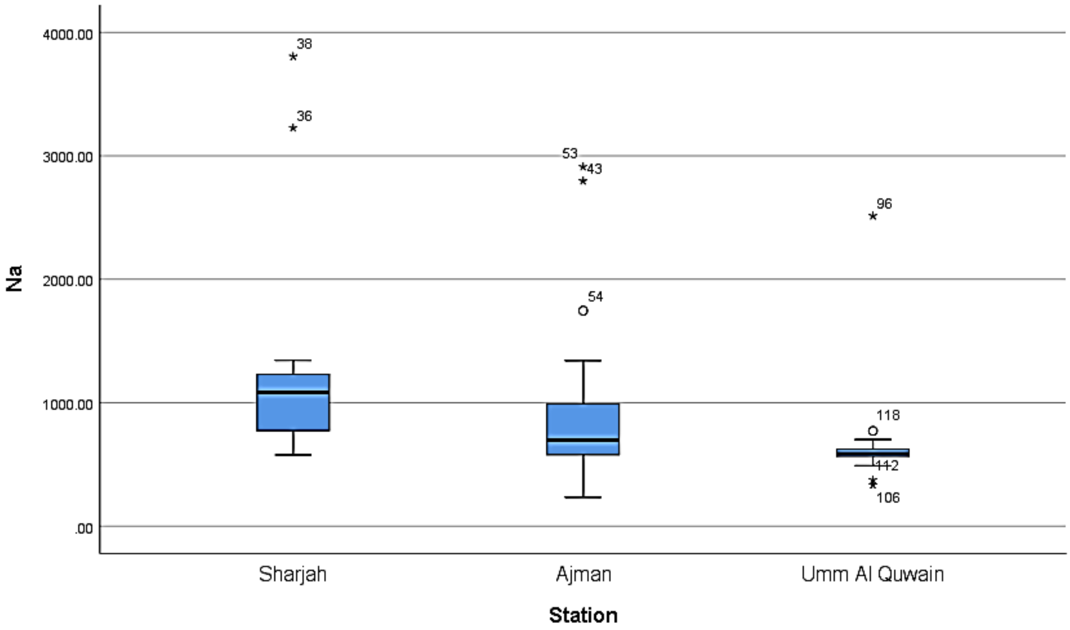

Figure 23: Representation of outliers for Na in liver.

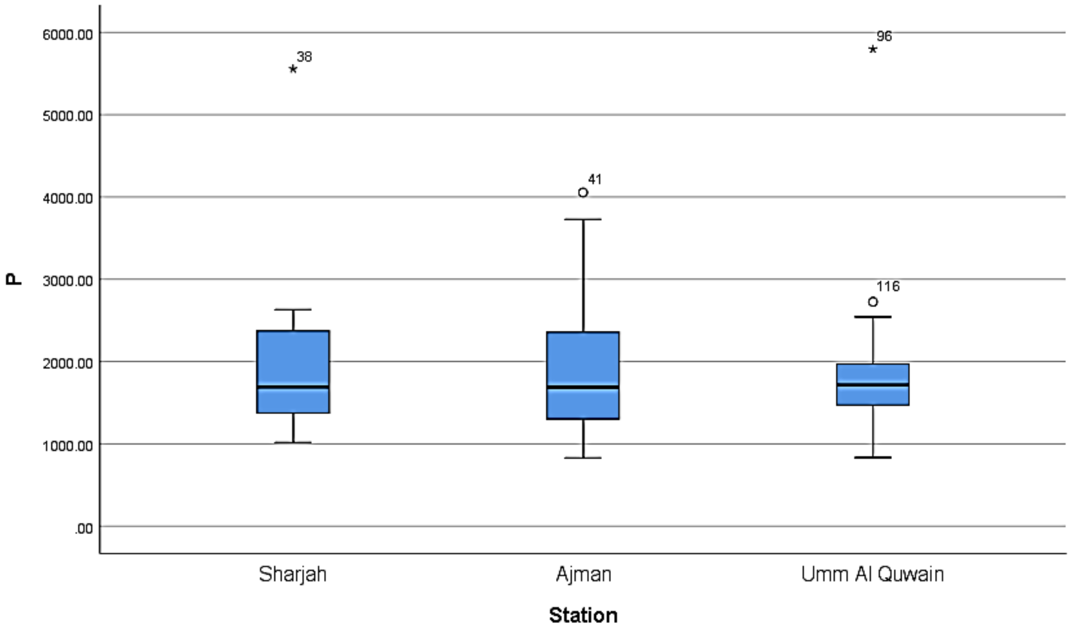

Figure 24: Representation of outliers for P in liver.

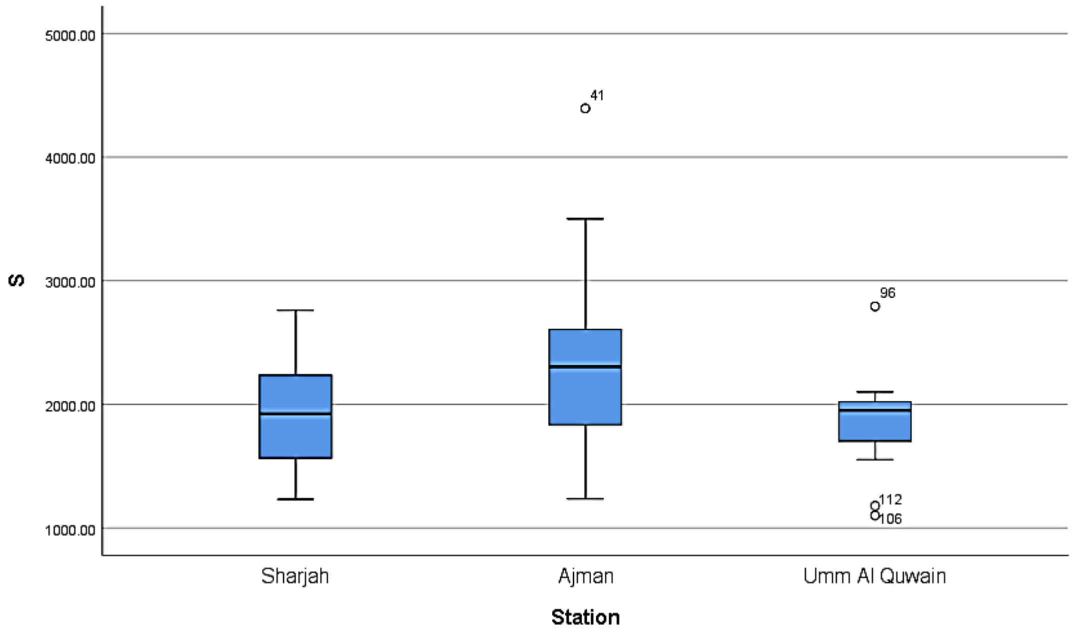

Figure 25: Representation of outliers for S in liver.

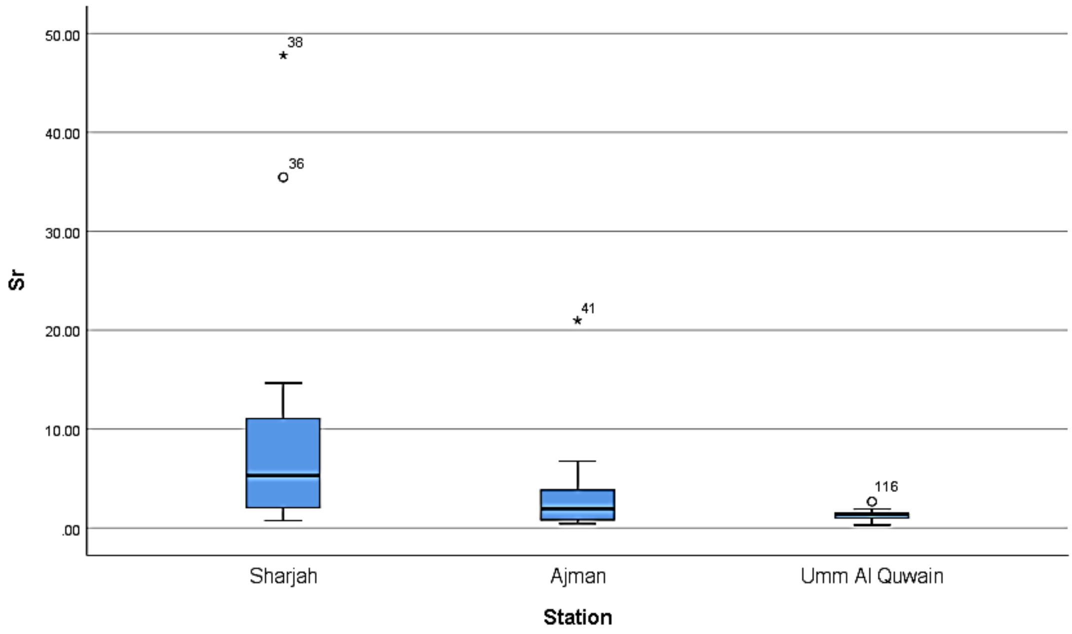

Figure 26: Representation of outliers for Sr in liver.

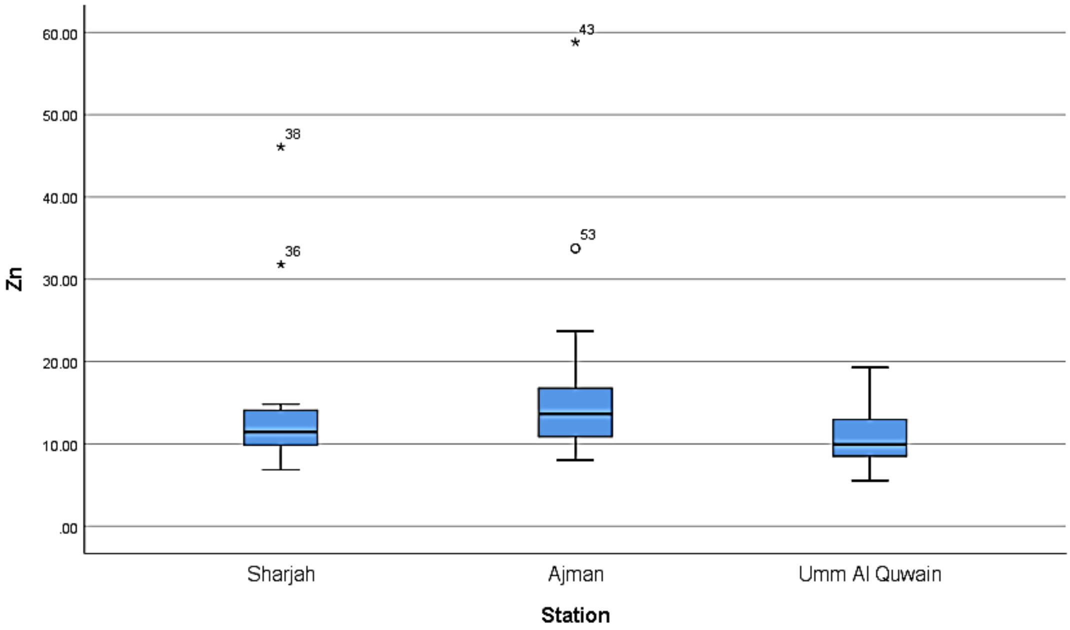

Figure 27: Representation of outliers for Zn in liver.

Appendix B: Metal and Non-metal Analysis in Gastrointestinal Tract

Descriptive statistic was performed for each predictor variables to check mean, standard error, standard deviation, maximum, minimum, interquartile range and skewness of the variables depending on sampling sites.

Table 33: Overview of descriptive statistic for metals and non-metals in GI.

	Station			Statistic	Std. Error
As	Sharjah	Mean		6.5405	.42061
		95% Confidence Interval for Mean	Lower Bound	5.6897	
			Upper Bound	7.3913	
		5% Trimmed Mean		6.3836	
		Median		6.2300	
		Variance		7.077	
		Std. Deviation		2.66019	
		Minimum		2.29	
		Maximum		13.70	
		Range		11.41	
		Interquartile Range		3.75	
		Skewness		.747	.374
		Kurtosis		.202	.733
	Ajman	Mean		6.5574	.18028
		95% Confidence Interval for Mean	Lower Bound	6.1925	
			Upper Bound	6.9224	
		5% Trimmed Mean		6.5189	
		Median		6.7000	
		Variance		1.268	
		Std. Deviation		1.12584	
		Minimum		4.65	
		Maximum		9.65	
		Range		5.00	
		Interquartile Range		1.67	
		Skewness		.443	.378
		Kurtosis		.087	.741
	Umm Al Quwain	Mean		6.9206	.42144
		95% Confidence Interval for Mean	Lower Bound	6.0650	
			Upper Bound	7.7761	
		5% Trimmed Mean		6.6862	
		Median		6.5600	
		Variance		6.394	
		Std. Deviation		2.52864	
		Minimum		2.74	
		Maximum		19.60	
		Range		16.86	
		Interquartile Range		1.53	
		Skewness		3.581	.393
		Kurtosis		18.595	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Ca	Sharjah	Mean		18409.5800	1366.97037
		95% Confidence Interval for Mean	Lower Bound	15644.6215	
			Upper Bound	21174.5385	
		5% Trimmed Mean		18112.6194	
		Median		17046.5500	
		Variance		74744319.259	
		Std. Deviation		8645.47970	
		Minimum		6346.10	
		Maximum		37711.20	
		Range		31365.10	
		Interquartile Range		13244.88	
		Skewness		.447	.374
		Kurtosis		-.755	.733
	Ajman	Mean		6164.3205	689.04892
		95% Confidence Interval for Mean	Lower Bound	4769.4139	
			Upper Bound	7559.2271	
		5% Trimmed Mean		5858.5390	
		Median		4363.6000	
		Variance		18516748.111	
		Std. Deviation		4303.10912	
		Minimum		1403.00	
		Maximum		17081.70	
		Range		15678.70	
		Interquartile Range		4982.40	
		Skewness		1.175	.378
		Kurtosis		.288	.741
	Umm Al Quwain	Mean		3204.8444	376.69020
		95% Confidence Interval for Mean	Lower Bound	2440.1227	
			Upper Bound	3969.5662	
		5% Trimmed Mean		2991.8105	
		Median		2862.4000	
		Variance		5108238.148	
		Std. Deviation		2260.14118	
		Minimum		579.00	
		Maximum		10365.70	
		Range		9786.70	
		Interquartile Range		2444.65	
		Skewness		1.467	.393
		Kurtosis		2.242	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Cd	Sharjah	Mean		5.3138	.37089
		95% Confidence Interval for Mean	Lower Bound	4.5636	
			Upper Bound	6.0639	
		5% Trimmed Mean		5.1908	
		Median		4.9650	
		Variance		5.502	
		Std. Deviation		2.34570	
		Minimum		1.48	
		Maximum		12.10	
		Range		10.62	
		Interquartile Range		2.88	
		Skewness		.754	.374
		Kurtosis		.749	.733
	Ajman	Mean		4.8564	.33239
		95% Confidence Interval for Mean	Lower Bound	4.1835	
			Upper Bound	5.5293	
		5% Trimmed Mean		4.7663	
		Median		4.3300	
		Variance		4.309	
		Std. Deviation		2.07576	
		Minimum		1.56	
		Maximum		10.90	
		Range		9.34	
		Interquartile Range		3.45	
		Skewness		.594	.378
		Kurtosis		.182	.741
	Umm Al Quwain	Mean		3.6097	.40376
		95% Confidence Interval for Mean	Lower Bound	2.7900	
			Upper Bound	4.4294	
		5% Trimmed Mean		3.3159	
		Median		3.2400	
		Variance		5.869	
		Std. Deviation		2.42256	
		Minimum		.83	
		Maximum		13.70	
		Range		12.87	
		Interquartile Range		2.25	
		Skewness		2.471	.393
		Kurtosis		8.271	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Co	Sharjah	Mean		.6463	.05236
		95% Confidence Interval for Mean	Lower Bound	.5403	
			Upper Bound	.7522	
		5% Trimmed Mean		.6361	
		Median		.6850	
		Variance		.110	
		Std. Deviation		.33117	
		Minimum		.10	
		Maximum		1.40	
		Range		1.30	
		Interquartile Range		.49	
		Skewness		.425	.374
		Kurtosis		-.521	.733
	Ajman	Mean		.2418	.02519
		95% Confidence Interval for Mean	Lower Bound	.1908	
			Upper Bound	.2928	
		5% Trimmed Mean		.2284	
		Median		.1900	
		Variance		.025	
		Std. Deviation		.15733	
		Minimum		.06	
		Maximum		.67	
		Range		.61	
		Interquartile Range		.17	
		Skewness		1.375	.378
		Kurtosis		1.189	.741
	Umm Al Quwain	Mean		.0867	.00950
		95% Confidence Interval for Mean	Lower Bound	.0674	
			Upper Bound	.1059	
		5% Trimmed Mean		.0811	
		Median		.0900	
		Variance		.003	
		Std. Deviation		.05697	
		Minimum		.01	
		Maximum		.33	
		Range		.32	
		Interquartile Range		.07	
		Skewness		2.252	.393
		Kurtosis		8.549	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Cr	Sharjah	Mean		7.9857	.67189
		95% Confidence Interval for Mean	Lower Bound	6.6267	
			Upper Bound	9.3448	
		5% Trimmed Mean		7.8533	
		Median		7.1000	
		Variance		18.057	
		Std. Deviation		4.24938	
		Minimum		1.60	
		Maximum		17.60	
		Range		16.00	
		Interquartile Range		6.74	
		Skewness		.409	.374
		Kurtosis		-.841	.733
	Ajman	Mean		2.2454	.32233
		95% Confidence Interval for Mean	Lower Bound	1.5929	
			Upper Bound	2.8979	
		5% Trimmed Mean		2.0814	
		Median		1.3600	
		Variance		4.052	
		Std. Deviation		2.01296	
		Minimum		.21	
		Maximum		7.35	
		Range		7.14	
		Interquartile Range		1.98	
		Skewness		1.421	.378
		Kurtosis		1.036	.741
	Umm Al Quwain	Mean		.3269	.03683
		95% Confidence Interval for Mean	Lower Bound	.2522	
			Upper Bound	.4017	
		5% Trimmed Mean		.2978	
		Median		.2800	
		Variance		.049	
		Std. Deviation		.22100	
		Minimum		.11	
		Maximum		1.21	
		Range		1.10	
		Interquartile Range		.23	
		Skewness		2.313	.393
		Kurtosis		7.008	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Cu	Sharjah	Mean		5.6222	.44516
		95% Confidence Interval for Mean	Lower Bound	4.7218	
			Upper Bound	6.5227	
		5% Trimmed Mean		5.4233	
		Median		5.3500	
		Variance		7.927	
		Std. Deviation		2.81541	
		Minimum		1.79	
		Maximum		13.90	
		Range		12.11	
		Interquartile Range		3.64	
		Skewness		1.044	.374
		Kurtosis		1.097	.733
	Ajman	Mean		4.2777	.30926
		95% Confidence Interval for Mean	Lower Bound	3.6516	
			Upper Bound	4.9038	
		5% Trimmed Mean		4.1393	
		Median		4.3100	
		Variance		3.730	
		Std. Deviation		1.93134	
		Minimum		1.66	
		Maximum		10.80	
		Range		9.14	
		Interquartile Range		2.33	
		Skewness		1.107	.378
		Kurtosis		2.115	.741
	Umm Al Quwain	Mean		3.9906	.34992
		95% Confidence Interval for Mean	Lower Bound	3.2802	
			Upper Bound	4.7009	
		5% Trimmed Mean		3.7202	
		Median		3.5150	
		Variance		4.408	
		Std. Deviation		2.09953	
		Minimum		1.78	
		Maximum		14.20	
		Range		12.42	
		Interquartile Range		1.66	
		Skewness		3.451	.393
		Kurtosis		15.988	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
K	Sharjah	Mean		4968.6300	270.11186
		95% Confidence Interval for Mean	Lower Bound	4422.2772	
			Upper Bound	5514.9828	
		5% Trimmed Mean		4927.2389	
		Median		4656.7000	
		Variance		2918416.723	
		Std. Deviation		1708.33741	
		Minimum		1897.90	
		Maximum		9272.80	
		Range		7374.90	
		Interquartile Range		1835.53	
		Skewness		.398	.374
		Kurtosis		.023	.733
	Ajman	Mean		4179.9256	146.17739
		95% Confidence Interval for Mean	Lower Bound	3884.0050	
			Upper Bound	4475.8463	
		5% Trimmed Mean		4146.6321	
		Median		4182.1000	
		Variance		833345.302	
		Std. Deviation		912.87748	
		Minimum		2560.00	
		Maximum		6573.40	
		Range		4013.40	
		Interquartile Range		1188.60	
		Skewness		.389	.378
		Kurtosis		.189	.741
	Umm Al Quwain	Mean		4609.0944	267.36839
		95% Confidence Interval for Mean	Lower Bound	4066.3078	
			Upper Bound	5151.8811	
		5% Trimmed Mean		4471.5086	
		Median		4450.2500	
		Variance		2573490.830	
		Std. Deviation		1604.21034	
		Minimum		2366.70	
		Maximum		11346.30	
		Range		8979.60	
		Interquartile Range		1576.82	
		Skewness		2.099	.393
		Kurtosis		7.924	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Mg	Sharjah	Mean		4970.7650	395.61054
		95% Confidence Interval for Mean	Lower Bound	4170.5671	
			Upper Bound	5770.9629	
		5% Trimmed Mean		4883.8417	
		Median		4599.6000	
		Variance		6260308.095	
		Std. Deviation		2502.06077	
		Minimum		1355.20	
		Maximum		10274.70	
		Range		8919.50	
		Interquartile Range		4207.88	
		Skewness		.372	.374
		Kurtosis		-.951	.733
	Ajman	Mean		1714.9923	173.50402
		95% Confidence Interval for Mean	Lower Bound	1363.7518	
			Upper Bound	2066.2328	
		5% Trimmed Mean		1617.5443	
		Median		1306.4000	
		Variance		1174042.171	
		Std. Deviation		1083.53227	
		Minimum		419.80	
		Maximum		4946.60	
		Range		4526.80	
		Interquartile Range		1128.20	
		Skewness		1.446	.378
		Kurtosis		1.645	.741
	Umm Al Quwain	Mean		1145.6528	96.06916
		95% Confidence Interval for Mean	Lower Bound	950.6220	
			Upper Bound	1340.6835	
		5% Trimmed Mean		1086.5086	
		Median		1090.5000	
		Variance		332254.229	
		Std. Deviation		576.41498	
		Minimum		501.50	
		Maximum		3375.60	
		Range		2874.10	
		Interquartile Range		637.27	
		Skewness		1.832	.393
		Kurtosis		5.202	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Mn	Sharjah	Mean		20.1980	1.67424
		95% Confidence Interval for Mean	Lower Bound	16.8115	
			Upper Bound	23.5845	
		5% Trimmed Mean		19.7931	
		Median		17.9000	
		Variance		112.123	
		Std. Deviation		10.58882	
		Minimum		4.76	
		Maximum		44.40	
		Range		39.64	
		Interquartile Range		17.00	
		Skewness		.450	.374
		Kurtosis		-.808	.733
	Ajman	Mean		5.6700	.73396
		95% Confidence Interval for Mean	Lower Bound	4.1842	
			Upper Bound	7.1558	
		5% Trimmed Mean		5.2376	
		Median		3.9600	
		Variance		21.009	
		Std. Deviation		4.58360	
		Minimum		.65	
		Maximum		18.60	
		Range		17.95	
		Interquartile Range		3.92	
		Skewness		1.571	.378
		Kurtosis		1.701	.741
	Umm Al Quwain	Mean		1.1689	.10721
		95% Confidence Interval for Mean	Lower Bound	.9512	
			Upper Bound	1.3865	
		5% Trimmed Mean		1.1117	
		Median		1.0350	
		Variance		.414	
		Std. Deviation		.64325	
		Minimum		.32	
		Maximum		3.43	
		Range		3.11	
		Interquartile Range		.77	
		Skewness		1.536	.393
		Kurtosis		3.316	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Na	Sharjah	Mean		4564.1800	233.21438
		95% Confidence Interval for Mean	Lower Bound	4092.4594	
			Upper Bound	5035.9006	
		5% Trimmed Mean		4552.9389	
		Median		4486.1000	
		Variance		2175557.927	
		Std. Deviation		1474.97726	
		Minimum		1658.90	
		Maximum		7940.80	
		Range		6281.90	
		Interquartile Range		1389.70	
		Skewness		.275	.374
		Kurtosis		-.138	.733
	Ajman	Mean		3022.8051	105.15914
		95% Confidence Interval for Mean	Lower Bound	2809.9216	
			Upper Bound	3235.6887	
		5% Trimmed Mean		3006.7073	
		Median		2946.7000	
		Variance		431279.319	
		Std. Deviation		656.71860	
		Minimum		1770.40	
		Maximum		4886.90	
		Range		3116.50	
		Interquartile Range		904.00	
		Skewness		.437	.378
		Kurtosis		.307	.741
	Umm Al Quwain	Mean		2831.3000	189.29342
		95% Confidence Interval for Mean	Lower Bound	2447.0139	
			Upper Bound	3215.5861	
		5% Trimmed Mean		2719.5562	
		Median		2586.5500	
		Variance		1289951.997	
		Std. Deviation		1135.76054	
		Minimum		1233.60	
		Maximum		7846.30	
		Range		6612.70	
		Interquartile Range		1031.18	
		Skewness		2.532	.393
		Kurtosis		10.215	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Ni	Sharjah	Mean		5.6645	.45093
		95% Confidence Interval for Mean	Lower Bound	4.7524	
			Upper Bound	6.5766	
		5% Trimmed Mean		5.5811	
		Median		5.4300	
		Variance		8.134	
		Std. Deviation		2.85195	
		Minimum		1.24	
		Maximum		12.07	
		Range		10.83	
		Interquartile Range		4.69	
		Skewness		.321	.374
		Kurtosis		-.818	.733
	Ajman	Mean		1.9195	.29195
		95% Confidence Interval for Mean	Lower Bound	1.3285	
			Upper Bound	2.5105	
		5% Trimmed Mean		1.6961	
		Median		1.2300	
		Variance		3.324	
		Std. Deviation		1.82324	
		Minimum		.31	
		Maximum		9.44	
		Range		9.13	
		Interquartile Range		1.33	
		Skewness		2.349	.378
		Kurtosis		6.847	.741
	Umm Al Quwain	Mean		.4028	.11250
		95% Confidence Interval for Mean	Lower Bound	.1744	
			Upper Bound	.6312	
		5% Trimmed Mean		.2877	
		Median		.2700	
		Variance		.456	
		Std. Deviation		.67501	
		Minimum		.09	
		Maximum		4.24	
		Range		4.15	
		Interquartile Range		.18	
		Skewness		5.553	.393
		Kurtosis		32.168	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
P	Sharjah	Mean		5450.5250	383.62437
		95% Confidence Interval for Mean	Lower Bound	4674.5715	
			Upper Bound	6226.4785	
		5% Trimmed Mean		5309.3694	
		Median		5082.2000	
		Variance		5886706.301	
		Std. Deviation		2426.25355	
		Minimum		1745.70	
		Maximum		12988.30	
		Range		11242.60	
		Interquartile Range		2834.52	
		Skewness		.985	.374
		Kurtosis		1.306	.733
	Ajman	Mean		5019.9923	267.23898
		95% Confidence Interval for Mean	Lower Bound	4478.9953	
			Upper Bound	5560.9893	
		5% Trimmed Mean		4859.4195	
		Median		4569.5000	
		Variance		2785250.292	
		Std. Deviation		1668.90692	
		Minimum		2971.90	
		Maximum		10919.60	
		Range		7947.70	
		Interquartile Range		1416.10	
		Skewness		1.743	.378
		Kurtosis		3.375	.741
	Umm Al Quwain	Mean		6525.5167	449.37357
		95% Confidence Interval for Mean	Lower Bound	5613.2398	
			Upper Bound	7437.7935	
		5% Trimmed Mean		6247.2198	
		Median		5965.5000	
		Variance		7269717.949	
		Std. Deviation		2696.24145	
		Minimum		2585.40	
		Maximum		17600.40	
		Range		15015.00	
		Interquartile Range		2011.73	
		Skewness		2.247	.393
		Kurtosis		7.356	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
S	Sharjah	Mean		4519.5975	280.87336
		95% Confidence Interval for Mean	Lower Bound	3951.4775	
			Upper Bound	5087.7175	
		5% Trimmed Mean		4457.4444	
		Median		4126.9000	
		Variance		3155593.764	
		Std. Deviation		1776.39910	
		Minimum		1441.80	
		Maximum		9278.20	
		Range		7836.40	
		Interquartile Range		1600.28	
		Skewness		.726	.374
		Kurtosis		.383	.733
	Ajman	Mean		4521.2872	149.35308
		95% Confidence Interval for Mean	Lower Bound	4218.9377	
			Upper Bound	4823.6367	
		5% Trimmed Mean		4481.4725	
		Median		4448.0000	
		Variance		869947.310	
		Std. Deviation		932.70966	
		Minimum		2813.60	
		Maximum		7422.10	
		Range		4608.50	
		Interquartile Range		877.70	
		Skewness		.794	.378
		Kurtosis		1.534	.741
	Umm Al Quwain	Mean		5209.2889	344.62906
		95% Confidence Interval for Mean	Lower Bound	4509.6547	
			Upper Bound	5908.9231	
		5% Trimmed Mean		4971.2556	
		Median		4680.9000	
		Variance		4275690.723	
		Std. Deviation		2067.77434	
		Minimum		2200.10	
		Maximum		15410.50	
		Range		13210.40	
		Interquartile Range		1588.20	
		Skewness		3.553	.393
		Kurtosis		17.162	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Sr	Sharjah	Mean		61.2875	4.51575
		95% Confidence Interval for Mean	Lower Bound	52.1535	
			Upper Bound	70.4215	
		5% Trimmed Mean		60.5194	
		Median		54.4000	
		Variance		815.680	
		Std. Deviation		28.56010	
		Minimum		20.20	
		Maximum		121.50	
		Range		101.30	
		Interquartile Range		42.90	
		Skewness		.430	.374
		Kurtosis		-.895	.733
	Ajman	Mean		17.4564	1.93878
		95% Confidence Interval for Mean	Lower Bound	13.5316	
			Upper Bound	21.3813	
		5% Trimmed Mean		16.2862	
		Median		13.7000	
		Variance		146.596	
		Std. Deviation		12.10767	
		Minimum		4.40	
		Maximum		50.70	
		Range		46.30	
		Interquartile Range		12.10	
		Skewness		1.604	.378
		Kurtosis		1.844	.741
	Umm Al Quwain	Mean		11.5694	1.31902
		95% Confidence Interval for Mean	Lower Bound	8.8917	
			Upper Bound	14.2472	
		5% Trimmed Mean		10.8475	
		Median		9.8000	
		Variance		62.634	
		Std. Deviation		7.91414	
		Minimum		2.00	
		Maximum		39.60	
		Range		37.60	
		Interquartile Range		11.10	
		Skewness		1.503	.393
		Kurtosis		3.120	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
V	Sharjah	Mean		3.5355	.30442
		95% Confidence Interval for Mean	Lower Bound	2.9198	
			Upper Bound	4.1512	
		5% Trimmed Mean		3.4572	
		Median		3.0550	
		Variance		3.707	
		Std. Deviation		1.92532	
		Minimum		.65	
		Maximum		8.16	
		Range		7.51	
		Interquartile Range		3.01	
		Skewness		.476	.374
		Kurtosis		-.709	.733
	Ajman	Mean		.9223	.13447
		95% Confidence Interval for Mean	Lower Bound	.6501	
			Upper Bound	1.1945	
		5% Trimmed Mean		.8553	
		Median		.5700	
		Variance		.705	
		Std. Deviation		.83978	
		Minimum		.00	
		Maximum		3.09	
		Range		3.09	
		Interquartile Range		.88	
		Skewness		1.396	.378
		Kurtosis		.952	.741
	Umm Al Quwain	Mean		.1247	.01530
		95% Confidence Interval for Mean	Lower Bound	.0937	
			Upper Bound	.1558	
		5% Trimmed Mean		.1188	
		Median		.1050	
		Variance		.008	
		Std. Deviation		.09179	
		Minimum		.00	
		Maximum		.37	
		Range		.37	
		Interquartile Range		.12	
		Skewness		1.030	.393
		Kurtosis		.475	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Zn	Sharjah	Mean		69.8775	5.98288
		95% Confidence Interval for Mean	Lower Bound	57.7760	
			Upper Bound	81.9790	
		5% Trimmed Mean		65.0000	
		Median		61.6000	
		Variance		1431.795	
		Std. Deviation		37.83907	
		Minimum		24.90	
		Maximum		225.70	
		Range		200.80	
		Interquartile Range		34.18	
		Skewness		2.376	.374
		Kurtosis		7.531	.733
	Ajman	Mean		63.2769	2.83781
		95% Confidence Interval for Mean	Lower Bound	57.5321	
			Upper Bound	69.0218	
		5% Trimmed Mean		62.2624	
		Median		60.9000	
		Variance		314.073	
		Std. Deviation		17.72210	
		Minimum		25.70	
		Maximum		112.10	
		Range		86.40	
		Interquartile Range		24.70	
		Skewness		.793	.378
		Kurtosis		1.205	.741
	Umm Al Quwain	Mean		80.9389	7.03066
		95% Confidence Interval for Mean	Lower Bound	66.6659	
			Upper Bound	95.2119	
		5% Trimmed Mean		75.5512	
		Median		69.4000	
		Variance		1779.486	
		Std. Deviation		42.18396	
		Minimum		37.60	
		Maximum		284.90	
		Range		247.30	
		Interquartile Range		32.20	
		Skewness		3.431	.393
		Kurtosis		15.606	.768

Table 33: Overview of descriptive statistic for metals and non-metals in GI (Continued).

	Station			Statistic	Std. Error
Hg	Sharjah	Mean		.0558	.00381
		95% Confidence Interval for Mean	Lower Bound	.0481	
			Upper Bound	.0635	
		5% Trimmed Mean		.0551	
		Median		.0465	
		Variance		.001	
		Std. Deviation		.02407	
		Minimum		.00	
		Maximum		.11	
		Range		.11	
		Interquartile Range		.03	
		Skewness		.589	.374
		Kurtosis		.039	.733
	Ajman	Mean		.0856	.00677
		95% Confidence Interval for Mean	Lower Bound	.0719	
			Upper Bound	.0993	
		5% Trimmed Mean		.0867	
		Median		.0884	
		Variance		.002	
		Std. Deviation		.04231	
		Minimum		.00	
		Maximum		.15	
		Range		.15	
		Interquartile Range		.05	
		Skewness		-.704	.378
		Kurtosis		.077	.741
	Umm Al Quwain	Mean		.0662	.00929
		95% Confidence Interval for Mean	Lower Bound	.0473	
			Upper Bound	.0850	
		5% Trimmed Mean		.0613	
		Median		.0558	
		Variance		.003	
		Std. Deviation		.05574	
		Minimum		.00	
		Maximum		.24	
		Range		.24	
		Interquartile Range		.06	
		Skewness		1.442	.393
		Kurtosis		1.996	.768

The boxplot was illustrated in order to see outliers for each predictor variables depending on sampling sites. Extreme outliers were pointed out with stars and potential outliers were depicted as a circle.

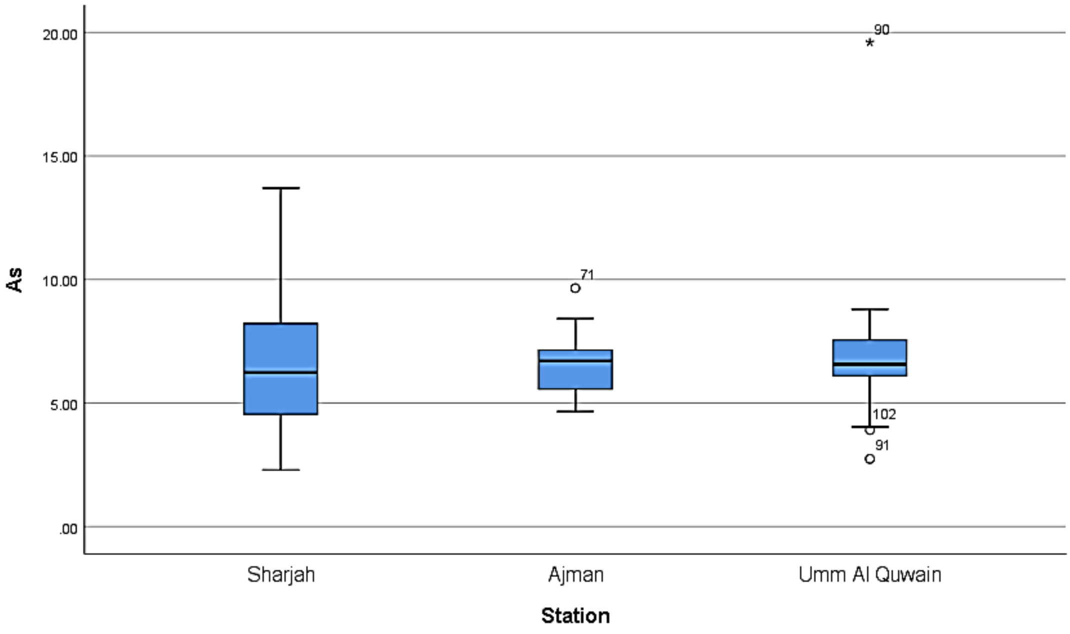

Figure 28: Representation of outliers for As in GI.

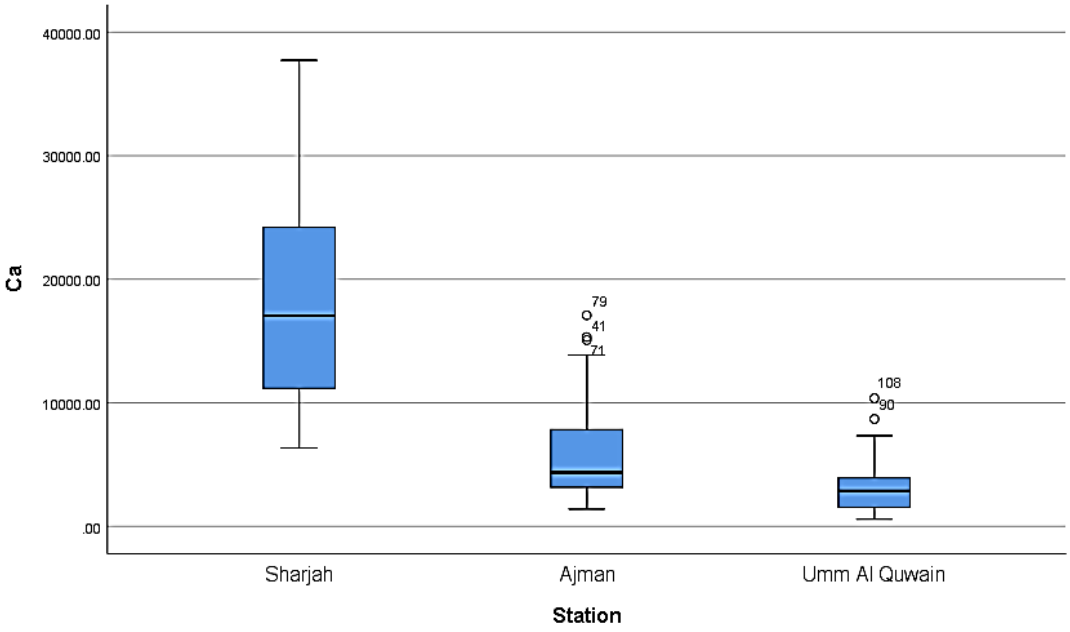

Figure 29: Representation of outliers for Ca in GI.

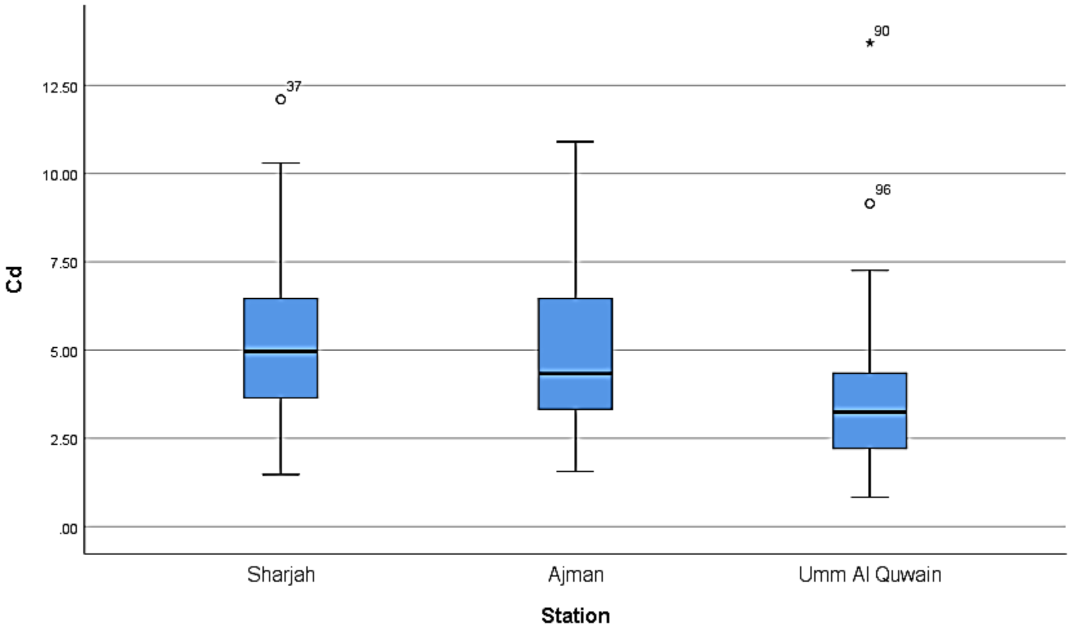

Figure 30: Representation of outliers for Cd in GI.

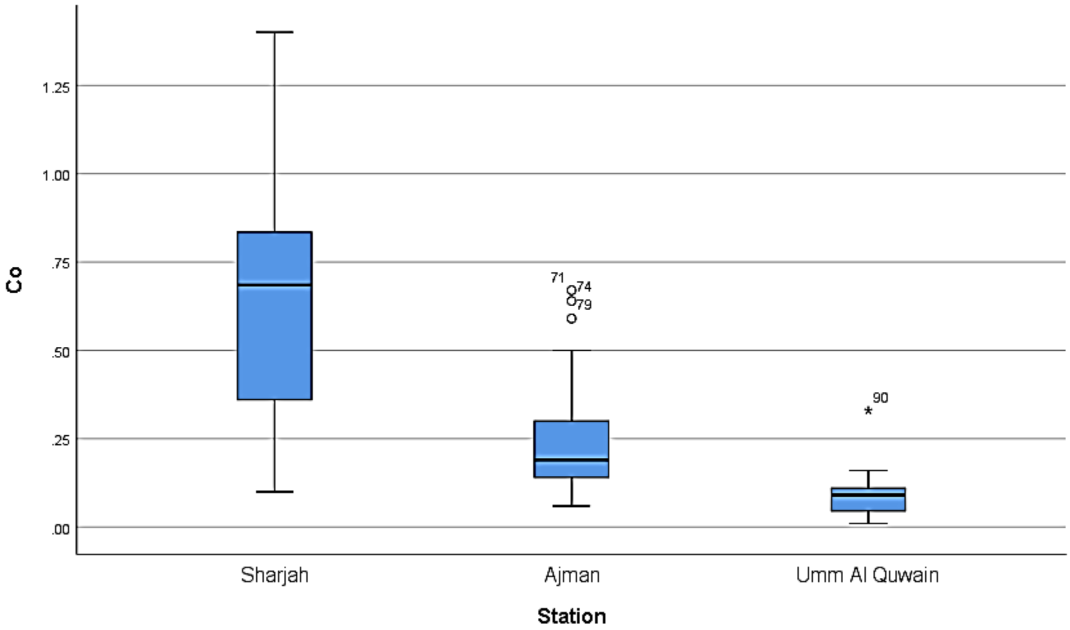

Figure 31: Representation of outliers for Co in GI.

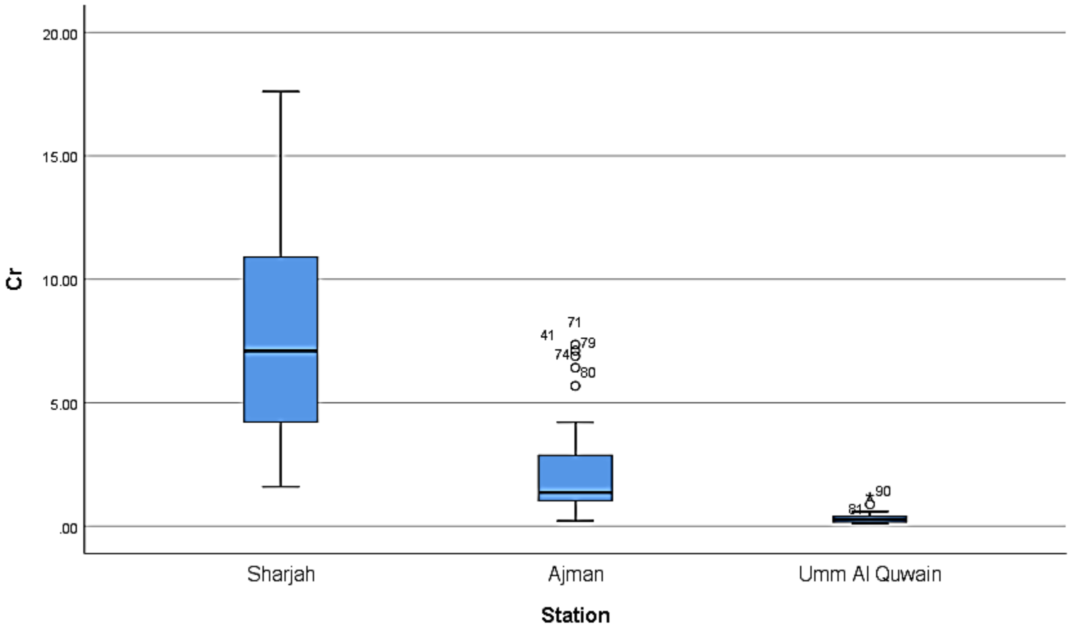

Figure 32: Representation of outliers for Cr in GI.

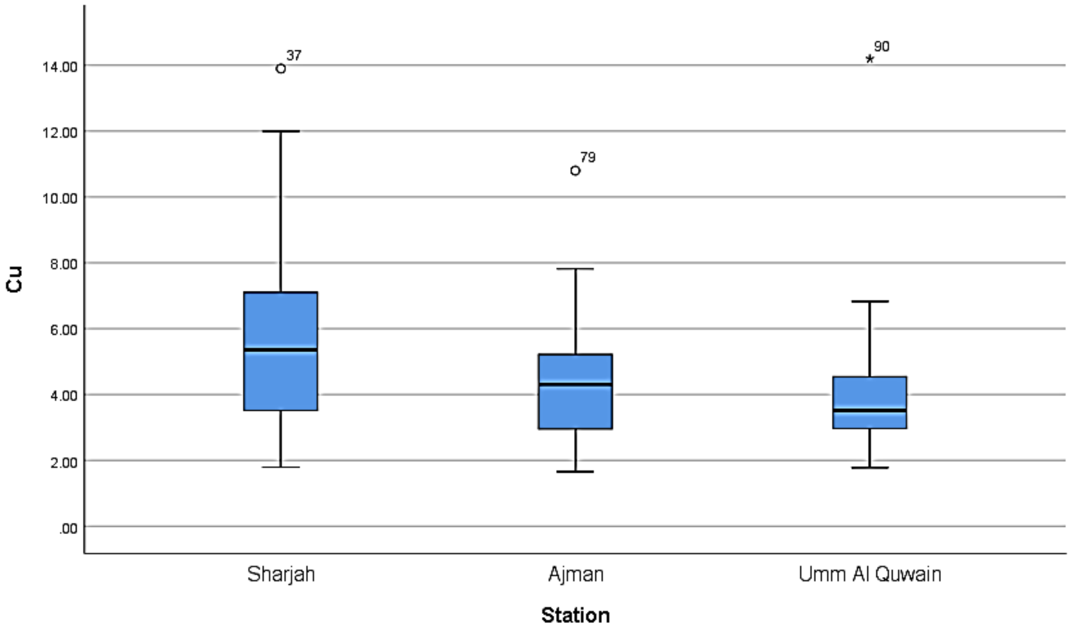

Figure 33: Representation of outliers for Cu in GI.

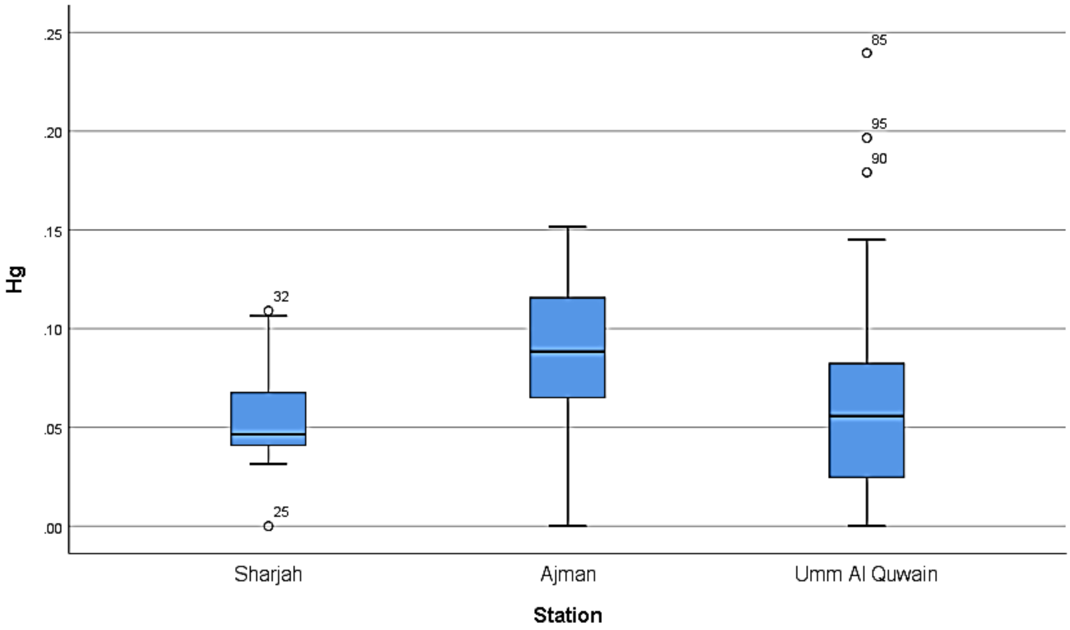

Figure 34: Representation of outliers for Hg in GI.

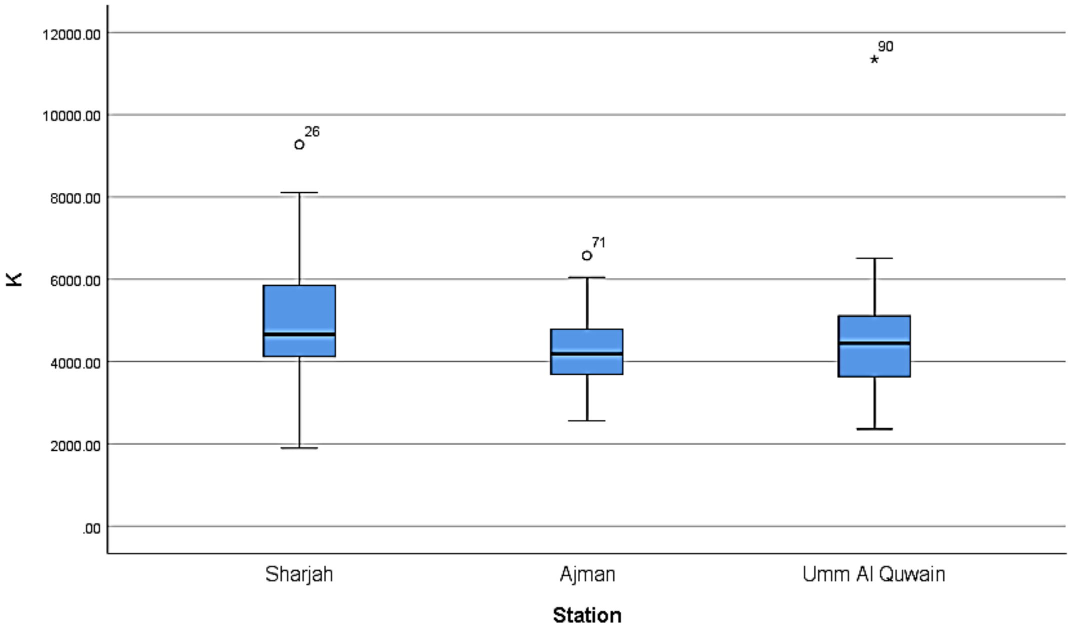

Figure 35: Representation of outliers for K in GI.

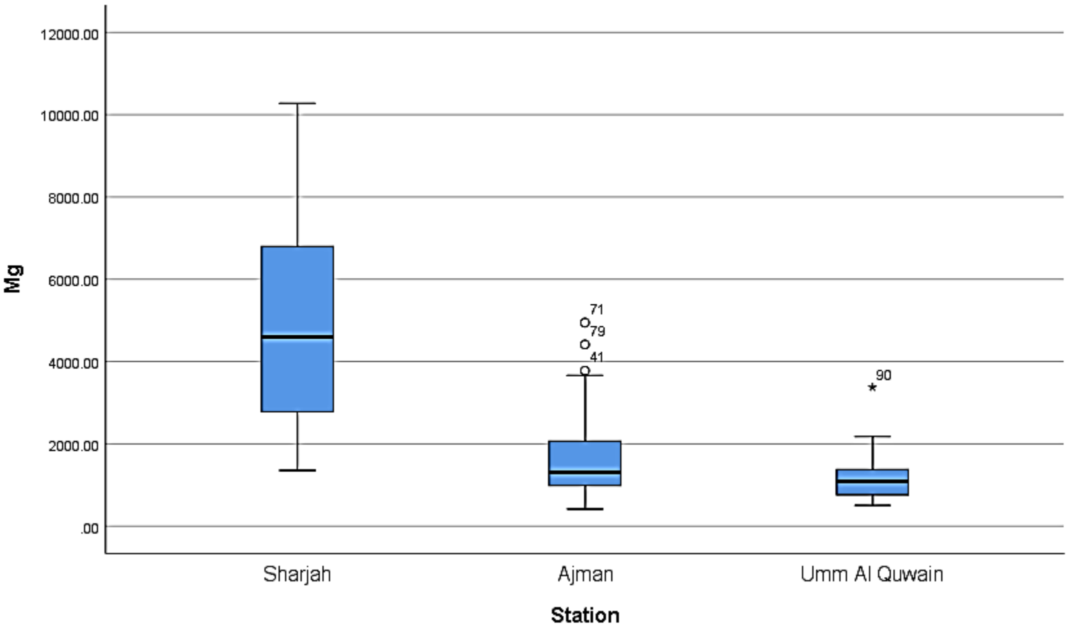

Figure 36: Representation of outliers for Mg in GI.

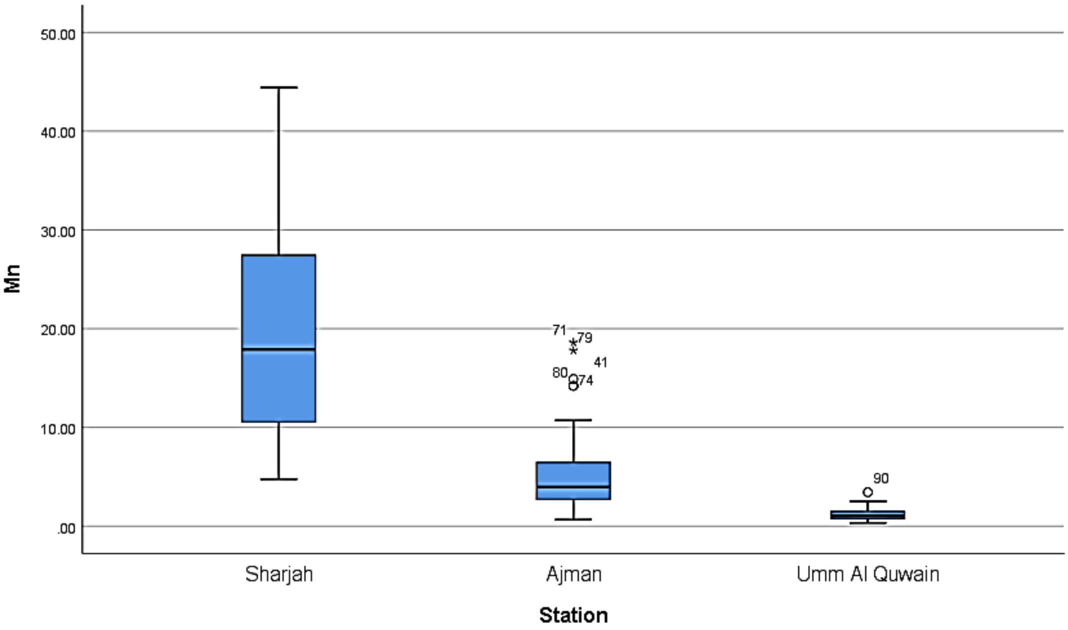

Figure 37: Representation of outliers for Mn in GI.

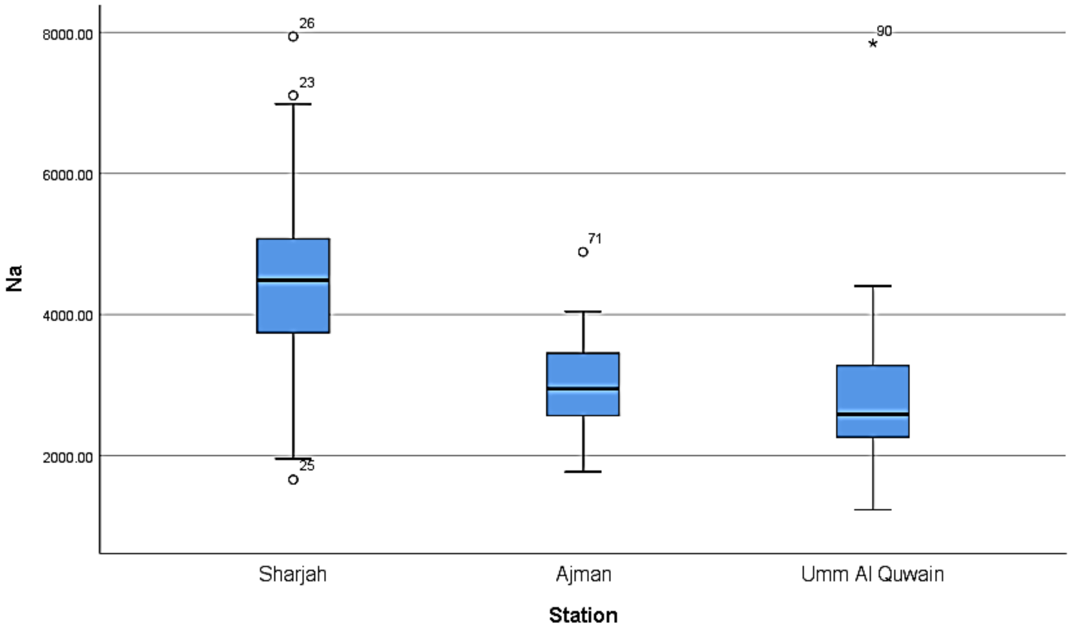

Figure 38: Representation of outliers for Na in GI.

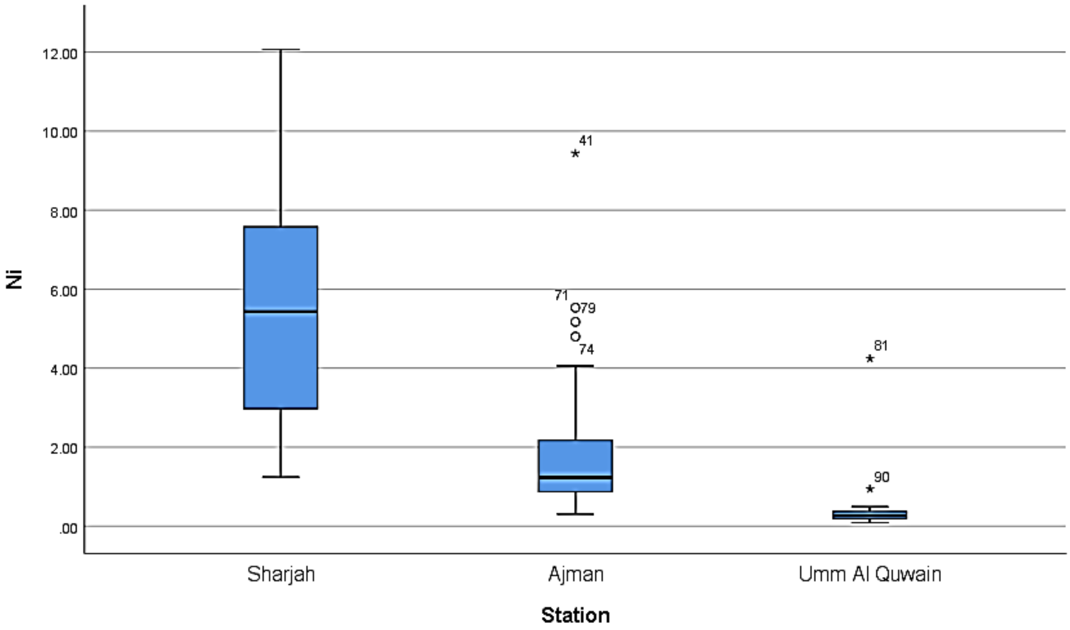

Figure 39: Representation of outliers for Ni in GI.

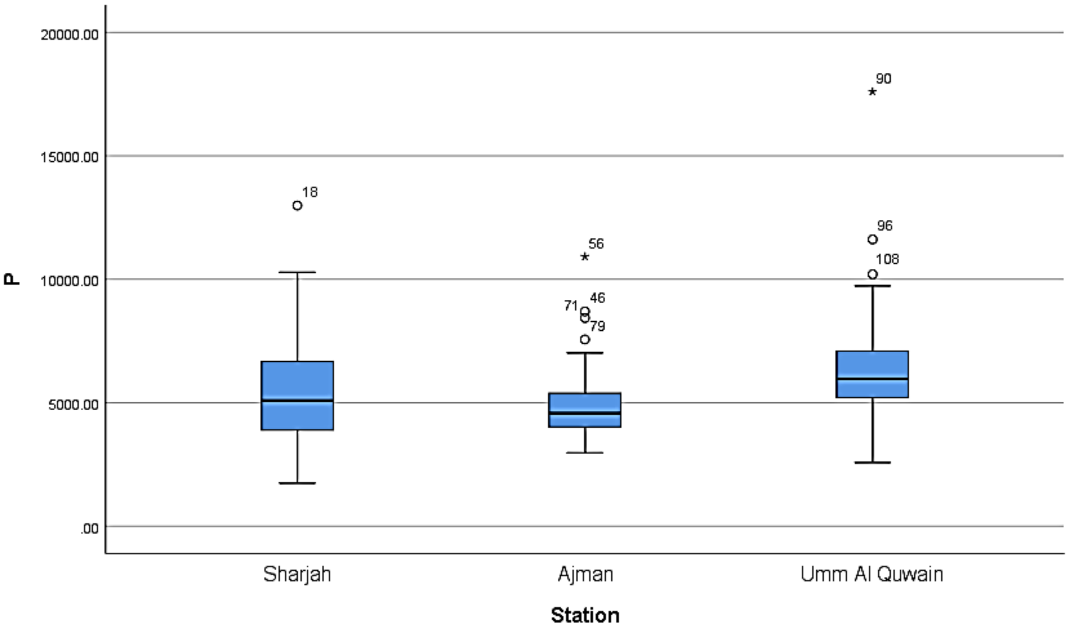

Figure 40: Representation of outliers for P in GI.

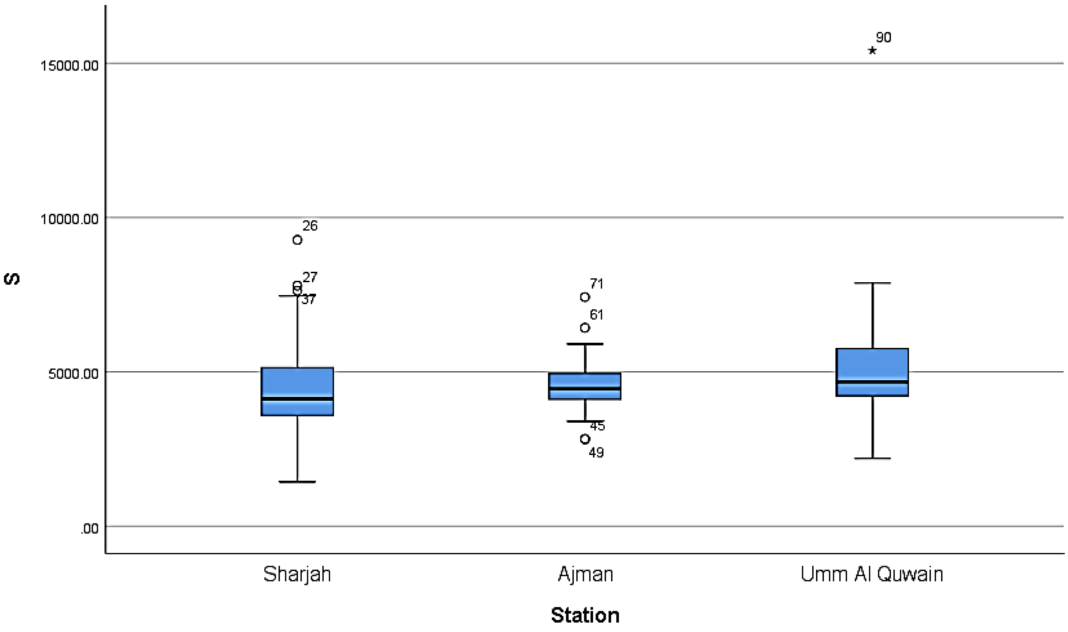

Figure 41: Representation of outliers for S in GI.

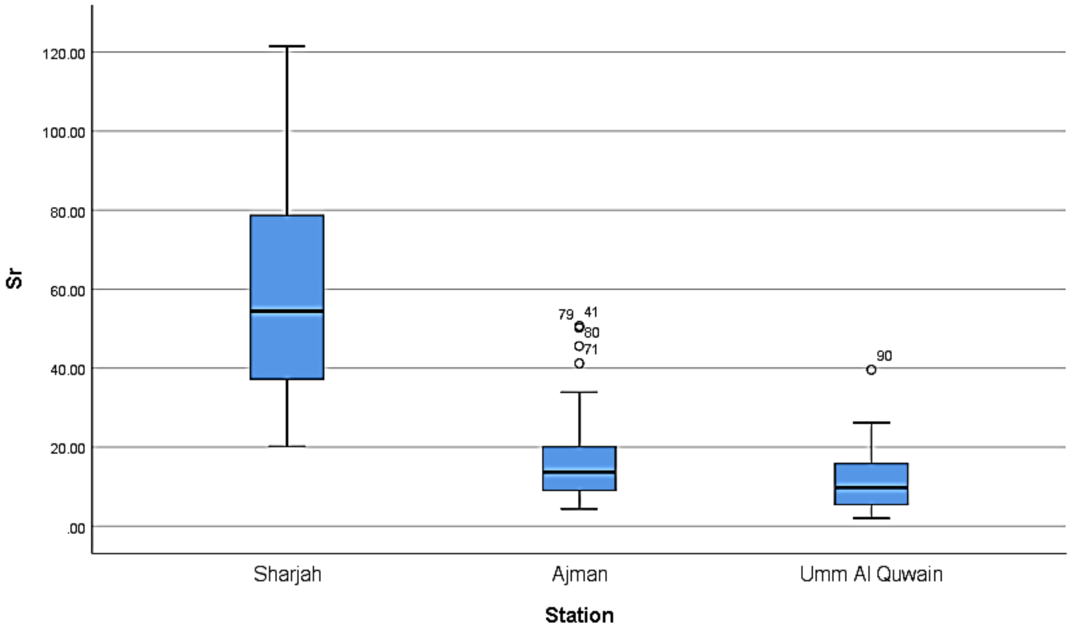

Figure 42: Representation of outliers for Sr in GI.

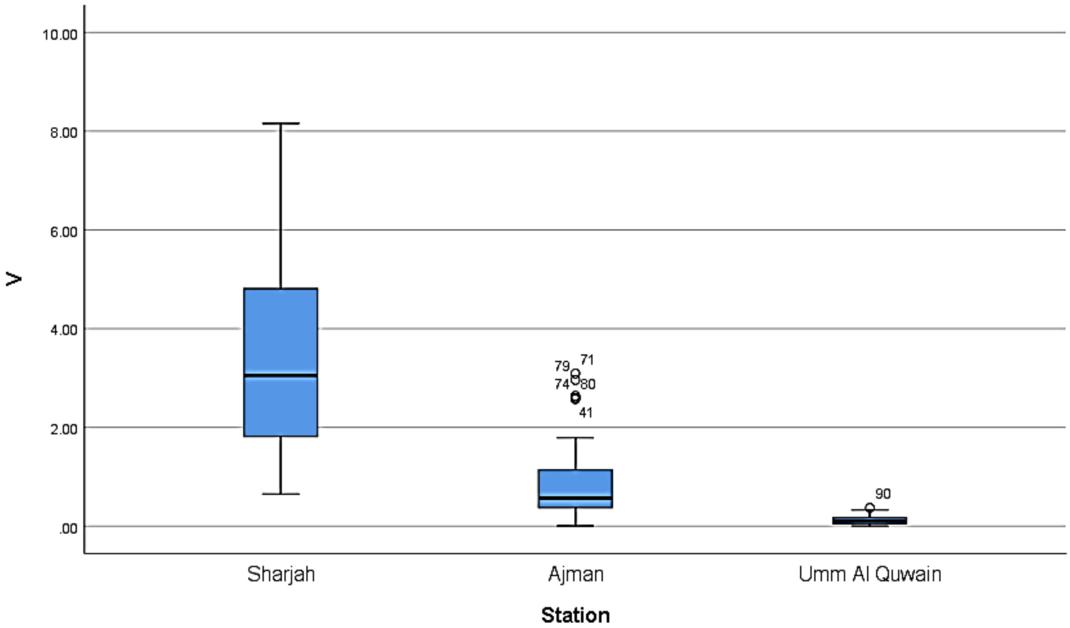

Figure 43: Representation of outliers for V in GI.

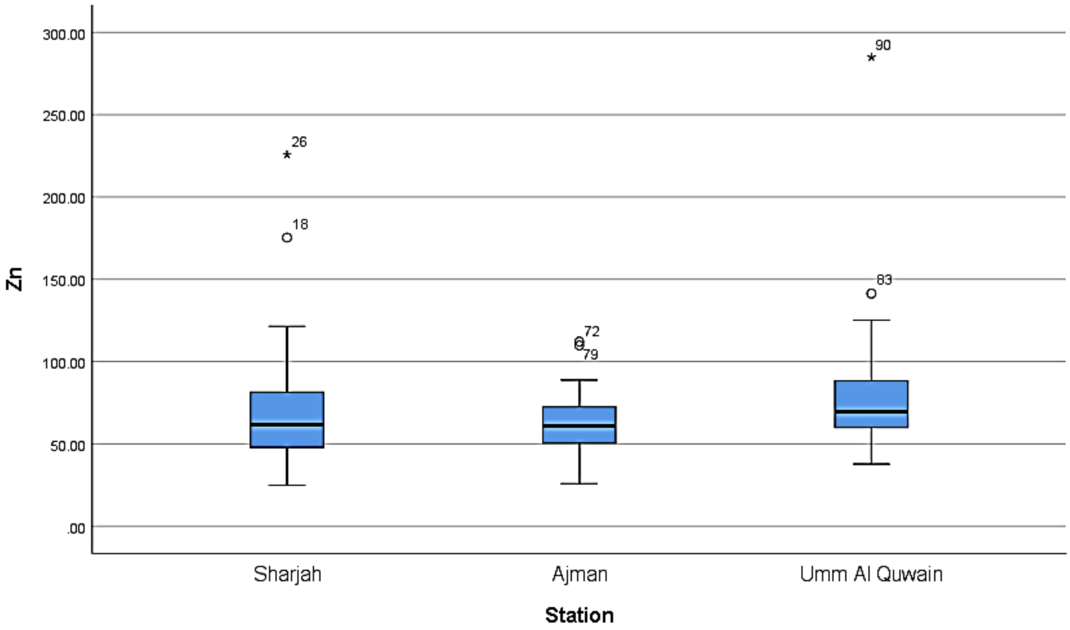

Figure 44: Representation of outliers for Zn in GI.

Appendix C: Metal and Non-metal Analysis in Muscle

Descriptive statistic was performed for each predictor variables to check mean, standard error, standard deviation, maximum, minimum, interquartile range and skewness of the variables depending on sampling sites.

Table 34: Overview of descriptive statistic for metals and non-metals in muscle.

	Station			Statistic	Std. Error
As	Sharjah	Mean		4.6291	0.25315
		95% Confidence Interval for Mean	Lower Bound	4.1041	
			Upper Bound	5.1541	
		5% Trimmed Mean		4.5947	
		Median		4.6700	
		Variance		1.474	
		Std. Deviation		1.21406	
		Minimum		2.75	
		Maximum		7.17	
		Range		4.42	
		Interquartile Range		2.16	
		Skewness		0.227	0.481
		Kurtosis		-0.656	0.935
	Ajman	Mean		4.7850	0.19963
		95% Confidence Interval for Mean	Lower Bound	4.3699	
			Upper Bound	5.2001	
		5% Trimmed Mean		4.7911	
		Median		4.7800	
		Variance		0.877	
		Std. Deviation		0.93634	
		Minimum		3.10	
		Maximum		6.36	
		Range		3.26	
		Interquartile Range		1.32	
		Skewness		-0.104	0.491
		Kurtosis		-0.680	0.953
	Umm Al Quwain	Mean		3.3195	0.21157
		95% Confidence Interval for Mean	Lower Bound	2.8796	
			Upper Bound	3.7595	
		5% Trimmed Mean		3.2963	
		Median		3.2250	
		Variance		0.985	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

Station				Statistic	Std. Error
Ca	Sharjah	Mean		9068.3217	589.93202
		95% Confidence Interval for Mean	Lower Bound	7844.8776	
			Upper Bound	10291.7659	
		5% Trimmed Mean		9021.3104	
		Median		8923.5000	
		Variance		8004455.182	
		Std. Deviation		2829.21459	
		Minimum		4005.80	
		Maximum		14970.50	
		Range		10964.70	
		Interquartile Range		3724.30	
		Skewness		0.352	0.481
		Kurtosis		-0.435	0.935
	Ajman	Mean		10007.4591	708.06150
		95% Confidence Interval for Mean	Lower Bound	8534.9646	
			Upper Bound	11479.9536	
		5% Trimmed Mean		9972.4778	
		Median		9188.3500	
		Variance		11029723.820	
		Std. Deviation		3321.10280	
		Minimum		4352.10	
		Maximum		16386.00	
		Range		12033.90	
		Interquartile Range		5007.20	
		Skewness		0.276	0.491
		Kurtosis		-0.632	0.953
	Umm Al Quwain	Mean		8430.5864	939.28210
		95% Confidence Interval for Mean	Lower Bound	6477.2423	
			Upper Bound	10383.9304	
		5% Trimmed Mean		8146.7444	
		Median		7628.7000	
		Variance		19409519.021	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

Station				Statistic	Std. Error
Cd	Sharjah	Mean		0.1922	0.03918
		95% Confidence Interval for Mean	Lower Bound	0.1109	
			Upper Bound	0.2734	
		5% Trimmed Mean		0.1654	
		Median		0.1400	
		Variance		0.035	
		Std. Deviation		0.18788	
		Minimum		0.03	
		Maximum		0.88	
		Range		0.85	
		Interquartile Range		0.10	
		Skewness		2.678	0.481
		Kurtosis		8.056	0.935
	Ajman	Mean		0.2359	0.04001
		95% Confidence Interval for Mean	Lower Bound	0.1527	
			Upper Bound	0.3191	
		5% Trimmed Mean		0.2206	
		Median		0.1650	
		Variance		0.035	
		Std. Deviation		0.18768	
		Minimum		0.03	
		Maximum		0.74	
		Range		0.71	
		Interquartile Range		0.33	
		Skewness		1.069	0.491
		Kurtosis		0.760	0.953
	Umm Al Quwain	Mean		0.1023	0.01834
		95% Confidence Interval for Mean	Lower Bound	0.0641	
			Upper Bound	0.1404	
		5% Trimmed Mean		0.0913	
		Median		0.0750	
		Variance		0.007	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

		Station		Statistic	Std. Error
Cr	Sharjah	Mean		0.3352	0.08576
		95% Confidence Interval for Mean	Lower Bound	0.1574	
			Upper Bound	0.5131	
		5% Trimmed Mean		0.2547	
		Median		0.2500	
		Variance		0.169	
		Std. Deviation		0.41130	
		Minimum		0.15	
		Maximum		2.20	
		Range		2.05	
		Interquartile Range		0.08	
		Skewness		4.618	0.481
		Kurtosis		21.794	0.935
	Ajman	Mean		0.2695	0.02259
		95% Confidence Interval for Mean	Lower Bound	0.2226	
			Upper Bound	0.3165	
		5% Trimmed Mean		0.2574	
		Median		0.2600	
		Variance		0.011	
		Std. Deviation		0.10594	
		Minimum		0.13	
		Maximum		0.65	
		Range		0.52	
		Interquartile Range		0.09	
		Skewness		2.247	0.491
		Kurtosis		7.573	0.953
	Umm Al Quwain	Mean		0.2168	0.01581
		95% Confidence Interval for Mean	Lower Bound	0.1839	
			Upper Bound	0.2497	
		5% Trimmed Mean		0.2149	
		Median		0.2100	
		Variance		0.005	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Cu	Sharjah	Mean		0.3457	0.04036
		95% Confidence Interval for Mean	Lower Bound	0.2619	
			Upper Bound	0.4294	
		5% Trimmed Mean		0.3302	
		Median		0.2800	
		Variance		0.037	
		Std. Deviation		0.19357	
		Minimum		0.12	
		Maximum		0.85	
		Range		0.73	
		Interquartile Range		0.20	
		Skewness		1.528	0.481
		Kurtosis		1.926	0.935
	Ajman	Mean		0.3864	0.03993
		95% Confidence Interval for Mean	Lower Bound	0.3033	
			Upper Bound	0.4694	
		5% Trimmed Mean		0.3731	
		Median		0.3600	
		Variance		0.035	
		Std. Deviation		0.18730	
		Minimum		0.14	
		Maximum		0.90	
		Range		0.76	
		Interquartile Range		0.29	
		Skewness		0.815	0.491
		Kurtosis		1.019	0.953
	Umm Al Quwain	Mean		0.9732	0.13794
		95% Confidence Interval for Mean	Lower Bound	0.6863	
			Upper Bound	1.2600	
		5% Trimmed Mean		0.9310	
		Median		0.6600	
		Variance		0.419	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Hg	Sharjah	Mean		0.0237	0.00119
		95% Confidence Interval for Mean	Lower Bound	0.0212	
			Upper Bound	0.0261	
		5% Trimmed Mean		0.0232	
		Median		0.0237	
		Variance		0.000	
		Std. Deviation		0.00573	
		Minimum		0.02	
		Maximum		0.04	
		Range		0.03	
		Interquartile Range		0.01	
		Skewness		1.281	0.481
		Kurtosis		3.276	0.935
	Ajman	Mean		0.0354	0.00222
		95% Confidence Interval for Mean	Lower Bound	0.0307	
			Upper Bound	0.0400	
		5% Trimmed Mean		0.0347	
		Median		0.0351	
		Variance		0.000	
		Std. Deviation		0.01042	
		Minimum		0.02	
		Maximum		0.06	
		Range		0.04	
		Interquartile Range		0.01	
		Skewness		0.883	0.491
		Kurtosis		0.615	0.953
	Umm Al Quwain	Mean		0.0361	0.00442
		95% Confidence Interval for Mean	Lower Bound	0.0269	
			Upper Bound	0.0452	
		5% Trimmed Mean		0.0336	
		Median		0.0312	
		Variance		0.000	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

Station				Statistic	Std. Error
K	Sharjah	Mean		1729.4217	59.39727
		95% Confidence Interval for Mean	Lower Bound	1606.2393	
			Upper Bound	1852.6041	
		5% Trimmed Mean		1741.1848	
		Median		1790.8000	
		Variance		81144.817	
		Std. Deviation		284.85929	
		Minimum		1081.60	
		Maximum		2157.50	
		Range		1075.90	
		Interquartile Range		398.70	
		Skewness		-0.743	0.481
		Kurtosis		0.209	0.935
	Ajman	Mean		1962.7955	85.03608
		95% Confidence Interval for Mean	Lower Bound	1785.9532	
			Upper Bound	2139.6377	
		5% Trimmed Mean		1981.8460	
		Median		2026.7000	
		Variance		159084.980	
		Std. Deviation		398.85459	
		Minimum		1022.10	
		Maximum		2563.00	
		Range		1540.90	
		Interquartile Range		380.60	
		Skewness		-1.093	0.491
		Kurtosis		1.314	0.953
	Umm Al Quwain	Mean		2411.0455	142.96888
		95% Confidence Interval for Mean	Lower Bound	2113.7254	
			Upper Bound	2708.3655	
		5% Trimmed Mean		2345.3561	
		Median		2402.9000	
		Variance		449682.244	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Mg	Sharjah	Mean		427.4696	19.15432
		95% Confidence Interval for Mean	Lower Bound	387.7459	
			Upper Bound	467.1932	
		5% Trimmed Mean		430.4019	
		Median		437.7000	
		Variance		8438.424	
		Std. Deviation		91.86090	
		Minimum		213.80	
		Maximum		584.30	
		Range		370.50	
		Interquartile Range		103.80	
		Skewness		-0.514	0.481
		Kurtosis		0.073	0.935
	Ajman	Mean		386.3364	20.14562
		95% Confidence Interval for Mean	Lower Bound	344.4413	
			Upper Bound	428.2315	
		5% Trimmed Mean		390.7833	
		Median		394.7000	
		Variance		8928.613	
		Std. Deviation		94.49134	
		Minimum		174.80	
		Maximum		517.80	
		Range		343.00	
		Interquartile Range		116.57	
		Skewness		-0.832	0.491
		Kurtosis		0.397	0.953
	Umm Al Quwain	Mean		421.1227	24.91865
		95% Confidence Interval for Mean	Lower Bound	369.3015	
			Upper Bound	472.9439	
		5% Trimmed Mean		415.6697	
		Median		380.4500	
		Variance		13660.666	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Mn	Sharjah	Mean		2.1478	0.13797
		95% Confidence Interval for Mean	Lower Bound	1.8617	
			Upper Bound	2.4340	
		5% Trimmed Mean		2.1300	
		Median		2.2700	
		Variance		0.438	
		Std. Deviation		0.66167	
		Minimum		1.16	
		Maximum		3.49	
		Range		2.33	
		Interquartile Range		1.12	
		Skewness		0.141	0.481
		Kurtosis		-0.898	0.935
	Ajman	Mean		2.1623	0.13685
		95% Confidence Interval for Mean	Lower Bound	1.8777	
			Upper Bound	2.4469	
		5% Trimmed Mean		2.1629	
		Median		2.0650	
		Variance		0.412	
		Std. Deviation		0.64189	
		Minimum		1.02	
		Maximum		3.28	
		Range		2.26	
		Interquartile Range		1.03	
		Skewness		0.206	0.491
		Kurtosis		-0.648	0.953
	Umm Al Quwain	Mean		1.9041	0.28020
		95% Confidence Interval for Mean	Lower Bound	1.3214	
			Upper Bound	2.4868	
		5% Trimmed Mean		1.7592	
		Median		1.4550	
		Variance		1.727	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Na	Sharjah	Mean		1644.3087	76.17289
		95% Confidence Interval for Mean	Lower Bound	1486.3358	
			Upper Bound	1802.2816	
		5% Trimmed Mean		1640.4804	
		Median		1706.4000	
		Variance		133453.111	
		Std. Deviation		365.31235	
		Minimum		902.10	
		Maximum		2510.00	
		Range		1607.90	
		Interquartile Range		438.10	
		Skewness		-0.128	0.481
		Kurtosis		0.857	0.935
	Ajman	Mean		1179.8091	59.32830
		95% Confidence Interval for Mean	Lower Bound	1056.4291	
			Upper Bound	1303.1890	
		5% Trimmed Mean		1185.4990	
		Median		1224.7000	
		Variance		77436.641	
		Std. Deviation		278.27440	
		Minimum		563.90	
		Maximum		1701.20	
		Range		1137.30	
		Interquartile Range		383.25	
		Skewness		-0.478	0.491
		Kurtosis		0.289	0.953
	Umm Al Quwain	Mean		1310.2273	65.75299
		95% Confidence Interval for Mean	Lower Bound	1173.4864	
			Upper Bound	1446.9681	
		5% Trimmed Mean		1298.1207	
		Median		1289.3000	
		Variance		95116.032	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Ni	Sharjah	Mean		0.4287	0.34746
		95% Confidence Interval for Mean	Lower Bound	-0.2919	
			Upper Bound	1.1493	
		5% Trimmed Mean		0.0836	
		Median		0.0800	
		Variance		2.777	
		Std. Deviation		1.66637	
		Minimum		0.02	
		Maximum		8.07	
		Range		8.05	
		Interquartile Range		0.04	
		Skewness		4.790	0.481
		Kurtosis		22.961	0.935
	Ajman	Mean		0.1105	0.05702
		95% Confidence Interval for Mean	Lower Bound	-0.0081	
			Upper Bound	0.2290	
		5% Trimmed Mean		0.0563	
		Median		0.0500	
		Variance		0.072	
		Std. Deviation		0.26743	
		Minimum		0.00	
		Maximum		1.30	
		Range		1.30	
		Interquartile Range		0.04	
		Skewness		4.592	0.491
		Kurtosis		21.347	0.953
	Umm Al Quwain	Mean		0.0550	0.00932
		95% Confidence Interval for Mean	Lower Bound	0.0356	
			Upper Bound	0.0744	
		5% Trimmed Mean		0.0494	
		Median		0.0400	
		Variance		0.002	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
P	Sharjah	Mean		7004.7435	300.13238
		95% Confidence Interval for Mean	Lower Bound	6382.3070	
			Upper Bound	7627.1799	
		5% Trimmed Mean		6957.4848	
		Median		7064.6000	
		Variance		2071827.184	
		Std. Deviation		1439.38431	
		Minimum		4663.90	
		Maximum		10148.10	
		Range		5484.20	
		Interquartile Range		2046.50	
		Skewness		0.678	0.481
		Kurtosis		-0.018	0.935
	Ajman	Mean		7491.4591	351.89092
		95% Confidence Interval for Mean	Lower Bound	6759.6619	
			Upper Bound	8223.2563	
		5% Trimmed Mean		7532.3682	
		Median		7490.0000	
		Variance		2724198.783	
		Std. Deviation		1650.51470	
		Minimum		3825.40	
		Maximum		10323.10	
		Range		6497.70	
		Interquartile Range		2161.60	
		Skewness		-0.103	0.491
		Kurtosis		-0.131	0.953
	Umm Al Quwain	Mean		6779.5318	568.74373
		95% Confidence Interval for Mean	Lower Bound	5596.7645	
			Upper Bound	7962.2991	
		5% Trimmed Mean		6575.1652	
		Median		6669.7500	
		Variance		7116327.399	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

Station			Statistic	Std. Error
Sharjah	Mean		1900.1609	35.27230
	95% Confidence Interval for Mean	Lower Bound	1827.0106	
		Upper Bound	1973.3111	
	5% Trimmed Mean		1897.4512	
	Median		1931.7000	
	Variance		28615.105	
	Std. Deviation		169.16000	
	Minimum		1626.60	
	Maximum		2222.60	
	Range		596.00	
	Interquartile Range		245.20	
	Skewness		0.124	0.481
	Kurtosis		0-.678	0.935
Ajman	Mean		1904.5409	52.86666
	95% Confidence Interval for Mean	Lower Bound	1794.5987	
		Upper Bound	2014.4832	
	5% Trimmed Mean		1892.4596	
	Median		1870.2000	
	Variance		61487.447	
	Std. Deviation		247.96663	
	Minimum		1563.00	
	Maximum		2478.00	
	Range		915.00	
	Interquartile Range		422.15	
	Skewness		0.543	0.491
	Kurtosis		-0.217	0.953
Umm Al Quwain	Mean		2312.9227	132.90790
	95% Confidence Interval for Mean	Lower Bound	2036.5256	
		Upper Bound	2589.3198	
	5% Trimmed Mean		2255.8662	
	Median		2253.1500	
	Variance		388619.211	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Sr	Sharjah	Mean		24.8130	1.85452
		95% Confidence Interval for Mean	Lower Bound	20.9670	
			Upper Bound	28.6591	
		5% Trimmed Mean		24.5222	
		Median		24.0000	
		Variance		79.103	
		Std. Deviation		8.89399	
		Minimum		9.40	
		Maximum		45.80	
		Range		36.40	
		Interquartile Range		11.50	
		Skewness		0.533	0.481
		Kurtosis		0.000	0.935
	Ajman	Mean		24.7773	1.97481
		95% Confidence Interval for Mean	Lower Bound	20.6704	
			Upper Bound	28.8841	
		5% Trimmed Mean		24.7197	
		Median		24.2000	
		Variance		85.797	
		Std. Deviation		9.26267	
		Minimum		9.50	
		Maximum		41.30	
		Range		31.80	
		Interquartile Range		12.50	
		Skewness		0.169	0.491
		Kurtosis		-0.693	0.953
	Umm Al Quwain	Mean		23.2091	3.12483
		95% Confidence Interval for Mean	Lower Bound	16.7107	
			Upper Bound	29.7075	
		5% Trimmed Mean		21.8313	
		Median		18.3500	
		Variance		214.820	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
V	Sharjah	Mean		0.0774	0.01006
		95% Confidence Interval for Mean	Lower Bound	0.0565	
			Upper Bound	0.0983	
		5% Trimmed Mean		0.0740	
		Median		0.0700	
		Variance		0.002	
		Std. Deviation		0.04826	
		Minimum		0.01	
		Maximum		0.21	
		Range		0.20	
		Interquartile Range		0.07	
		Skewness		1.132	0.481
		Kurtosis		1.371	0.935
	Ajman	Mean		0.0886	0.01199
		95% Confidence Interval for Mean	Lower Bound	0.0637	
			Upper Bound	0.1136	
		5% Trimmed Mean		0.0868	
		Median		0.0750	
		Variance		0.003	
		Std. Deviation		0.05626	
		Minimum		0.01	
		Maximum		0.20	
		Range		0.19	
		Interquartile Range		0.08	
		Skewness		0.618	0.491
		Kurtosis		-0.650	0.953
	Umm Al Quwain	Mean		0.0914	0.01911
		95% Confidence Interval for Mean	Lower Bound	0.0516	
			Upper Bound	0.1311	
		5% Trimmed Mean		0.0815	
		Median		0.0700	
		Variance		0.008	

Table 34: Overview of descriptive statistic for metals and non-metals in muscle (Continued).

	Station			Statistic	Std. Error
Zn	Sharjah	Mean		20.9348	1.44650
		95% Confidence Interval for Mean	Lower Bound	17.9349	
			Upper Bound	23.9346	
		5% Trimmed Mean		20.4012	
		Median		18.6000	
		Variance		48.124	
		Std. Deviation		6.93716	
		Minimum		10.60	
		Maximum		42.10	
		Range		31.50	
		Interquartile Range		8.70	
		Skewness		1.264	0.481
		Kurtosis		2.581	0.935
	Ajman	Mean		21.8773	1.35984
		95% Confidence Interval for Mean	Lower Bound	19.0493	
			Upper Bound	24.7052	
		5% Trimmed Mean		21.6717	
		Median		20.6000	
		Variance		40.682	
		Std. Deviation		6.37823	
		Minimum		13.40	
		Maximum		34.00	
		Range		20.60	
		Interquartile Range		9.42	
		Skewness		0.692	0.491
		Kurtosis		-0.654	0.953
	Umm Al Quwain	Mean		22.6091	2.37877
		95% Confidence Interval for Mean	Lower Bound	17.6622	
			Upper Bound	27.5560	
		5% Trimmed Mean		20.9510	
		Median		19.9500	
		Variance		124.488	

The boxplot was illustrated in order to see outliers for each predictor variables depending on sampling sites. Extreme outliers were pointed out with stars and potential outliers were depicted as a circle.

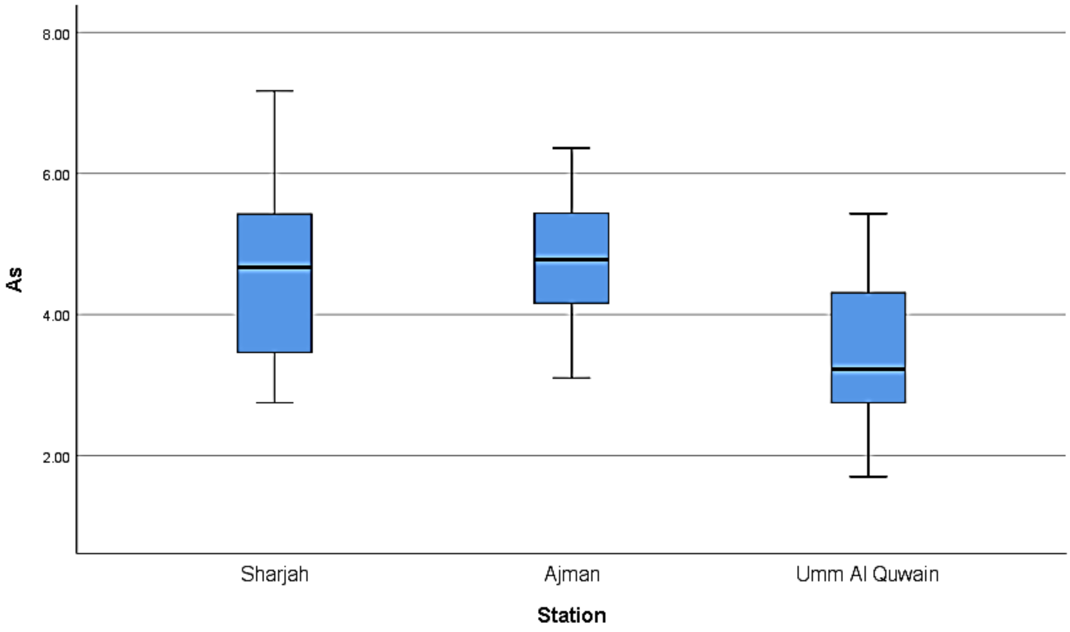

Figure 45: Representation of outliers for As in muscle.

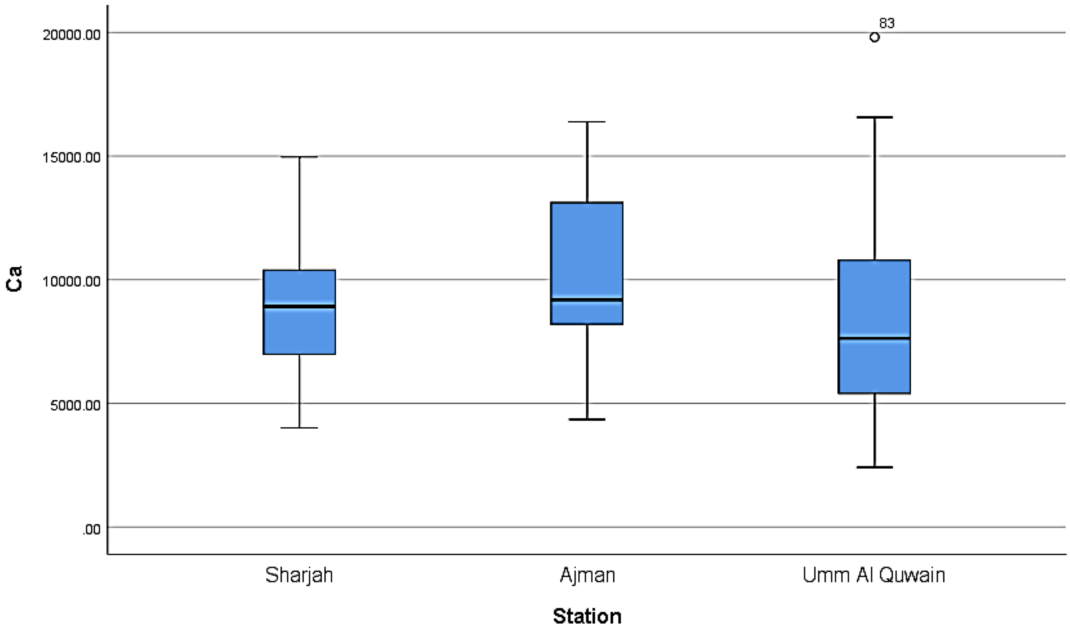

Figure 46: Representation of outliers for Ca in muscle.

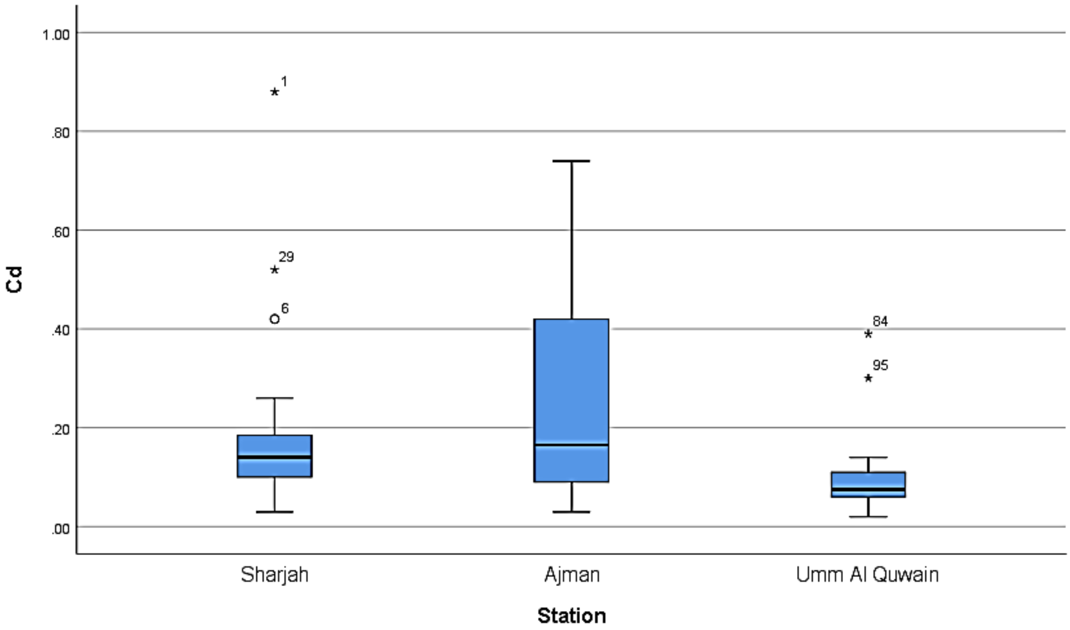

Figure 47: Representation of outliers for Cd in muscle.

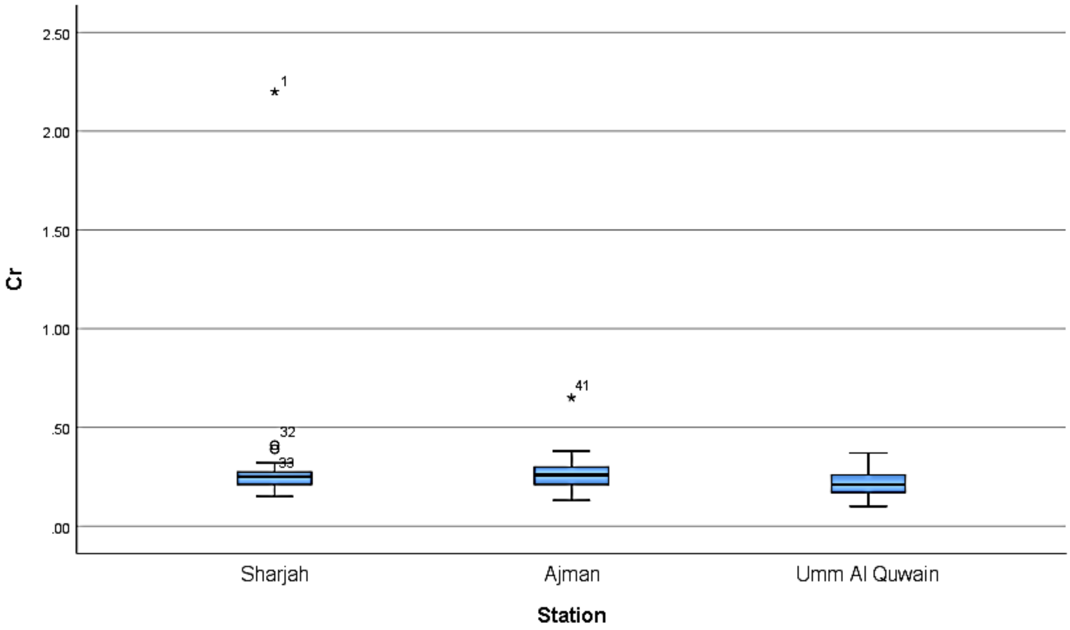

Figure 48: Representation of outliers for Cr in muscle.

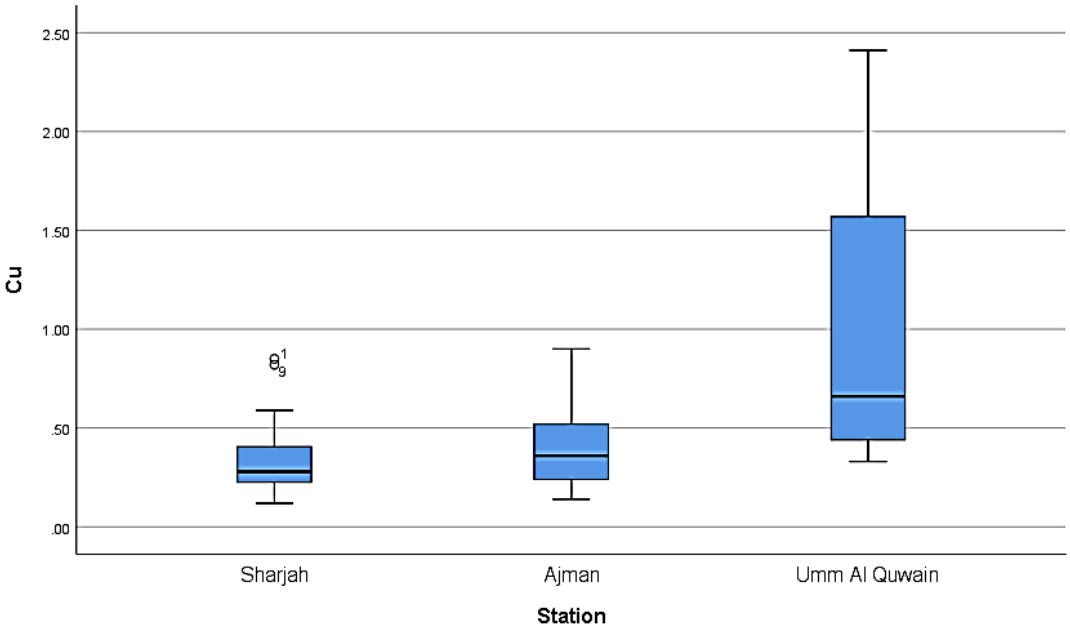

Figure 49: Representation of outliers for Cu in muscle.

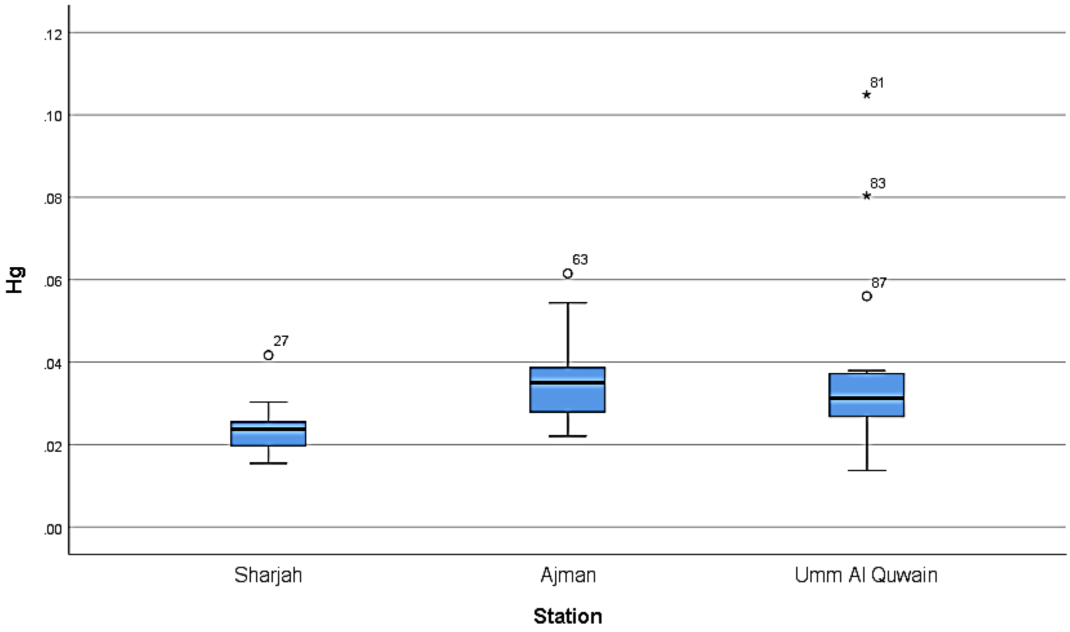

Figure 50: Representation of outliers for Hg in muscle.

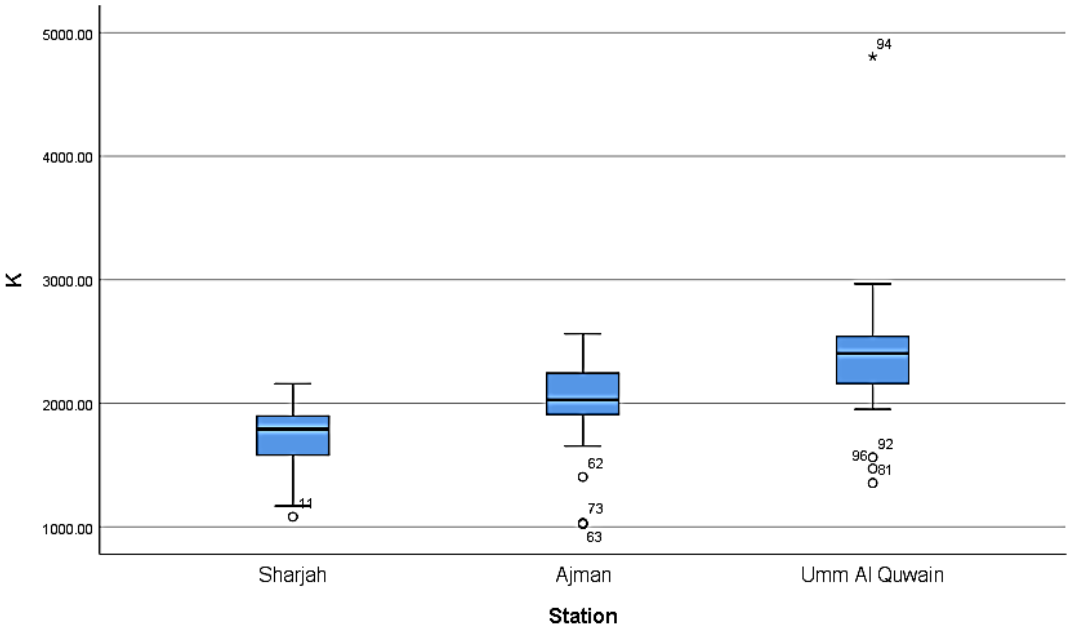

Figure 51: Representation of outliers in K for muscle.

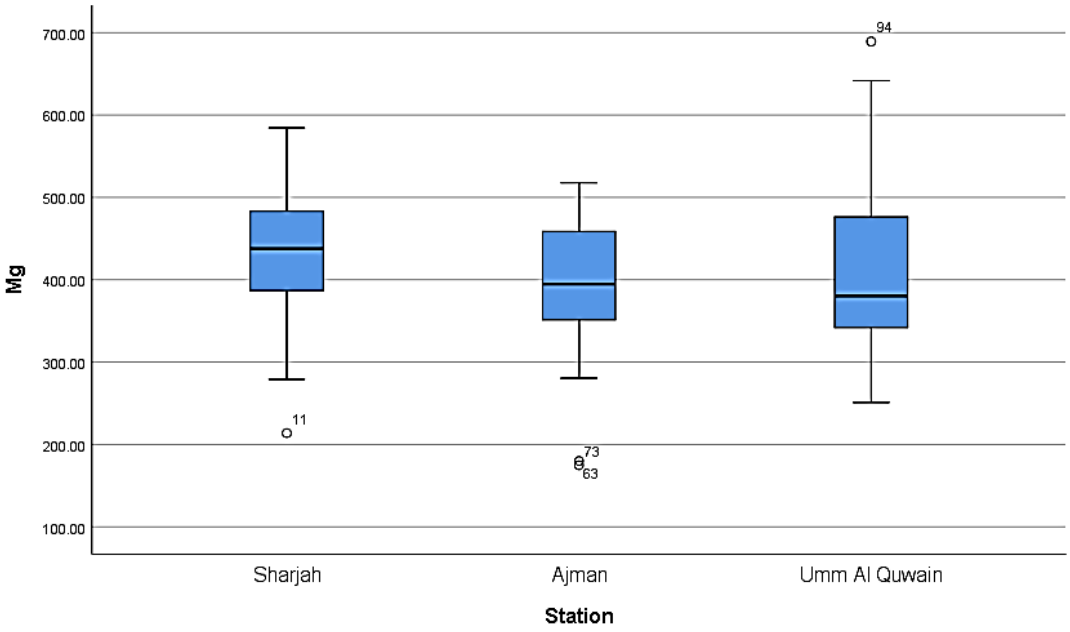

Figure 52: Representation of outliers for Mg in muscle.

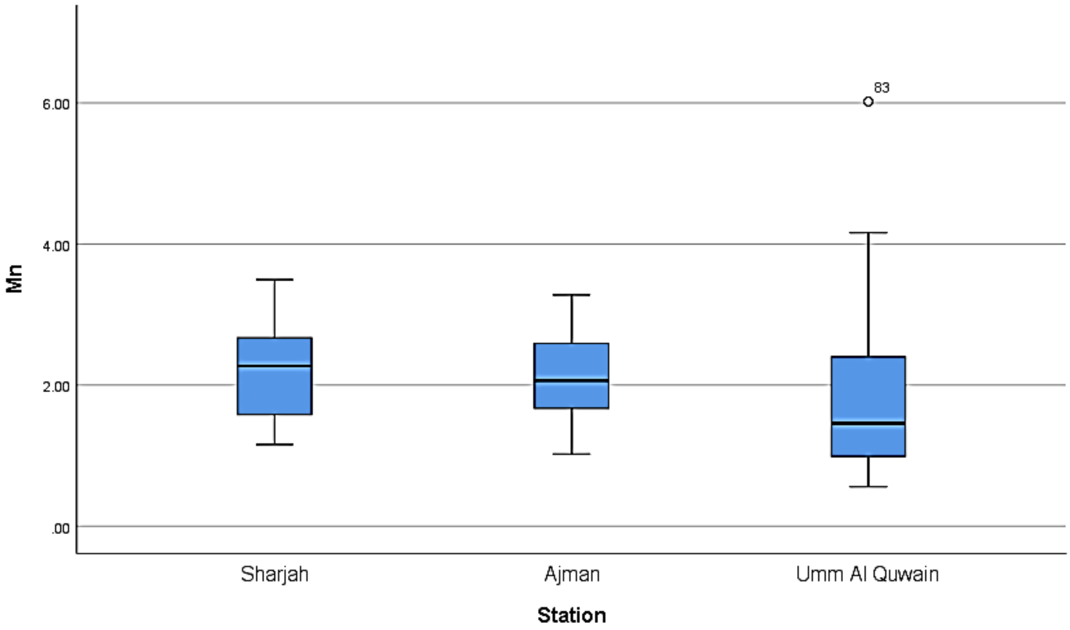

Figure 53: Representation of outliers for Mn in muscle.

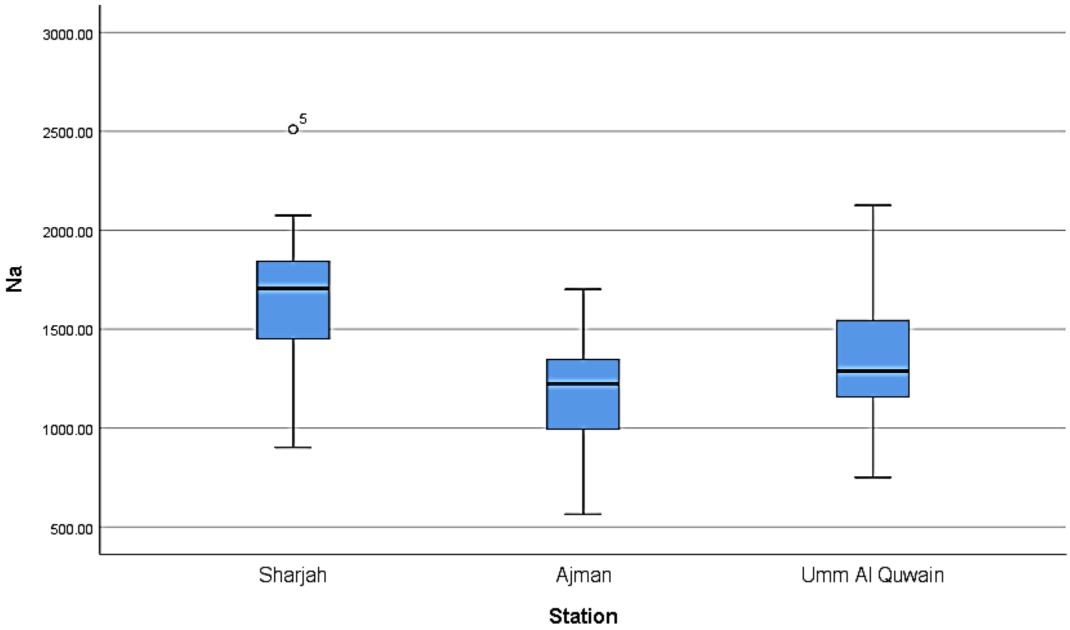

Figure 54: Representation of outliers for Na in muscle.

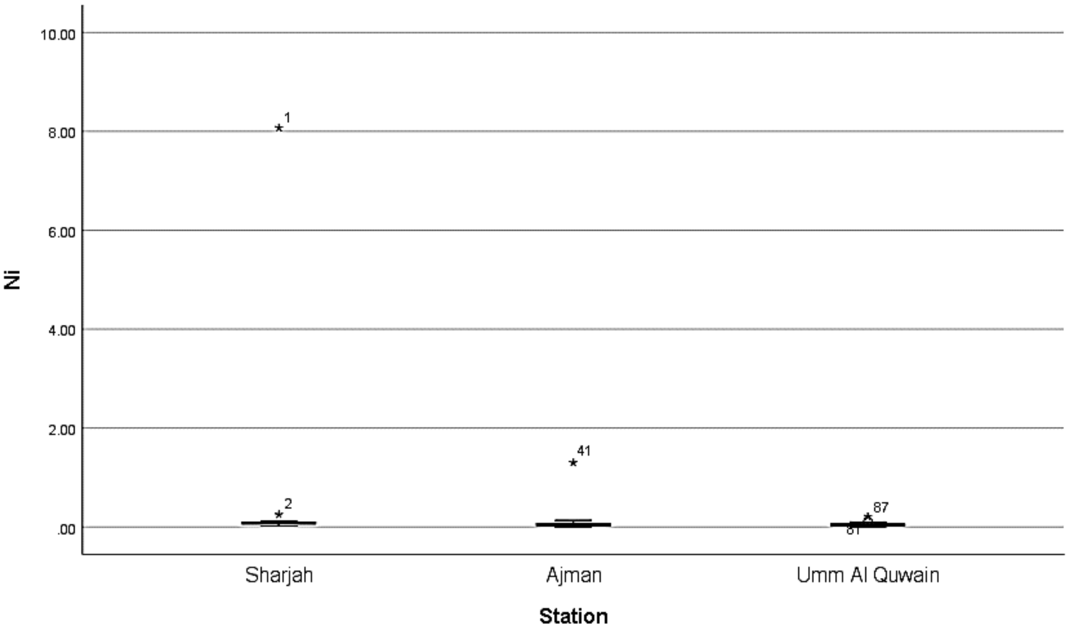

Figure 55: Representation of outliers in Ni for muscle.

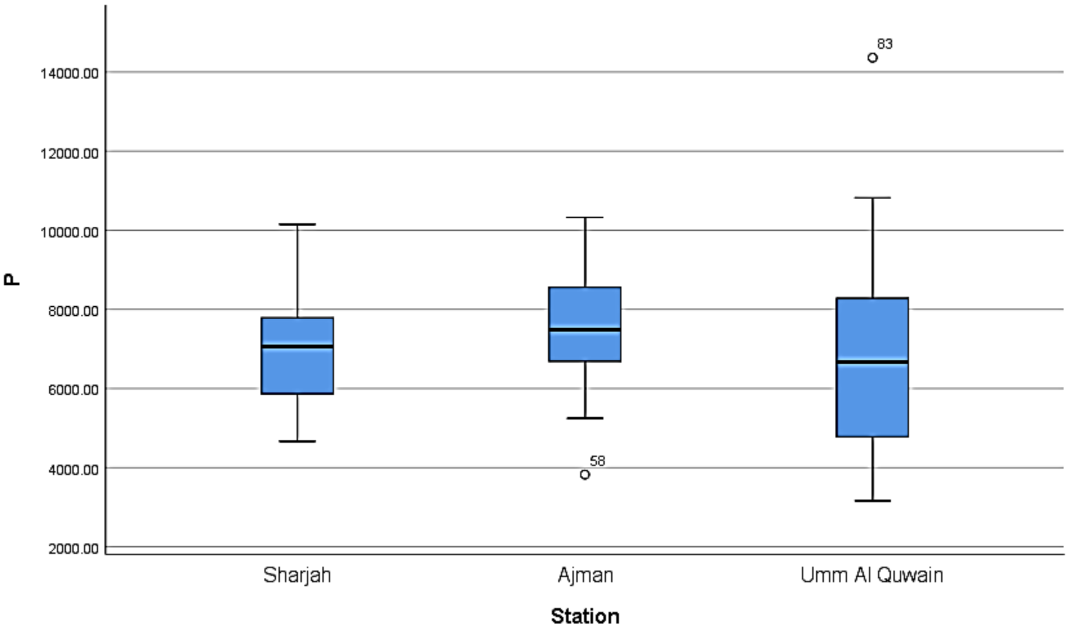

Figure 56:Representation of outliers for P in muscle.

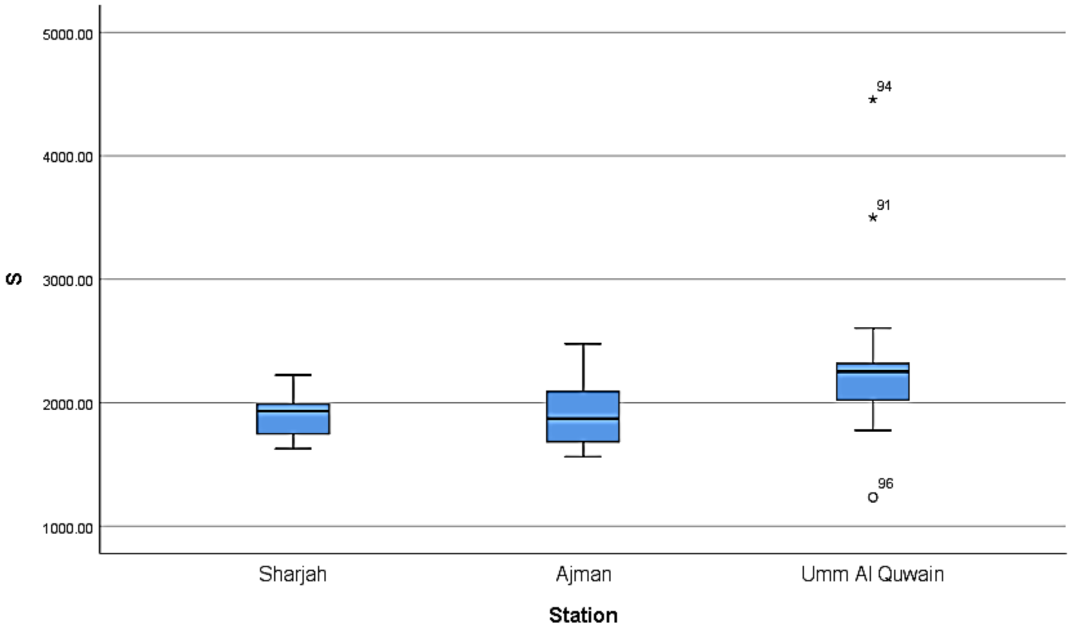

Figure 57: Representation of outliers for S in muscle.

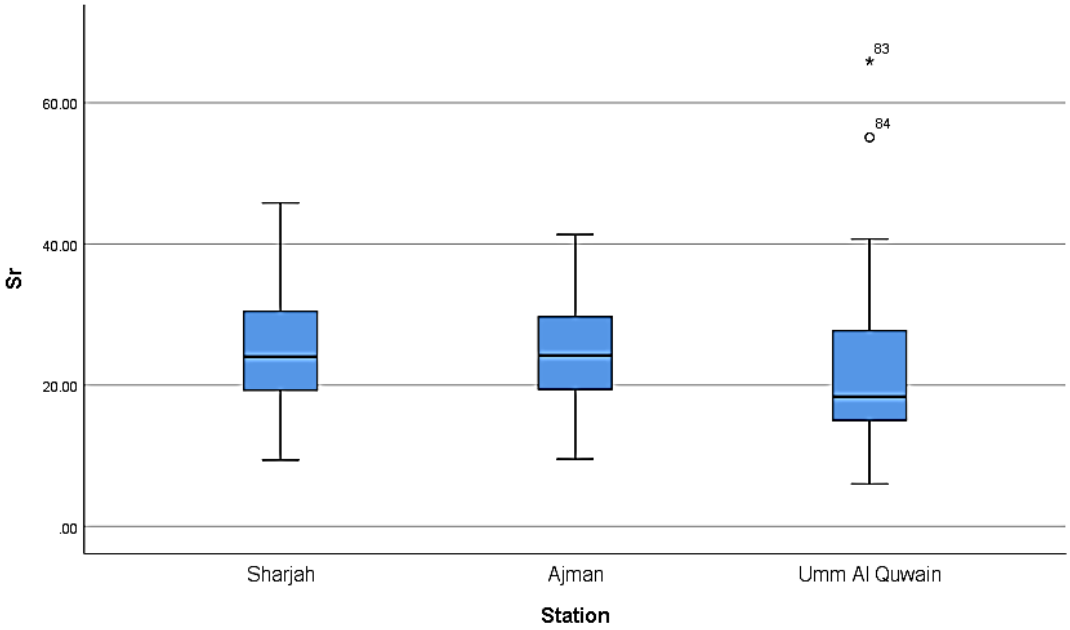

Figure 58: Representation of outliers for Sr in muscle.

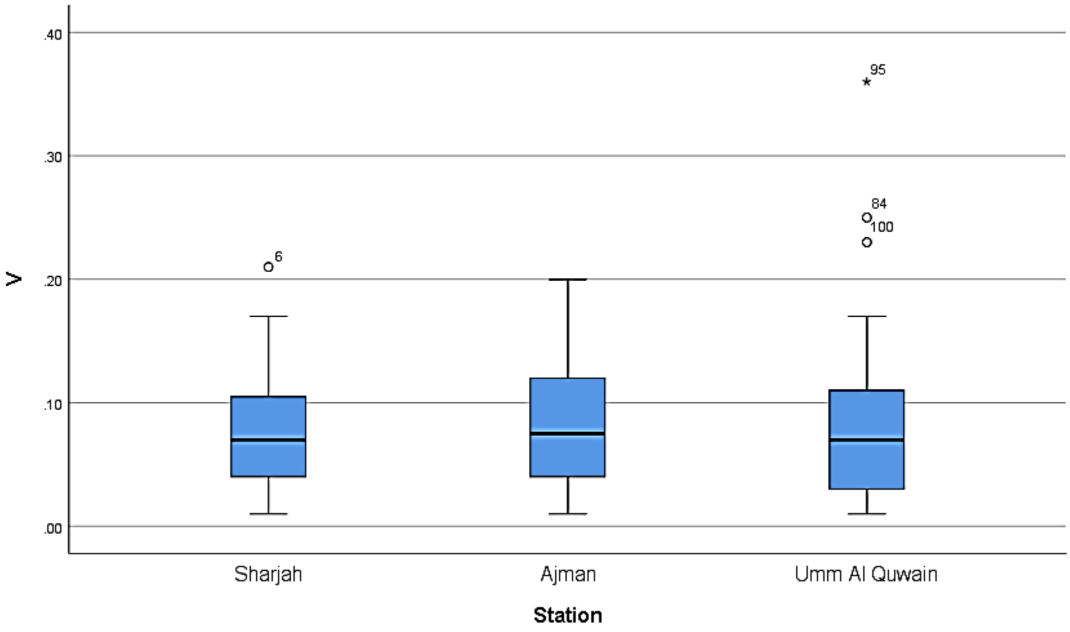

Figure 59: Representation of outliers for V in muscle.

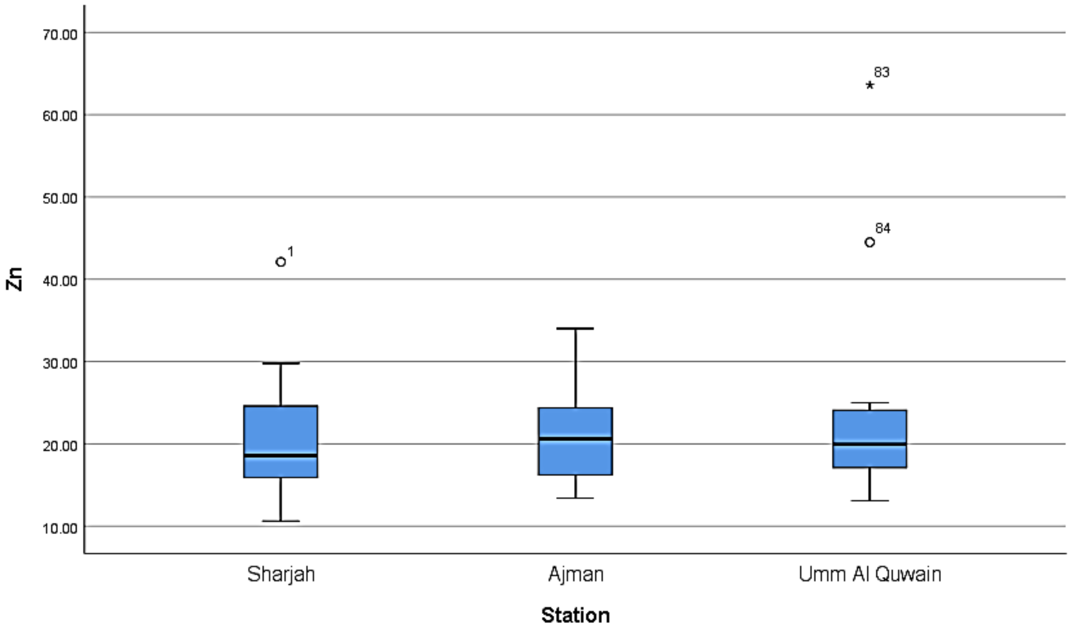

Figure 60: Representation of outliers for Zn in muscle.