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UNITED ARAB EMIRATES UNIVERSITY
College of Graduate Studies
Water Resources Master Program

Distribution and Geochemical Speciation of Pb, Cd, Zn, Cr and Cu in Sediments of Major Dams in UAE

A Thesis
Submitted in partial fulfillment for the requirements of the
Degree of Master of Water Resources Program

By
Mona Rashed Musabah Al-Alili
B.Sc. (2000), UAE University

December 2008

United Arab Emirates University
College of Graduate Studies
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Title:

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ABSTRACT

Assessment of availability and mobility is required to predict the behavior of heavy metals in dam's sediments, which hold up rainwater and make use of them. Therefore, a total number of ninety-three of sediments samples collected from the major dams Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dam were analyzed by several sedimentological and geochemical analyses procedures for Cu, Cd, Cr, Pb, Zn, Al, and Fe. The samples were investigated for mineralogy using X-ray diffraction analyses for non-clay and clay fractions. ICP-OES and Atomic Absorption Spectrophotometer (AAS) were used to measure the concentration of heavy metals. The statistical treatments and graphical presentations of the obtained data are conducted by means of Excel (Microsoft office 2003, windows xp). The correlation matrixes of the obtained data of the chemical and controlling parameters prepared using JUMPIN and SPSS version software. Google Earth software was used to percent the location of the studied areas and GIS used to distribute the histogram of element on the maps.

Sequential extraction procedures were used to predict the percentages of the Cu, Cd, Cr, Pb, and Zn presences in each of the sediments geochemical phases. The non-clay minerals of the sand size fraction are composed mainly of quartz, calcite, dolomite, serpentine, plagioclase, amphibole, and pyroxene. The clay mineral assemblage encountered in the analyzed samples is composed of quartz as major mineral, Illite as subordinate mineral and chlorite as minor mineral. These mineral phases are not likely to contribute to the metal load or act as source of toxic heavy metals. The studied sediments samples from the dams were not enriched with Cu, Cd, Cr, Pb, Zn, Al, as evident from the calculations of the enrichment factor; however, the sediment were slightly enriched with Fe.

According to the index of geoaccumulation, the sediments of the investigated area can be described as uncontaminated with respect to Cu, Cd, Cr, Pb, Zn, and uncontaminated to moderately contaminate with respect to Al and Fe. The measured metals correlated positively with the determined physiochemical factor such as pH, TDS, $CaCO_3$, TOM, P_2O_5, and CEC differentiated depend on the nature and grain size of each dam; indicating that these physicochemical conditions could control the geochemical behavior of the analyses heavy metals. The concentration of Cu, Cd, Cr, Pb, Zn, Al, and Fe contents are nearly reflected the background values. The sequential extraction procedure and geochemical fractionation indicate that most of analyzed elements are associated mainly with the residual phases and are relatively immobile.

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CHAPTER ONE

INTRODUCTION

1. INTRODUCTION

Although total metal concentrations indicate the overall level of metals in sediments, they provide no information regarding the chemical nature or potential mobility and bioavailability of a particular element (Vijver, et al., 2004; Jin, et al., 2005 and Powell, et al., 2005). Assessment of availability and mobility are required to elucidate the behavior of heavy metals in sediments and to prevent potential toxic hazards (Silveira, et al., 2006). Trace metals may be distributed among several sediment components and may be associated with these components in different ways and strengths. The present study focuses on the possibility of metal remobilization from sediment materials, which will depend on the type of metal linkages to the sediment material and the possibilities of transformation in more labile species. This is important because slight changes in metal availability in environmental conditions can cause these elements to be toxic to animals and plants. The present research work intendeds to assess the mobility of Pb, Cd, Zn, Cr, and Cu in sediments systems based on published sequential extraction procedures which mainly dependant on the chemical form of sediments-metal interaction. Those metals have been chosen primarily because they are very common contaminants coming mainly from Anthropgenic sources and they are toxic at high levels of concentrations. However, knowing that metal associated with the aqueous phase of sediments can be transported to groundwater and be available to ecological receptors, it becomes important to know the form of association of metal to various geolochemical phases. In other words the research will demonstrate whether the geochemical forms of the sediments can hold the metal in immobile form and consequently prevent them from reaching ground water or not. The bulk chemical analyses will also help to identify possible contamination in reservoirs using the geoaccumulation indices, enrichment factor, and through doing some comparisons with some regulatory and health standards. In addition, the relation between the distribution of heavy metals and the different physico-chemical conditions will be demonstrated. The mineralogical and textural analyses were performed in an attempts to characterize the sediments and to relate the geology of reservoirs locations to metal content of the studied sediments of the reservoirs.

1.1. Climate and Water Resources in UAE

The climate in UAE is arid with very high summer temperatures. The inhabited area has a hot and humid climate in the summer (May-October) with temperatures and relative humidity reaching 46°C and 100% respectively. Winters are generally mild with temperatures between 14 and 23°C. The interior desert region has hot summers with temperatures rising to about 50°C and cool winters during which the lowest temperature may fall to 4°C (Böer, 1997; Environment & Agriculture information center, 2007; (FEA), 2008 and Ministry of Presidential Affaire, 2008). Mean annual rainfall is about 100 mm, almost 90% of rainfall occurs during the winter (October-March) and the wettest month is February. Spring and summer witness only occasional concentrated heavy rainfall. The rainfall distribution is highly variable over space and time. Rainfall tends to be more reliable in the northeastern mountain region (FEA, 2008 and Ministry of Presidential Affaire, 2008). The average annual groundwater recharge is about 120 million cubic meters (Ministry of Environment and Water, 2007). The over-extraction of groundwater resources has led to lowering of the water table by more than one meter on average during the last two decades, while seawater intrusion is increasing in the coastal areas (Ministry of Environment and Water, 2007). It is important to utilize the rainwater by expanding the water-harvesting project or enhancing water recharge projects (Environment & Agriculture Information Center, 2007). However, it is import to test the quality of sediments of these dams, which the rainwater will pass, or recharge to the ground.

1.2. Dams in UAE

Several dams in the study areas were built to increase the groundwater recharge in UAE. A number of these have been built at various locations in the major wades (Environment & Agriculture Information Center, UAE, 2007). There are about 114 dams and embankments of various dimensions having a total storage capacity about 122 million cubic meters (Ministry of Environment and Water, 2007).

1.3. Overview of the Investigated Site

The study area includes four main dams in different location in the UAE (Figure 1.1), and their location characterized by different geological formations for example Al-Shuweib dam is relatively close to the carbonate formations of Jabel Hafit and it about 78 km, from Al-Ain city (Municipality of Al-Ain, 2006).

Figure 1.1. Locations of the investigated dams.

The rest of the dams, which include Al-Bih, Al-Tawiyeen and Ham dam, are located in northern part of the country were dominated by both ophiolite sequence of Oman overthrust, igneous and carbonate sedimentary formation. With a very hot and humid climate the rates of evaporation will increase in the summer, shows the most appropriate types of dams on the nature of the state is the temporary detention dams that feed water projects.

1.3.1. Wadi Al-Shuweib Dam

Al-Shuweib dam built in 1990 to collect 31 million cubic meters of annual rainwater and is located 78 kilometer from Al-Ain city. The water is used in surrounding land reclamation for aquculture pruposes. The dam is 3000 meters long, and 8 meters high at the top of the riprap (Environment Agency, 2007). The type of this dam is sandy and gravel dam (Ministry of Environment and Water, 2007). As can be noticed from Figure (1.2), there are scattered vegetation around this dam. Also close to this dam, a major highway is connected Al-Ain city with Al-Fujirah city, which can be considered as a source of pollution.

1.3.2. Wadi Al-Bih Dam

This 1.8 million square meters gravel and ripraped faced dam (Environment & Agriculture Information Center, 2007) is located in northern agricultural region. The main purpose of this dam was to recharge ground water aquifer for the region of Albrairat and Hamraneh (Ministry of Environment and Water, 2007). It is built on October 1982 with capacity of 7.5 million cubic meters. As it can be observed in the Figure (1.3), the dam has gravel floor, which enhances water infiltration and the carbonates sedimentary rocks surround this dam.

1.3.3. Wadi Al-Tawiyeen Dam

This dam is 342 meters long, and 23.5 meters height with storage capacity of 18.5 million cubic meters and is located one kilometer from Dibba city. The total length of this valley reached to 5 km, and the main objective of the dam is to slow down the runoff, which spreads in the gravel plain. Many valleys meet in this main valley such as SAhakh, Walueen, Khab, Hiyar, Khrus, Riyama, Jareef, Sarm, Mehterga, Yaqel, Sadkh, Awsaj, Maya, and Nimr (Municipality of Dibba, 2006).

Figure 1.2. View of Wadi Al-Shuweib dam.

Figure 1.3. View of Wadi Al-Bih dam.

The area of Toben considers as the richest of rainwater, therefore the dam type is soil and gravelly. The contraction of the dam was completed in April 1991. The catchments area of the dam is 190 km^2 and reservoir area is 3.24 million square meters (Ministry of Environment and Water, 2007; Municipality of Al-Fujirah, 2006). As can be observed in Figure (1.4), scattered traces and some depositional landforms exist around and within the body of this dam. The depsitonal features could form a future problem by plugging the pores of the earth fill material.

1.3.4. Wadi Ham Dam

This Wadi from the region of Massafi with a length of about 30 kilometers and is located in the eastern region of the UAE, it is the largest and longest dam in the country. Its purpose is to direct the surface water to Wadi Laham to recharge the aquifer and to halt the advancement front of seawater. In addition, to other objectives such as protection from flood risk and improve the quality of water and feed the dam areas. Many branch wadis contribute to the drainage area upstream of the dam and these branches are wadis of Furfar, Saham, Beiga, Mudouk, and Alihatti.

The dam opened on 15th February 1983 and serves the city of Fujarah, Madouk area and Furfarah. The body of the dam is composed of three parts; the main body, the northern dam and the southern dam. Generally the dams form a half circle shape which is 2.5 kilometers long and stores about 10 millions cubic meters of water which increases the storage reservoir of water supplies (Municipality of Al-Fujirah, 2006).

The length of the main wing of the dam is 600 m, and the height is 16 m, while the width at bottom is 92 m and 5 m at top. The dam has two water disposing channels. The first channel is 62 m long and 12 m high, with a capacity of passing 889 m^3 of water per second. The second channel is 118 m long and 12 m high, with a capacity of passing 1711 m^3 of water per second. These channels serve as safety releases during high floods (Ministry of Environment and Water, 2007). As shown in the Figure (1.5), rock fragments of different colors exist which could be derived from the nearby ophiolite sequence.

Figure 1.4. View of Wadi Al-Tawiyeen dam.

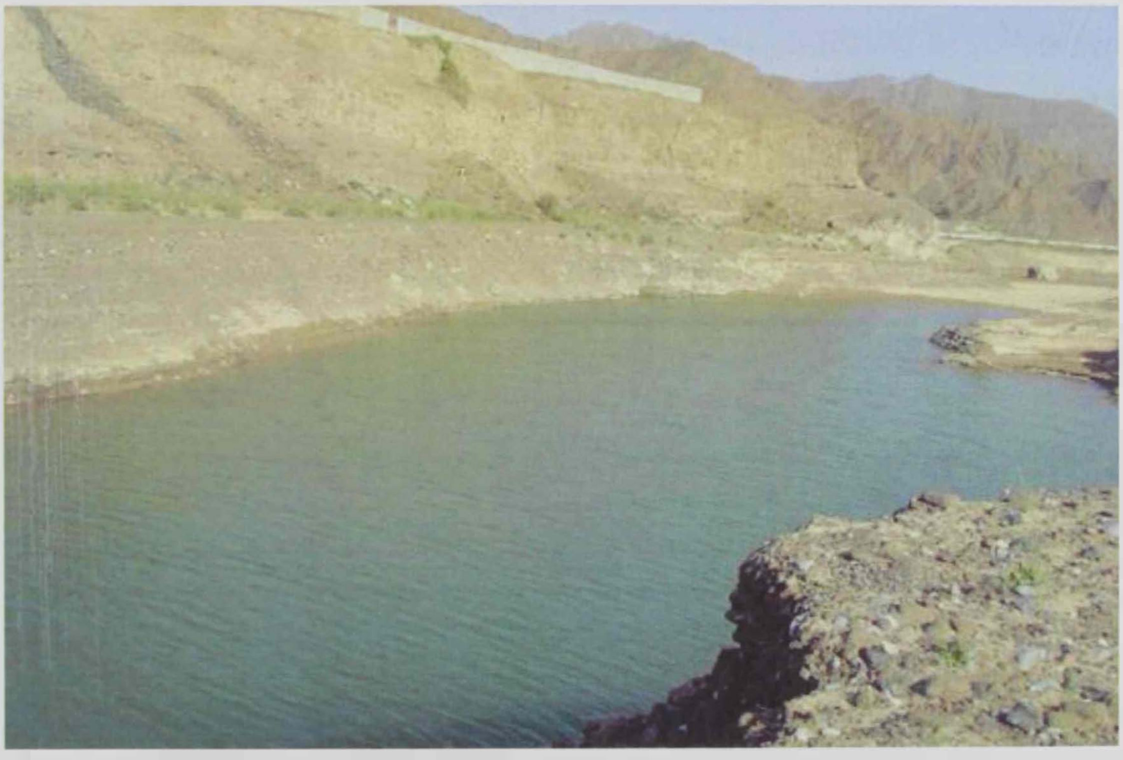


Figure 1.5. View of Wadi Ham dam.

1.4. The Significant of Dams in UAE

In UAE, the groundwater removed by pumping is greater than natural recharge. The declining in groundwater will put pressure on the urban settlement, and it is possible to see abandoned farms because of the lack of fresh water resources near Al-Shuweib.

Desalination offers a solution for domestic consumption but the link between the fossil fuel and the desalinated water costly, as is the carbon footprint. Therefore, increasing rainwater harvesting in UAE to increase options for potable water could be considered as a viable options, and this can be done by establishing recharge types of dams. The most appropriate types of dams are detention types that are designed to increase groundwater recharge and to stop seawater intrusion. In addition, it can provide a source of water for agriculture and drinking, protect from risks caused by floods and reduce the damages, use of sediment accumulated behind the dam to improve agricultural soils (Ministry of Environment and Water, 2007).

1.5. Environmental Significant of Heavy Metals and their Risks

Heavy metals are those having large atomic number, and are widespread in nature. Heavy metals are used in industrial advance technological countries. Some are physicologically essential for plants and animals, and thus have a direct impact on human health, agricultural productivity, and many are significant as pollutants of ecosystems throughout the world. Heavy metals are found in surface, groundwater, seawater, marine organisms and sediments (Alloway, 1990). The concentration of heavy metals in sediments and soils can be influenced by variation in their texture, composition, reduction/oxidation reactions, adsorption, and physical transport or sorting in addition to anthropogenic metal input (Ahumada, et al., 1999; Adriano, 1999 and Howari and Banat, 2001).

1.6. Sources of Heavy Metal Pollutes in Soil

Some of the major sources of heavy metals pollutant in soils are atmospheric pollute from motor vehicles. The use of leaded petrol has been responsible for the global dispersion of Pb aerosols (Alloway, 1990). The disposal of ash is a further source of heavy metals (Howari et al., 2005). In agricultural fertilizers and pesticides, several of these including phosphatic fertilizers, slags from iron manufacture, pesticides and herbicides contain combinations of heavy metals.

Organic manures include poultry manures, which may contain high content of Cu or As concentrations fed to improve food conversion efficiency. The disposal of urban and industrial wastes can lead to soil pollution from the deposition of aerosol particles emitted by the incineration of metal-containing materials. The careless (or unauthorized) dumping or disposal of metal-containing items, ranging from dry-cell batteries (Ni, Cd and Hg) to abandoned cars and car components (e.g. Pb-acid batteries) can give rise to small areas of very high metal concentrations in soils (Förstner,1981). The disposal of some domestic wastes by burning or burial in the garden can also result in localized anomalously high concentrations of metals, such as Pb, in soils used for growing vegetables. Metallurgical industries can contribute to soil pollution in several ways such as by emissions of fumes and dusts containing metals, which are transported in the air and eventually deposited onto soils and vegetation. Also by effluents which may pollute soils when watercourses flood or by the creation of waste dumps (and scrap yards) from which metals may be leached and thus pollute underlying or nearby soils. Metals are dispersed in dusts, effluents and seepage water. Tailings discharged into water- courses have polluted alluvial soils downriver from mines during flooding, especially when the dams in tailings lagoons fail (Allowy, 1990).

1.7. Heavy Metals Considered in this Study

Heavy metal polluted soils constitute a major environmental problem because many of the elements will persist in the soil or sediment for hundreds or even thousands of years, therefore, careful management required to assess the environmental behavior and ecological risk of heavy metals in the sediments (Förstner and Wittmann , 1981 and Alloway, 1990).

Table 1.1. Average heavy metals content in earth's crust and soil.

Parameter	Earth's crust (µg/g)	World mean Soil content (mg/kg)	Metal content in Soil (mg/l)	Agricultural Soil (mg/Kg)
Cadmium	0.1	0.62	0.06	0.01-2.4
Chromium	100	–	100	5-1500
Copper	50	26	20	2-250
Lead	14	29	10	2-300
Zinc	75	60	50	10-300

Table (1.1), show the mean heavy metal contents of earth's crust (Krauskopf, 1967 and Rose, et al., 1979), world mean soils content compiled from (Sharp, 1989; Ure, 1983 and Wilkins, 1983), heavy metal content in soils (Förstner, 1981), concentration of heavy metals in agricultural soils compiled from (Bowen, 1979 and Webber, 1984). Table (1.2) gives the mean concentrations of heavy metals in a range of representative types of igneous and sedimentary rocks (Krauskopf, 1967; Rose, et al., 1979 and Alloway, 1990).

Table 1.2. Mean heavy metal contents of major rock types (µg/g).

Parameter	Earth's crust (µg/g)	Igneous rocks			Sedimentary rocks		
		Ultramafic*	Mafic*	Granitic	Limestone	Sandstone	Shales*
Cadmium	0.1	0.12	0.13	0.09	0.028	0.05	0.22 (<240)
Chromium	100	2980	200	4	11	35	90
Copper	50	42	90	13	5.5	30	39
Lead	14	14	3	24	5.7	10	23
Zinc	75	58	100	52	20	30	120

* Ultramafic rocks are also called 'ultrabasic', e.g. dunite, peridotite and serpentinite, Mafic rocks are also called 'basic igneous rocks', e.g. basalt 'Shales' also include clays

Table (1.3) gives Trace element concentrations (µg/dry g) from various sources. Values were compared with sediment quality standards, SQS, (WDOE, 1995), and background concentrations of elements (Turekian and Wedepohl, 1961; Mason, 1966; Bowen, 1979 and Salomons and Förstner, 1984).

Table 1.3. Trace element concentrations (µg/dry g) from various sources.

Parameter	Average Shale[a]	Soil[b]	Mean Crust[c]	Mean Sediment[d]	Sedimentmanagement Standards[e]
Cadmium	0.3	0.2	0.11	0.17	5.1
Chromium	90	100	100	72	260
Copper	45	55	50	33	390
Lead	20	13	14	19	450
Zinc	95	70	75	95	410

[a] Turekian and Wedepohl, 1961, [b] Mason, 1966, [c] Bowen, 1979; [d] Salomons and Förstner, 1984,

[e] WDOE, 1995

1.7.1. Cadmium (Cd)

Cadmium can mainly be found in the earth's crust. Sedimentary rocks show a greater rang of Cd concentrations than other rock types, with phosphorites and marine black shales having the highest contents (Allowy, 1990). It always occurs in combination with zinc and it consists in mining industries as an inevitable by-product of zinc, lead and copper extraction. Cadmium pollution of the environment has been rapidly increasing in recent decades because of rising consumption of Cd by industry. Another important source of cadmium emission is the production of phosphate fertilizers. Part of the cadmium ends up in the soil after the fertilizer is applied on farmland and the rest of the cadmium ends up in surface waters when waste from fertilizer productions is disposed of by production companies (James, 1997; Alloway, 1990 and Förstner, et al., 1981). Source of soil contamination by Cd are the mining and smelting of Cd and Zn; atmospheric pollution from metallurgical industries; the disposal of wastes containing Cd, such as the incineration of plastic containers and batteries; and the burning of fossil fuels (Hutton, 1982). Cadmium strongly adsorbs to organic matter in soils. When cadmium is present in soils, it can be extremely dangerous, as the uptake through food will increase (US Environmental Protection Agency, 2005).

1.7.2. Chromium (Cr)

Chromium is the seventh most abundant element on earth, but 21st in abundance in the crystal rocks, with an average concentration of 100 mg/kg in igneous rock (Allowy, et al., 1990). There are two valence states of chromium that differ in their effects upon organisms. Chromium enters the air, water and soil in the chromium (III) and chromium (VI) through natural and human activities (Förstner, et al., 1981, Lenntech, 2007). The main human activities that increase the concentrations of chromium (III) are steel, leather and textile manufacturing. However, the main human activities that increase chromium (VI) concentrations are chemical, leather and textile manufacturing, electro painting and other chromium (VI) applications in the industry. These applications will mainly increase concentrations of chromium in water. Chromium will also enter the air and be deposited on the soil as a result of coal composition and through waste disposal (James, 1997; Alloway, 1990 and US Environmental Protection Agency, 2005).

1.7.3. Copper (Cu)

Copper is a widely used common substance that also occurs naturally in the environment and is transported in environment through natural phenomena. For instance, it is applied in the industries and in agriculture. The production of copper has increased over the last decades and due to this, copper quantities in the environment have been expanded (Allowy and Baker, 1990 and Wiley, 1979). Most copper compounds will settle and be bound to either sediment or soil particles. Soluble copper compounds form the largest threat to human health. Usually water-soluble copper compounds occur in the environment after release through application in agriculture (James, 1997; Förstner, et al., 1981 and Lenntech, 2007). When copper ends up in soil, it strongly attaches to organic matter and minerals. As a result, it does not travel very far after release and it hardly ever enters groundwater. In surface water, copper can travel great distances, suspended either on sludge particles or as free ions. Copper can accumulate in plants and animals when it is found in soils (US Environmental Protection Agency, 2006).

1.7.4. Lead (Pb)

Lead occurs naturally in the environment. However, environmental elevated lead concentrations that are a result of human activities. Due to the application of lead in gasoline, an unnatural lead-cycle has been consisted (James, 1997; Alloway, 1990 and Förstner, et al., 1981). In car engines lead is burned, so that lead salts (chlorines, bromines, oxides) will originate (US Environmental Protection Agency, 2006 and Lenntech, 2007). Lead and its compounds tend to accumulate in soils and sediments where, due to their low solubility and relative freedom from microbial degradation, they will remain accessible to the food chain and to human metabolism far into the future (Allowy, 1990).

1.7.5. Zinc (Zn)

Zinc is a very common substance that occurs naturally. Many foodstuffs contain certain concentrations of zinc. Drinking water also contains amounts of zinc, which may be higher when it is stored in metal tanks. Industrial sources or toxic waste sites may cause the zinc amounts in drinking water to reach levels that may cause health concerns. Zinc occurs naturally in air, water and soil, but zinc concentrations are rising due to addition of zinc through human activities (James, 1997; Alloway, 1990 and Förstner, et al., 1981).

Most zinc is added during industrial activities, such as mining, coal and waste combustion and steel processing. Some soils are heavily contaminated with zinc, and these are to be found in areas where zinc has to be mined or refined, or were sewage sludge from industrial areas has been used as fertilizer. The world's zinc production is still rising. This basically means that more and more zinc ends up in the environment. On zinc-rich soils, only a limited number of plants have a chance of survival. That is why there is not much plant diversity near zinc-disposing factories. Due to the effects upon plants, zinc is a serious threat to the productions of farmlands. Despite of this zinc-containing manures are still applied (US Environmental Protection Agency, 2006 and Lenntech, 2007).

1.8. Other Analysed Elements

A common practice used to improve the sensitivity of comparing trace element and organic contaminant concentrations in sediments is to normalize them to some sediment constituent which is unaffected by human activities such as contaminant input (Luoma, 1990; Hanson, 1993; Daskalakis and O'Connor, 1995; Nolting, et al., 1999 and Chatterjee, et al., 2007). Some of the constituents commonly used include aluminum, iron, and Total Organic Carbon (Taylor, 1964; Daskalakis and O'Connor, 1995; Nolting, et al., 1999; Birth, 2003 and Chiu, et al., 2007). In this study, Aluminum and Iron were used as a normalization of heavy metals in investigated sediments samples.

1.8.1. Aluminum (Al)

Aluminum is an abundant element in Earth's crust, which believed to be contained in a percentage from 7.5% to 8.1% (US.EPA, 2003). It is low concentration in ionic form and is mainly an insoluble aluminum hydroxide (Lenntech, 2007). Aluminum is a reactive metal and it is hard to extract it from its ore, aluminum oxide (Al_2O_3). It is among the most difficult metals on earth to refine, the reason is that aluminum is oxidized very rapidly and that its oxide is an extremely stable compound that, unlike rust on iron, does not flake off. The very reason for which aluminum is used in many applications is why it is so hard to produce. The concentrations of aluminum appear to be highest in acidified lakes. In these lakes, the number of fish and amphibians is declining due to reactions of aluminum ions with proteins in the gills of fish and the embryo's of frogs.

Another negative environmental effect of aluminum is that its ions can react with phosphates, which causes phosphates to be less available to water organisms (US Environmental Protection Agency, 2003). High concentrations of aluminum may not only be found in acidified lakes and air, but also in the groundwater of acidified soils. There are strong indications that aluminum can damage the roots of trees when it is located in groundwater (Lamotte, 2007).

1.8.2. Iron (Fe)

Iron is the most abundant (by mass, 34.6%) element making up the earth (US.EPA, 2003), the concentration of iron in the various layers of the earth ranges from high at the inner core to about 5% in the outer crust. Most of this iron is found in various iron oxides, such as the minerals of hematite, magnetite, and taconite. Iron is essential to almost living things, from microorganisms to humans (US Environmental Protection Agency, 2003 and Lenntech, 2007). Most soils will contain iron in sufficient quantities to satisfy the needs of most plants. A deficiency of iron is sometimes noted in alkaline soils, and is indicated by chlorotic conditions of the plants (Lamotte, 2007). Accordance with toxicity data obtained from various studies, the drinking water standards have been proposed by various governmental bodies, a brief summary is given in Table (1.4) (complied by Hattingh, 1977).

Table 1.4. Drinking water quality standards for trace metal*.

Parameter	USPHS (1962)	Japan (1968)	WHO European (1970)	WHO Intern. (1971)	NAS (1972)	Australia (1973)	US EPA (1975)
Cadmium	10	–	10	10	10	10	10
Chromium	50	50	50	–	50	50	50
Copper	1,000	10,000	50	50	1,000	10,000	–
Lead	50	100	100	100	50	50	50
Zinc	5,000	100	5,000	5,000	5,000	5,000	–

* As proposed by US Public Health Service (USPHS), Japan and Environmental Protection Agency (EPA), World Health Organization (WHO), USA National Academy of Sciences (NAS), Australia. All concentrations in µg/l .

1.9. Expected Results of this Study

The study of heavy metals in UAE sediments is important for two reasons: First to set background geochemical data for the wadi sediments quality in the country, and second to assess any possible source of pollution. The intent of this study is to investigate the distribution and geochemical aspect and quantify the heavy metal concentrations (Cd, Pb, Cu, Cr, and Zn) in the sediments of four reprehensive UAE dams, and assess their possible sources. It is also important to study the impact of the physico-chemical parameters (pH, TDS, $CaCO_3$, P_2O_5, TOM, and CEC) on the distribution of heavy metals. Based on the published and widely accepted sequential extraction procedures, this research work will suggest possible sequence of mobility for the metals based on their percentage of retention with five geochemical forms: F1, soluble–exchangeable; F2, sorbed--carbonate; F3, oxidizable; F4, reducible; and F5, residual. This is important to predict the fate and transport of heavy metals should the pH – Eh values change to a mode favorable for metal movement.

CHAPTER TWO

LITERATURE REVIWE

2. LITERATURE REVIEW

Numerous studies concerning enrichment and accumulation of toxic heavy metals in sediments as well as soil media have been conducted during the recent years. Such studies covered a wide rang of interests in several parts of the world as will be given in the following sections.

2.1. Advances in Heavy Metal Analyses and the Remediation

In Italy, Selena, et al., (2007), investigated the remediation of lead contaminated soils by using ball milling reactors. In these study, lead immobilization was achieved without the use of reactants but only through the exploitation of weak transformations induced on the treated soil by mechanical loads taking place during collisions among milling media, after a relative short milling time, leachable fraction of Pb (II) was reduced under the EPA regulatory limits for drinkable water for all the considered soils.

Stripping technique has been recognized that it is very effective in the analysis of heavy metal ions in environmental and biological samples. Thus, Serrano, et al., (2007), in Spain, developed a new mathematical treatment and implemented an EXCEL spreadsheet that includes equation relates the governing factors for this techniques will determine the average equilibrium functions from the full set of data measured by Scanning Stripping Chrono-Potentiometry (SSCP) in solutions containing different proportions of heavy metal ions and small-size ligands The good agreement between the complecation parameters determined in this way, those predicted from literature data and those obtained using a cadmium ion selective electrode (ISE) confirms the validity of the proposed methodology and encourages its further refining analysis.

On the other hand, Vasil Simeonov, et al., (2007), assessed sediment-quality in the Tarawa Lake in SW Poland, by intelligent data analysis using chemometric interpretation of monitoring data from physicochemical parameters and toxicity tests. The dataset comprised results from lake-sediment samples. The monitoring results were considered both separately (chemical and toxicity data) and simultaneously in order to identify pollution sources in the region and to detect correlation between chemical and toxicity tests. The effort of this study was to establish simple relation between two different types of parameters measured (chemical and ecotoxicity) which did not give hint of serious correlation between them. This study concluded that sediment assessment needs to be done in two separate analytical tracks-chemical and ecotoxicological (which uses biological tests to obtain independent information about acute or chronic toxicity).

In Malaga, Southern Spain, the distribution and fixation of trace elements were studied, and they indicate that alkaline soils behave as buffer mitigating the impact of the acid solution, and the distribution of elements over the soil profile can be attributed to pH. The sequential extraction analyses indicated that Pb, Cu, Co, Ni, Zn, and Cd are accumulated in the soluble and interchangeable fractions under acid conditions, whereas they are fixed to the carbonate, iron and manganese oxide fraction in an alkaline environment (Mercedes, et al, 2007).

Whereas, in Australia the storage of sediment and distribution of heavy metals were associated downstream of the remediate Rum Jungle Mine on the East Branch of the Finniss River in Northern Territory, using instrumental neutron activation analysis (INAA). The results reveal that channel and over bank environments are contaminated with heavy metals, with many samples exceeding the low and high Australian sediment quality guidelines values. Metal concentrations are strongly correlated to sediment pH and Fe values, which are significant controlling the distribution of sediment-associated metals (Mark, 2007).

In USA David, et al., (2006), studied the direct major and trace-element analyses of rock varnish by high-resolution laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) from the Lahontan Range, near Fallon, NV and near the San Juan River. The data indicate that this method of analyses provide ample analytical resolution for semi-quantitative compositional determinations of both trace and major elements in the varnish despite the two localities are grossly similar to rock varnish, which mostly contribute to soil formation. The data presented in David, et al., (2006), study suggested that LA-ICPMS might not be the ideal analytical technique for the characterization of rock varnish trace element chemistry.

In Berlin, Germany, on-site analysis of heavy metal contaminated areas were studied by means of total reflection X-ray fluorescence analysis (TXRF) which is a well established analytical technique for trace element determination in various sample types. He applied the low power TXRF spectrometer PicoTAX for the one-site analysis metal contaminated soils and sediments later on are evaluated. The task was the fast analysis of the main target elements antimony, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, vanadium, and zinc (Hagen Stosnach, 2006).

On other hand, in USA, Feimeng Zhou, (2005), combined on-line Electro-chemistry with atomic mass spectrometry and related techniques for trace-metal analysis and electrode-reaction studies. He summarized recent advances based on EC coupled with atomic MS and related techniques for trace-metal analysis and studies of electrode processes. Particular emphasis is placed on EC combined with ICP-MS (EC-ICP-MS) and electrospray–MS (EC-ES-MS). In addition, this study described the criteria for selecting the suitable EC flow-cell designs and the MS sample-introduction systems or interfaces.

Förstner U., (2004), in Germany assessed the traceability of sediment chemical analysis, which provides an efficient tool for water quality management in Germany. He reported that basic sequence of measurement comprises three steps, which includes; sampling and sample preparation as well as grain size as a characteristic sediment feature; and analytical procedures based on standardized extraction schemes and reference materials. Further steps are that Förstner, (2004), recommended considering while doing metal environmental assessment studies include biological effect; coupling of sediment-quality data with erosion-risk, chemical changes and modeling of chemical sediment data.

In Scotland, quantitative determination of cerussite (lead carbonate) by X-ray powder (XRPD) diffraction and inferences for lead speciation and transport in stream sediments from a former lead mining area was studied. They concluded that for techniques such as quantitative (XRPD) its application to heavily contaminated sites in particular should be relatively straightforward, and it should even find increased application in studies of less severe contamination. Such procedures have often been used in a qualitative fashion, but as demonstrated in the present investigation quantitative analysis is not exceptionally difficult (Hilier, et al., 2001).

Joanna, (2000) studied the problems related to species selective analysis in water insoluble fractions of solid samples and trace element speciation analysis of biomaterials by high-performance liquid chromatography with inductively coupled plasma mass spectrometric detection. The coupling of HPLC with ICP-MS is currently the primary tool for species selective analysis of metallocompounds that are not volatile and cannot be derivatised to thermally stable species amenable to gas chromatography. It has large area of potential applications in the field of trace element speciation analysis. The limitation of coupling are no longer related to instrumentation but appear on the levels of sample preparation and chromatography of natural samples and are related to elimination of artifacts, contamination control and peak identification.

2.2. Distribution of Heavy Metal in Arid region

In Jordan, Banat, et al., (2005), studied the distribution of heavy metals in soils and also investigated for mineralogy using X-ray, electron and optical microscopes. Sequential extraction procedures were used to predict the soil geochemical phases for the heavy metals (Pb, Zn, Cd and Cr). The result of the analysis indicated that the urban soils of Central Jordan has been effected by human activity such as industrial cement particular which lead to a high accumulation of heavy metals compared with the natural background levels. The distribution of heavy metals in the soils indicted that the cement industry together with the agricultural fertilizers and vehicle exhausts were mainly responsible for metal pollution.

In Kuwait Bay, Northern Arabian Gulf a qualitative and quantitative assessment of suspended sediment levels and transport pathways. The collected sediments were subjected for heavy metals concentration analysis, mineralogical composition and grain size constituents. The distribution pattern of the sediments samples indicates that possibility of tidal current activity, dust fallout contribution and to a lesser extent, the effect of Shatt Al-Arab. The distribution of various types of sediments and the variations of their textural, compositional and concentrations are controlled largely by the hydrodynamic conditions and nature of sediments. The result of the study demonstrate clearly the potential impact of the Gulf War as manifested by the increase of SSC in 1992 compared to 1989/1990 (Al-Ghadban et al., 2005).

On other hand, sedimentological and geochemical studies on sediments samples collected from Arabian Gulf during 1992, to investigate the petroleum hydrocarbon and trace metal pollutants transferred from the Kuwait oil slick to the sea bed and residing in these sediments. Total organic carbon (TOC), total petroleum hydrocarbons (TPH), and selected trace metals in sediment samples were measured. None of the previous studies provided detailed information about the nature and importance of sedimentation rate and bioturbation in the Arabian Gulf. Both environmental factors have certain implications in any data interpretation that concerns the fate of pollutants in any marine environment (Al-Ghadban et al., 1998).

The distribution and phase association of major trace elements Al, Fe, Mg, Ba, Mn, Zn, Cu, Cr, V, Ni and Hg in the Arabian Gulf sediments were investigated by Basaham and El-Sayed (1998). The result observed two major sediment types, which are a terrigeneous fine-grained and Al rich type predominate alone the Iranian side and a coarse graned and carbonate rich type predominating along the Arabian Gulf side.

2.3. Fractionation of Heavy Metal

The mobility of metals in the environment depends strongly on their chemical bonds of the element, therefore, in Slovakia Mária, et al., (2006), modified three step sequential extraction procedure for the fractionation of heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn), which proposed by commission of the European Communities Bureau of Reference (BCR), has been applied in soil reference materials of different origins. The sum of the element contents in the three fractions plus aqua-regia extractable content of the residue was compared to the aqua-regia extractable content of the elements in the origin soils. The accuracy obtained by comparing the determined contents of the elements with certified values of BCR CRM 701 in sediment, and the result found to be satisfactory.

In Brazil, sequential fractionation procedures for Cu and Zn in tropical soils were developed. Chemically reactive Mn forms were satisfactorily assessed by the new modified procedure. Amorphous and crystalline Fe oxides were more selectively extracted in a new two-step extraction. Soil-born Zn and Cu were primarily associated with recalcitrant soil fractions. The proposed procedure provided more detailed information on metal distribution in tropical soils and better characterization of the various components of the soil matrix (Silveira, et al., 2006). On other hand, in Turkey, Şenol, et al., (2006), modified the European Community Bureau of Reference (BCR) sequential extraction procedure to determine the concentrations of metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in street sediment samples. Correlation analysis and Principal component analysis were applied to the data matrix to evaluate the analytical results and to identify the possible pollution sources of metals. PCA revealed that the street sediment samples were mainly influenced from three pollution sources, which are traffic, industrial and natural sources, and the result show that chemical sequential extraction is a precious tool.

In Germany, Margareta, et al., (2006), investigated the influence of carbonate and other buffering substances in soils on the results of a three step sequential extraction procedure (BCR) used for metal fractionation. By applying the original BCR-sequence to the calcareous soil carbonate was found in the residues of the first two steps and extract pH values rose by around two units in the first and second step, caused mainly by carbonate dissolution, which lead to wrong assignment of the carbonate elements Ca, Mg, Sr, Ba, and also to decrease desorption and increase re-adsorption of ions in those steps. The effects on ion release in the fine fraction > 2μm were similar to those of the whole soil. Since the destruction of the organic matter was incomplete after regular oxidation, the H_2O_2 treatment of the fine fraction had to be repeated. In addition, the extractable amounts of the two fractions show good agreement to the results obtained for extraction of the whole soils. Likewise the pH values of the carbonate free soil extracts did not increase significantly, therefore it was concluded that repetitions of extraction steps for this soil were not necessary.

Pyrite and other reactive iron-sulfide minerals are important to sedimentary trace element behavior, which provide sinks for potentially toxic trace elements that are introduced to estuarine systems from anthropogenic and natural sources. Toward this in Australia, Edward, et al., (2006), described iron and sulfur fractionation, and the related extractability of selected trace elements (As, Cd, Cr, Cu, Ni, Pb and Zn) in estuarine sediments. The extractability trends for Cr suggested that digenesis in sulfidic sediments may enhance Cr reactivity. Moreover, replacement of Acid Volatile sulfide (AVS) by pyrite during digenesis may enhance the reactivity of Cd, Cr, Pb and Zn, whereas As, Cu, and possibly Ni may rendered less reactive.

In France, the effect of sulfate by using modified BCR sequential heavy metals extraction from polluted soils was assessed. The results indicated that the goethite-surface adsorption sites for sulfate are limited. In addition, the study shows that the significant changes in Cd and Pb fractionation were observed in the presence of sulfate, whereas Cu remained strongly adsorbed on the solid phases. The main conclusion for this study was a decrease in metal onto the studied solids was enhanced by the presence of sulfate (Sonia, et al., 2005).

In Canada, Loring, et al., (1992), assent accurate and precise sampling and analytical procedures in environmental geochemical studies. This study provided a detailed description of the techniques and analytical procedures for sampling, grain size determination, and for precise and accurate AAS determination of the major and trace metals in marine sediment and suspended particulate matter. In addition, the study described the procedures for the chemical partition of the metals, determination of readily oxidizable organic matter, calcium carbonate and normalization of trace metal data. Where as Tessier et al. (1986), assessed the factors effect the partitioning of trace metals in sediments, as obtained with a sequential extraction procedure are the techniques used to preserve the sediments before analysis and the presence/absence of atmospheric oxygen during the extraction steps. This study reported that no storage method tested completely preserved the initial chemical and physical characteristics of the sediments. Drying of the sediment should be avoided; acceptable preservation techniques include freezing or short-term wet storage. Among the different metals copper, iron and zinc were particularly sensitive to sample pretreatment. For anoxic sediments, the maintenance of oxygen-free conditions during the extractions is of critical importance. On other hand, Kirk, (2003), assessed of sequential extraction schemes, which were modified from a procedure developed by Tessier, et al., (1979). These procedures were originally developed for the examination of aquatic sediments but gained wide acceptance as tools for the speciation of metals in soils. Sampling techniques and actual extraction routines can be standardized to some degree. Results from sequential extraction procedures may vary widely in complex matrices such as soils and sediments. Lack of specificity on the fractions attacked by a particular extractant can mobilize elements that are associated with solid phases other than the phase targeted by the extraction.

Abaychi and Doubul (1986) investigated the trace element geochemical associations in the Arabian Gulf. They determined the geochemical fraction of Cd, Cr, Cu, Fe, Mn, Ni, V, and Zn in surficial sediments from the northwestern part of Arabian Gulf.

The result of the study indicate that in the non-lithogenous fraction, the easily or freely leachable and exchangeable fraction is not geochemically significant while the carbonates and Fe-Mn oxides and hydroxides fractions appear to be the most dominant phases.

2.4. Toxicity of Heavy Metals

Toxic substances of environmental concentrations are not necessarily constant but it could be fluctuate over time. In Germany Wiebke, et al., (2007), studied the impact of exposure duration on the observed toxicities and to determine the potential for recovery. The bio-concentrations of the tested metals (Zn, Cu, Ni, Cd) were recorded during the exposure to analyse, whether changes in the internal concentrations are a governing factor for dynamics of toxicity. After the exposure of 7 days, the results indicated the necessity to more thoroughly consider the dynamics of toxicity, instead of recording toxic effects only after a constant exposure over a fixed time.

In Morocco, the heavy metal toxicity and soils collected from five mines located by using the MetPAD^{TM} biotest Kit, which detect the toxicity specifically due to the heavy metals in environmental samples were investigated. The general trend observed was an increase in metal toxicity measured by the biotest with increase sensitive predictive tool to assess the heavy metal availability in soils highly contaminated by mining activities (Ali, et al., 2006).

In Denmark, Anne, et al., (2006), studied the toxicity of water and sediment in a small urban river. The study underlines that a toxicity assessment is needed for risk assessment of sediments related to wet weather discharges. The toxicity assessment should be based on both chemical and biological methods as sediment toxicity was found to be high and could not be predicted directly from chemical analyses covering metals and PAH-compounds. On other hand, in Spain, Silvia, et al., (2006), studied the evaluation of heavy metal acute toxicity and bioaccumulation in soil ciliated protozoa by using the fluorescence method that might by a very useful tool for monitoring metals in heavy metals pollution in soils. The result of the analyses indicated that soil ciliates are quite resistant to heavy metals pollution with regard to ciliates from other habitats whereas an antagonism between Cd and Zn has also been detected in colpodid ciliates, after using mixtures of these metals. However, metals can exert a selective pressure on the organisms, resulting in microbial populations with higher tolerance to metals, which also adversely influence microorganisms, affecting their growth, morphology and activities. For these reason in Portugal Sofia, et al., (2006), studied the heavy metal toxicity in Rhizobium leguminosarum biovar viciae isolated from soil subjected to different sources of heavy-metal contamination and there effect on protein expression. They suggested that there is a relationship between Rhizobium's tolerance, heavy metals soil contamination and alterations in protein pool. As a result of the analyses of protein, alteration seems to estimate the level of stress imposed on Rhizobium populations submitted to heavy metal contamination.

In Northern Province of Serbia and Montenegro Dalmacija, et al., (2006), assessed the pollution of the Begej Canal sediment heavy metals, radioactivity and toxicity. The quality of sediment was assessed according to Dutch standards, but the results were also compared with Canadian and US-EPA guidelines for sediment quality. The result indicated severe pollution with Cr, Cu, Cd and Zn whereby the anthropogenic origin of these contaminants. It can be speculated that, despite of high metal contents, the observed toxicity was low because of the high contents of clay and iron, as well as sulphide.

Everett, et al., (1984), assessed the factors limit the quantitative description of toxic element mobility in natural water and soil-water system. First, scientists lack quantitative data to adequately describe the equilibrium and kinetic aspects of both adsorption and absorption onto earth materials. Second, thermodynamic data is insufficient to describe complexation of the metals by natural dissolved organic compounds; formation of selected aqueous species and solubility of certain solids and trace metal content of solids that are composed primarily of major elements for example solid solution behavior. Finally, the kinetics of dissolutions and precipitation reactions used in mass transfer calculations are inadequately known.

2.5. Pollution of Heavy Metals in the soil of Tropical Region

In China Wei Luo., et al., (2007), collected surface soil samples from 52 sites around Guanting Reservoir in Beijing, China, and contents of 'total' metals (Cu, Zn, Pb, Cd, As, Ni and Cr) were determined. The results indicate that the degree of heavy metal pollution in the soil declined in the order of Cd > Cr > Zn > As > Cu > Ni > Pb. Based on the results of a combination of multivariate spastics and geostatical analysis, methods have been developed and applied to soil systems. It was concluded that land application of phosphate fertilizer, wastewater and sludge were the primary sources of Cd and Zn in soils, whereas As, Cu, Cr and Ni in some soils were due to natural rock weathering. The sources of Pb in soils only partially originated from land application of phosphate fertilizer, but mainly from vehicle exhaust. Also in China, YuanPeng, et al., (2007), studied the influence of soil heavy metals pollution on soil microbial biomass enzyme activity, and community composition near a copper smelter. The set of methods applied in this study were sensitive to site differences and contributed to a better understanding of heavy metals effects on the structure, size, and activity of microbial communities in soil. The results show similar correlations between total and extractable contents of the heavy metals and soil microbial activity and community composition.

Habes et al., 2006 assessed the extent of environmental pollution and discussed the origin of these contaminants in sediments of the Wadi Al-Arab Dam in Jordan. The study focused on the level of Mn, Fe, Cu, Zn, Cd, total organic matter (TOM) and carbonate content. The result indicate that the heavy metals in sediments have different anthropogenic and natural sources. The results also confirm the complicated behavior of these pollutants, which can be influenced by many factors. Sediments pollution assessment was carried out using enrichment factor (EF) and the geoaccumulation index.

A different studies and laboratory investigations were demonstrated that many pollutant chemicals become readily associated with sediments, which known as a harbor community of microorganisms with diverse metabolic capabilities and consequently some of these chemicals will be biodegraded. Thus Pritchard, (1984), summarized the relevant research which has been undertaken to detect, quantitate and characterize biodegradation processes in sediments and to relate this information, where appropriate, to hazard assessment problems.

Heavy metals in soils received increasing attention in recent years, partly because of the growing scientific and public awareness of environmental issues, and partly because of the development of analytical techniques to measure their concentrations accurately.

Thus, Alloway, (1990), brought together the information available about the behavior of some heavy elements in soil; their sources and uptake by plants and entry onto the food chain. Moreover, data and information from wide variety of sources were used in order to present the global situation.

On other hand, Förstner, (1981), discussed the direct and indirect influences of pollutions on ecosystem and humans' life, and defined group of pollutants to two groups. First, all trace metals are not usually eliminated from the aquatic ecosystems by natural processes, in contrast to most organic pollutants, and secondly, most metal pollutants are enriched in mineral and organic substances. Toxic metals such as Hg, Cd, As, Cu and many other species tend to accumulate in bottom sediments from which they may be released by various processes of remobilization, and can move up to biologic chain, thereby reaching human beings where they produce chronic and acute ailments.

2.6. Heavy Metals in Arabian Gulf with Focus on UAE

In Arabian Gulf and Gulf of Oman Stepen, et al., (2004), assessed the marine contamination due to heavy metals based on marine biota and coastal sediment collected from Bahrin, Oman, Qatar and the United Arab Emirates. The results indicated that the sediment metal loading were generally not remarkable, although hot spots were noted in Bahrain (Cu, Hg, Pb, Zn) and on the east coast of the UAE (As, Co, Cr, Ni). Concentration of As and Hg were typically low in sediments and sediment in the Gulf of Oman off the east coast of UAE contained extremely high levels of some heavy metals, especially Ni.

In Saudi Arabian, the effect of the heavy metals (Cd, Cu, Pb, Mn, Ni and Co) on the growth of the soil yeasts at different concentration of these heavy metals was investigated. The results provide evidence of the accumulation of metals analysed in the cell of yeasts, and they are able to survive and grow in a medium containing up to 400 µg/ml of metal ions tested (Abdullah, 1997).

In UAE, Howari, (2005), studied the distribution of heavy metals concentrations in surface sediments in Dubai creeks and compared it with local historical record of heavy metal concentrations. The results indicated that the average recorded heavy metal concentration in the colleted sediments samples for this study were slightly higher than metal concentration recorded in 2001, however both results of samples were lower than those of the average earth crust.

Also in UAE, Howari, (2004), assessed the heavy metal speciation and mobility of arid soils in the vicinity of Al-Ain landfill. The results of the study show that the heavy metals contents in the sediments samples were found to be significantly effected by different physico-chemical parameters. The geoaccumulation (I-geo) values indicate that the investigated sediments are uncontaminated with respect to Cd, Cr, Ni, Pb, and Zn and contaminated to moderately contaminate with Cu. The heavy metal data are significantly affected by the distribution of carbonate and grain size.

The sediments samples were collected from Dubai offshore in the Arabian Gulf starting by Al-Mamzar mouth and ending by Ras Ghantoot in order to assess the organic and inorganic pollutants affecting the coastal region in Dubai. The textural class was determined through grain-size analysis and the mineral composition was identified by X-ray diffraction. The organic pollutants were characterized through the determination of total organic carbon (TOC), total kjeldahl nitrogen (TKN), total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), individual polychlorinated biphenyls and inorganic pollutants of some major oxides and trace elements concentrations. The presented study indicates that most of the investigated area is covered by unpolluted sediments except for the northeastern part of the investigated area, which reflects a heavy polluted case (Al-Darwish, 2004).

Al-rashidi, 2004 assessed the geological environment of some selected areas along the coast zone of the Arabian Gulf (northern coast) and the Gulf of Oman (eastern coast). Sediment samples were collected and subjected to grain-size analysis, X-ray diffraction analysis, microfacies and petrographic study and chemical analysis. The grain size analysis shows that the Arabian Gulf coast is covered by coarse sand, whereas the Gulf of Oman coast is covered by medium sand. Sediments samples were also analyzed to determine the concentrations of Al, Fe, Mg, Ca, Na, K, P, Mn, As, Ba, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sr, V and Zn. Geochemical data revealed high variations in the distribution of elements between the Gulf of Oman coast and the Arabian Gulf coast. The concentration of trace metals in the Gulf of Oman coast are controlled mainly by the mineralogy of the land-derived fragments on the other hand, the lower concentrations of trace metals in the Arabian Gulf coast indicate that metals pollution in the studied area is unpolluted. On other hand, Al-Ali, (2003), assessed the natural radioactivity of UAE coastal area by using gamma ray spectrometry HPGe detector for Uranium, Thorium and Potassium measurements. The results of the study indicated that the activates of naturally occurring radionuclide vary considerably from region to region and slightly inside the same region and the average of results were lower than the average world dose rate.

The heavy metals concentrations and pollution in the offshore sediments, off Abu Dhabi, Dubai and Sharjah were quantified and assessed. The collected samples were subjected to grain size analysis, organic carbon and total carbonate determinations, mineralogical analysis and heavy metals. The calculated index of geoaccumulation (Igeo) indicates that Igeo values for different sites are low as they fall into the lowest grades of Igeo. The recorded low values of Igeo for various metals indicate that sediments of the offshore areas as well as those of the creak have a minimum metal pollution accumulation except for those of Ni (Al-Qubaisi, 2001).

The heavy metal pollution in bottom sediments of Dubai, UAE were investigated by El-Sammak (2001). He quantified the metal pollution using statistical methods and simple quantification methods, and observed that most of the stations in investigated area reflect natural background composition of different metals. On the other hand, few samples reflect the man-made impact on the metals contents in the studied area.

Al-sheriani, (1998), focused in her study on the mineralogical, geochemical and textural characteristics of soils from mountainous area and Al Ain district, in UAE. The results indicated that soils in the mountainous area are of colluviums nature where in Al Ain area the soil is generally composed of fine sand, poorly sorted, strongly coarse skewed and very leptokurtic. The soils in this study are markedly poor in organic matter and contain accumulation of calcium carbonate, which mean that the soil is with an alkaline nature.

Al-Asam, 1997 investigated the subsurface condition of Wadi Al-Bih limestone aquifer, evaluated the aquifer's hydrochemical characters, and assessed the impact of the dam on groundwater recharge. The results of the study indicate that the geologic structures and karstification have the main control on groundwater recharge to Wadi Al-Bih area.

CHAPTER THREE

METHODOLOGY

3. METHODOLOGY

3.1. Sample Collection

Ninety-three sediment samples (Appendix I.1), were collected from different representative stations between June and October 2006 (Figure 3.1), from four dams. Forty-one sediments samples were collected from Al-Shuweib dam as shown in Figure (3.2), twenty-three samples from Al-Bih dam as shown in Figure (3.3), eleven samples from Al-Twaiyeen dam as shown in Figure (3.4), and eighteen samples from Ham dam as shown in Figure (3.5). Sediment samples were collected by scooping up the sediments from the top few centimeters with a plastic scoop, and stored in labeled clean airtight plastic bags and the reference of each samples recorded in each plastic bag.

Sediment samples were directly transferred to the laboratory after few hours from the collection time and follow the procedure of analysis (Figure 3.6),where they were dried at 60°C, disaggregated, homogenized and the coarse materials (<2mm); such as pebbles, coarse organic matter and shells were discarded at this stage. Representative subsampling was carried out from the dried ones by coning and quartering unit reaching an adequate volume. However, extreme care was taken to avoid any unexpected metallic contamination, so that all the glassware and polypropylene centrifuge tubes and bottles used were cleaned with detergents and previously soaked in HNO_3 (1:1) and rinsed with distilled water.

Figure 3.1. Sediment sampling from the dams.

Figure 3.2. Location of the samples collected from Al-Shuweib dam.

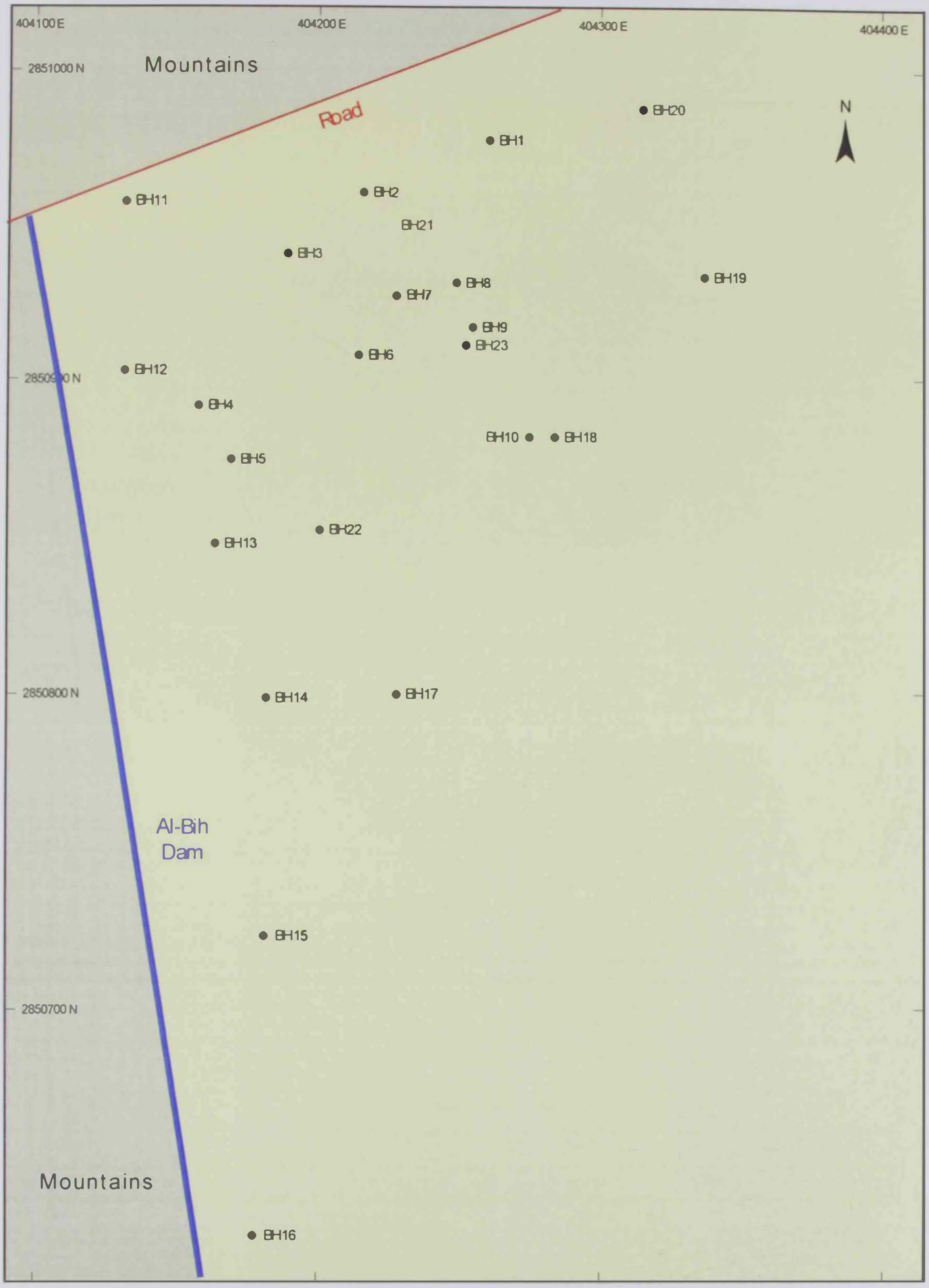


Figure 3.3. Location of the samples collected from Al-Bih dam.

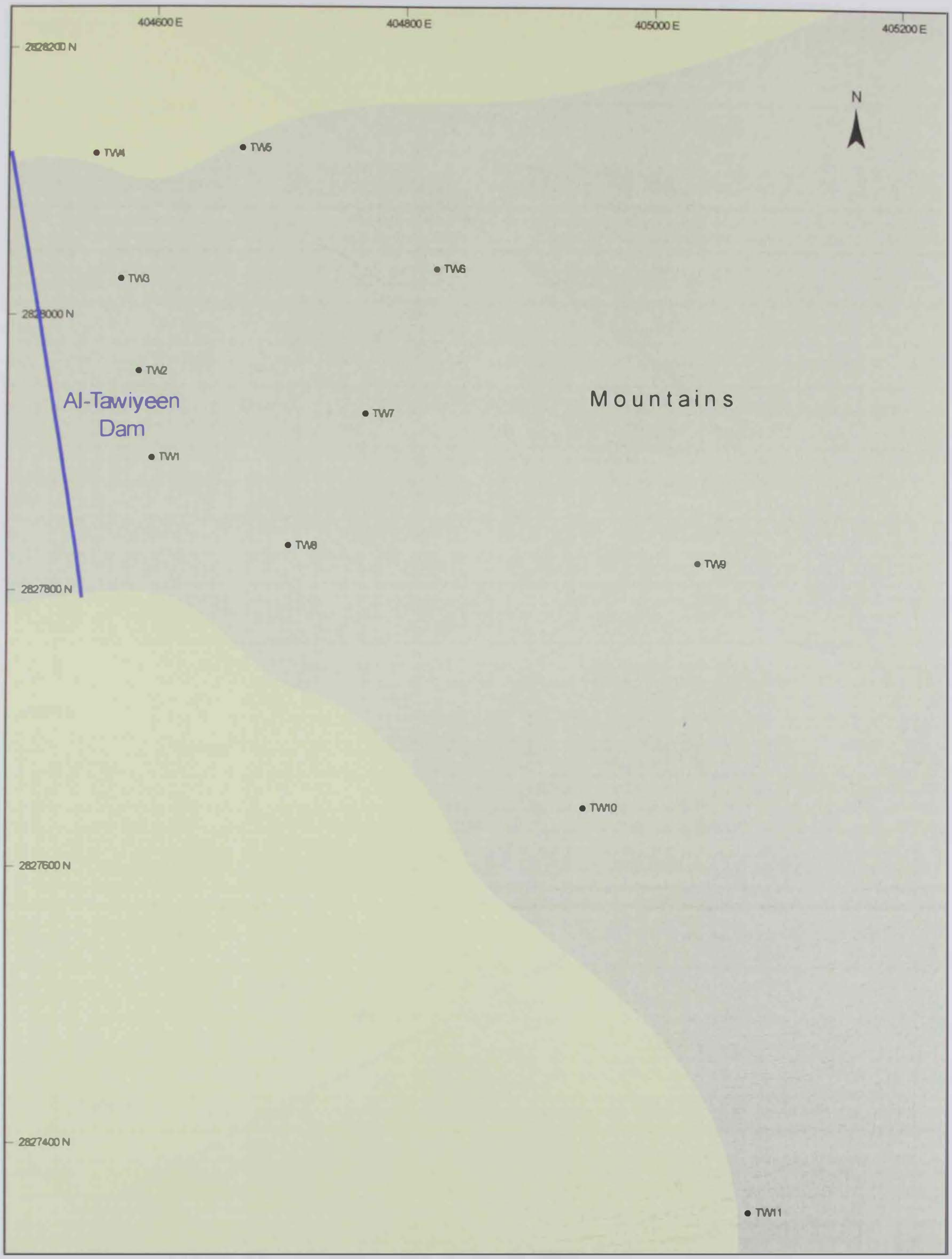


Figure 3.4. Location of the samples collected from Al-Tawiyeen dam.

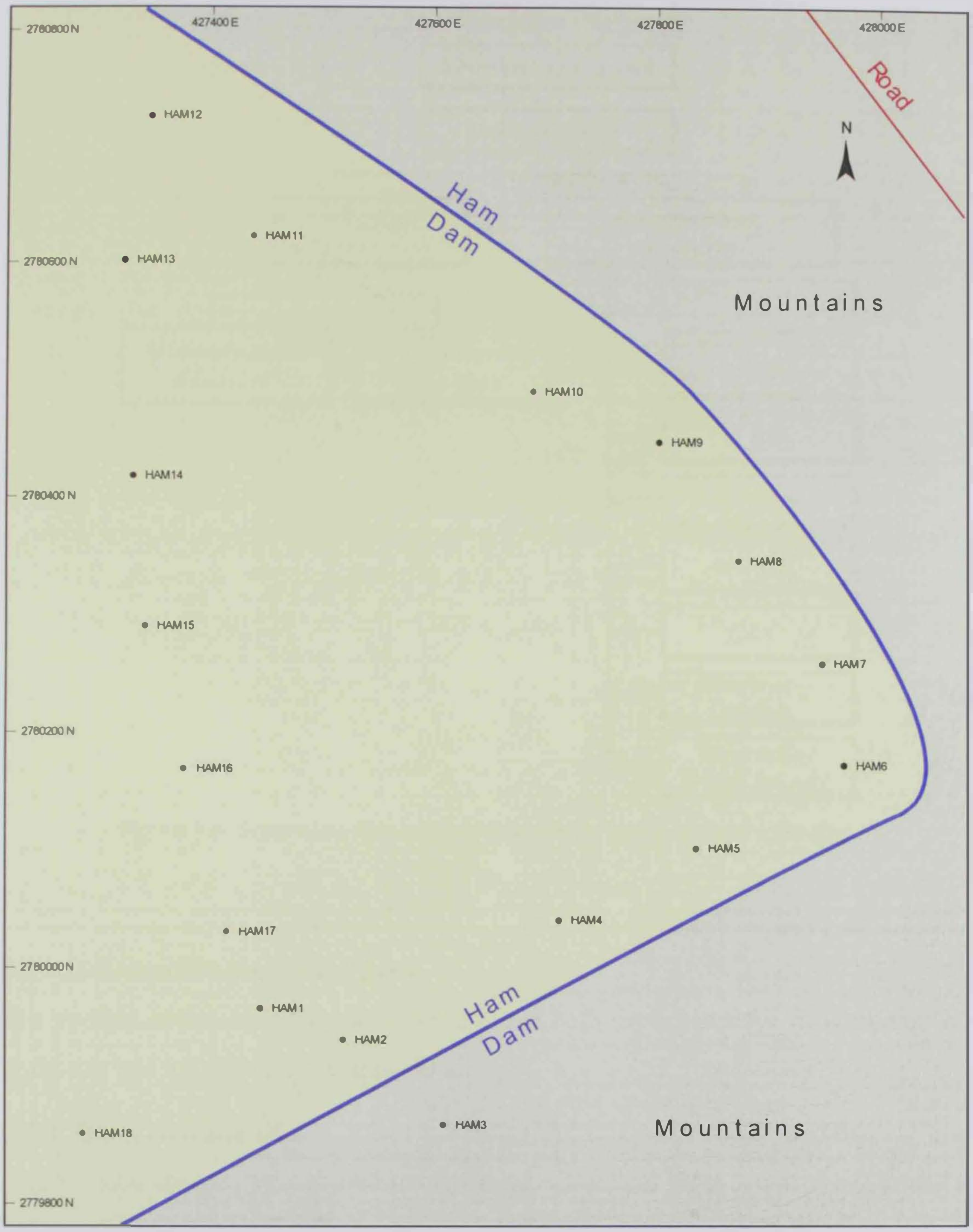


Figure 3.5. Location of the samples collected from Ham dam.

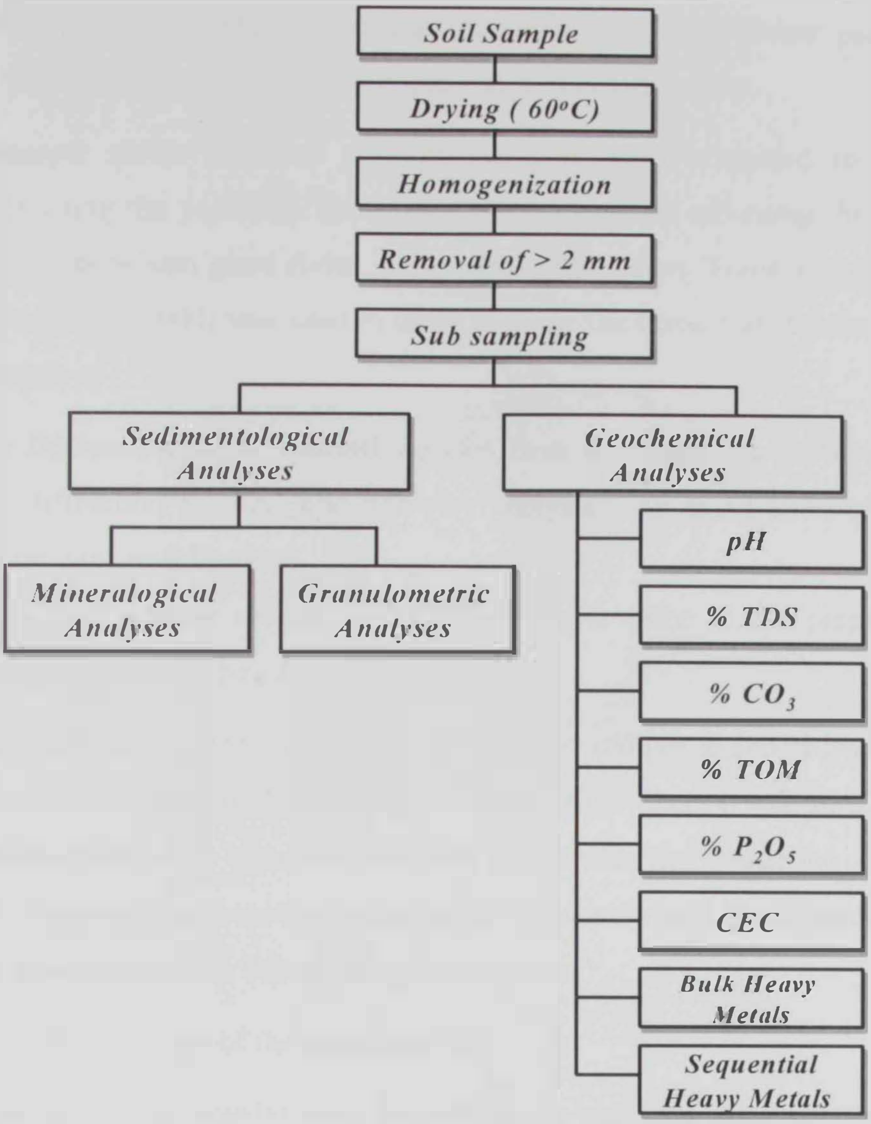


Figure 3.6. Schematic flow chart of procedures and analytical methods.

3.2. Sedimentological Analyses

The applied sedimentological analyses include both procedures for determining the grain size and mineralogical composition.

3.2.1. Grain size analysis

A grain size analysis was carried out by using a stainless steel standard sieve, and a sedimentation analysis for the separation of the <63 mm measurement of grain size within accuracy of the Wentworth grade scale down to silt grade. The weight of sediment retained on each sieve is measured and converted into a percentage of the total sediment sample.

3.2.2. Mineralogical analyses

The mineralogical assemblages, non-clay minerals, for the different particle size fractions were studied by using microscopic and X-Ray Diffraction.

I). Microscopic study: Selected sediment samples were examined for non-clay minerals by using the polarized transmitted microscope; by mounting the sand size gains on Canada balsam glass slides, before the examination. Transmission Electron Microscope (Nikon 3000) was used in order to show the texture of the clay minerals in the samples.

II). X-Ray Diffraction: Nine selected samples from the major Dams were analyzed by X-Ray Diffraction for clay and non-clay analysis. The preparation of non-clay samples were done as following:

1. Dry representative sample at 50ºC for 1 hour prior to the preparation of randomly oriented powder mounts.
2. Grind the dried sample thoroughly in a mortar and pestle and brush it through the sieve. The particles should be much finer than 0.062 mm to avoid fractionation of the minerals. The finer the powder, the greater the opportunity for obtaining an adequate number of particles with random orientation. Sieve the sample to ensure that grinding is complete.
3. Tape the open part of the sample holder.
4. Pour the excess powder onto the sample holder and distribute the powder evenly
5. Use a glass slide to pack sample into the cavity
6. The mounts are typically X-rayed between the angles of 2 and 60 degrees two theta using copper Kα radiation at a scanning rate to 1 degree 2θ per minute

Instrument parameters: A Philips X-ray diffractometer model PW/1840, with Ni filter, Cu-Kα radiation (λ=1.542A°) at 40 kV, 30 mA and scanning speed 0.02°/S will be used. The diffraction peaks between $2\theta=2°$ and $2\theta = 60°$ will be used in case of bulk samples. The corresponding spacing (dA°) and the relative intensities (I/I°) calculated and compared with the standard data.

The preparation of clay analysis was as following steps:

1. Drying (Soil samples are dried before they are ground and separated into various particle sizes.
2. Pre-treatments: The soil sample may require certain pre-treatments before they can be analyzed to remove undesirable coatings and cements, to improve the diffraction characteristics of the sample. These can be summarized into the following:
    a) Removal of soluble salts and carbonaceous materials: Dissolve the carbonates before the clay minerals can be identified. Use dilute acetic acid followed by hydrochloric acid to remove the carbonates because it less likely to affect clay crystallinity.
    b) Removal of organic matter by hydrogen peroxide: The presence of organics, which causes abroad hump on X-ray powder diffraction patterns, can obscure the diffraction maxima of mineral species. Treat the sample with dilute hydrogen peroxide (3%) to remove an organic matter.
3. Separation of silt and clay by decantation: Decantation is the gravity settling of particles in a suspension. For this technique, the coarse fraction (sand and gravel) has been removed and that the fine fraction (silt and clay) has been retained as a suspension. Disperse a muddy suspension and allow it to settle, withdraw the clay suspension from above 5 cm in depth at certain times and temperatures according to withdrawal time and depth tables (Folk, 1974).
4. Orientation of aggregate mounts: The separated clay fraction is mounted as an oriented aggregate mount for clay-mineral identification. The oriented aggregate mounts force the clay mineral particles, usually plate-shaped phyllosilicates, to lie flat, allowing the operator to direct the incident X-ray beam down the z axis of the minerals and to record the diagnostic basal diffractions. It is the z axis that shows the extent of d-spacing expansion and/or contraction indicative of certain clay minerals during subsequent treatments. These treatments include air drying, glycolation with ethylene glycol, heating to 550°C. Cut glass slides to fit the sample holder of the diffractometer prior to analysis.

5. Ethylene glycol treatment: Organic liquids, primarily ethylene glycol and glycerol, are extensively used as an auxiliary treatment to expand swelling clays. Whether or not a mineral expands and the amount of expansion can provide essential supplementary information aiding clay-mineral identification. Swelling clays include smectites (e.g. montmorillonite, nontronite, and beidellite), some mixed-layer clays, and vermiculite. Two methods are used: a vapor ethylene glycol treatment (place oriented aggregate mounts on the shelf of desiccators containing of ethylene glycol) and a rapid method (applying a drop of ethylene glycol directly to the surface of the oriented aggregate mount with glass rod. The advantage of the vapor treatment is less disturbance of the sample and less amorphous scattering of X-rays by excess liquid than in the case of the rapid method.
6. Heat treatments: Heat glass slides to temperature of 550°C prior to identification of clay minerals.

3.3. Geochemical Analyses

3.3.1. Determination of pH

In any aqueous solution, the pH is a measure of the hydrogen ion or proton activity. However in many if not most cases, pH is treated as the concentration of protons in solution rather than their activity. The soil solution is not different except that the measurement is more complex. The complexity arises from two sources. First, an electrical potential develops at all interfaces. In soil, there are interfaces between solids and solution and suspension, suspension and the electrode surface, and reference electrode and all these interfaces. Second the concept of activity is extremely important in soil. Protons or hydronium ions attached to exchange sites or other components in the system will not be measured as part of the solution composition. For these reasons, a standard method of measuring soil pH is chosen and all phenomena related to pH or involving pH is related to this "standardized" pH measurement. The most common method is to use a 1: 1 ratio of soil to water, typically 10 ml of distilled water and 10 g of soil. In this method, the soil and water are mixed and allowed to stand for 10 min, and the pH determined using a pH meter (Alfred, 2005).

3.3.2. Total dissolved solids content (TDS %)

The percentages of TDS content of sediments samples was calculated by weigh 20 g of 2-mm soil into a suitable shaking bottle and add 100 cm^3 of distilled water. Stopper the bottle and shake for 30 minutes, then allow standing for 15 minutes to let the bulk of sediment settle. Centrifuge and filter the supernatant liquid; centrifuging first will remove much of the suspended matte (Hesse, 1972). If the soil contains relatively little salt, it may be highly dispersed and difficult to clarify; such a membrane filter will help (Hesse, 1972). The determination of the TDS by the electrical conductivity methods was determined and double checked with the drying method given by ASTM, (1989), by dissolving 5 gm of soil in 50 ml water and filtrate it then dry it in the oven over night at 180^{o}C, the differences in the weight is the TDS value in ppm.

3.3.3. Total carbonate content (CO_3 %)

The principle of total carbon analysis is to convert the element completely into carbon dioxide which is then determined gravimetrically or volumetrically. Oxidation is achieved by combustion, either wet or dry, and all forms of carbon can be included. As inclusion of the inorganically bond carbon is seldom, if ever, desired, it is usual to determine carbonate and hydrogen carbonate separately or to destroy them with acids before combustion of the sediment samples as suggested by Hesse, (1972). Weight 5 gm of sediments (<63mm) and add a concentrated HCl until the reaction will stop completely, let it dry and weight it again and calculate the differences.

3.3.4. Total organic matter content (TOM %)

The principle of determining total organic matter by weight loss in simple; the organic matter in a weighed quantity of sediment is destroyed in high temperature 550°C, the sample re-weighted and the loss in weight represents the organic matter (Hesse,1972). By following the procedure of the method suggested by Hesse, weight 10 gm of sediments sample in non-weight of crucible and add it in high temperature oven 550^{o}C for over night, and cool it, then re-weight the dried sample again and calculate the differences in the weight.

3.3.5. Total phosphate (P_2O_5%)

The percentage of the phosphorus content was determined by digest 1 g of sediments with perchloric acid, during the evaporation of the digest there is no need to drive off completely the perchloric acid; take up the filtrated digest in dilute hydrochloric acid and dilute it to 1 ml, and analyze the aliquots of digest for phosphorus by ICP-OES instrument (Hesse, 1972).

3.3.6. Bulk metals chemical analysis

The digestion procedure (Hesse, 1972), weight 0.2 g of the sediment sample in 100 ml polyethylene bottle. Then add 4 ml of (25%) HCl, 4 ml of (25%) HNO_3 and 2 ml of concentrated HF and place the bottles in the water bath (70°C) for 2 hours. After that add 50 ml of Boric acid (39 g of Boric acid in 1L distillated water); and 40 ml of distilled water. Re-place the bottles in water bath to let the solution to be clear. Analyze the solution in ICP-OES (Thermo Elemental IRIS Intrepid), and determine the value of (Al, Fe, Cu, Zn, Pb, Cd and Cr).

3.3.7. Cation exchange capacity (CEC)

Cation exchange capacity of the sediments samples were determined using method suggested by Hesse (1972); weigh 5g of 2-mm soil into a $50cm^3$ centrifuge tube, add 30 cm^3 of sodium acetate solution (1.0M: $136gdm^{-3}$ sodium acetate trithydrate and adjusted to pH 8.2), and shake it for 5 minutes. The tubes should be stoppered with polythene or clean rubber stoppers and not corks, which introduce errors, centrifuge the tubes 200 rev/s for about 5 minutes until the supernatant liquid is clear. Decant and discard the liquid and repeat the shaking and centrifuging four times more with fresh potions of acetate solutions. Shake the soil with 30 cm^3 of 95% ethanol for 5 minutes, centrifuge and discard the liquid. Repeat the ethanol washing three times. Finally extract the soil three times with 30 cm^3 potions of ammonium acetate solutions (1.0 M: add $57cm^3$ glacial acetic acid and 68 cm^3 strong ammonium hydroxide to 800 cm^3 of water. Dilute to one dm^3 and adjust to pH 7.0); and collect the extracts in a 100 cm^3 graduated flask.

Occasionally it is necessary to filter the extracts after centrifuging. Dilute the combined extracts to 100 cm^3 and determine the sodium content, preferably by using Atomic Absorption Spectroscopy (AAS)-Thermo, and used the following equation (3.1), to calculate the value of CEC/100 g.

$$\text{CEC. M.e./100 g soil} = \frac{10 \times Na\,concentration\ in\,m.e.dm^{-3}}{weight\ of\ sampl} \quad \ldots\ldots\ldots\ldots\ldots \quad \text{Eq. (3.1)}$$

3.3.8. Sequential heavy metals analysis (Chemical speciation)

Many sequential extraction schemes are modifications stemming procedure developed by (Tessier, et all, 1979). This procedure was originally developed for the examination of aquatic sediments but gained wide acceptance as tools for the speciation of metals in soils (Kirk, et al., 2003).

Sequential Extractions procedure described by Tessier, et al, (1979), was employed with slight modifications and applied on five samples from each dam.

Fraction (1) -Exchangeable: The samples were extracted at room temperature for 1 h with 8 ml of magnesium chloride solution (1 M $MgCl_2$, pH 7.0) with continuous agitation.

Fraction (2) -Bound to Carbonates: The residue from Fraction (1) was leached at room temperature with 8 ml of 1 M NaOAc adjusted to pH 5.0 with acetic acid (HOAc). Continuous agitation was maintained and the time necessary for complete extraction was evaluated based on Pb carbonate prior to experimental trials and was determined to be 3 hours.

Fraction (3) -Bound to Iron, Manganese Oxides: The residue from Fraction (2) was extracted with 20 ml of 0.04 M $NH_2OH.HCl$ in 25% (v/v) HOAc. This fraction experiment was performed at 96$\pm$3°C with occasional agitation for 6 hours.

Fraction (4) -Bound to Organic Matter: The residue from Fraction (3), 20 ml of 7 M NaOCl (adjusted to pH 8.5 with HCl) was added, and the mixture was heated to 90$\pm$2°C for 2 hours with occasional agitation. After centrifuge separation, a second 20 ml aliquot of NaOCl (adjusted to pH 8.5) with HCl) was then added and the samples was heated to 90$\pm$2°C for 2 hours with intermittent agitation.

Fraction (5)-Residual: The residue from Fraction (4) was digested with concentrated HNO_3 in a microwave digester according to EPA method 3051; 0.5 g of the residue is digested in 10 ml of concentrated HNO_3 for 10 min using microwave heating with a suitable laboratory microwave unit. The sample and acid are placed in a fluorocarbon (PFA or TFM) microwave vessel. The vessel is capped and heated in the microwave unit. After cooling, the vessel contents are filtered and centrifuged, or alloed to settle and then diluted to volume and analyzed by the appropriate SW-846 method (Keith, 1996). After the prescribed time interval for each extraction (Fraction 1-4), samples were supernatant filtered through a 0.45 μm filter. The remaining solid samples were washed twice with Millipore DI water before continuing with the next extraction step. For fraction 5, the final dilution was filtered through a 0.45 μm filter and stored at 4°C. Once an entire, sequential extraction replication was completed, the samples were analyzed for (Al, Fe, Cr, Cd, Pb, Cu and Zn) by Inductive Coupled Plasma Spectrometry (ICP-OES) according to EPA Method 6010B (Keith, 1996).

3.4. Statistical Treatment of Data

The statistical treatments and graphical presentations of the obtained data are conducted by means of Excel (Microsoft office 2003, windows xp). The correlation matrixes of the obtained data of the chemical and controlling parameters by JUMPIN software, the differences of variance (ANOVA) by SPSS.

CHAPTER FOUR

SEDIMENTOLOGCAL ANALYSES OF THE STUDIED DAMS

4. SEDIMENTOLOGCAL ANALYSES OF THE STUDIED DAMS

The main purpose of sedimentologcal analyses is to determine and understand their grain size characteristics, textural and mineralogical properties. This information is essential for the assessment of depositional environment and the determination of some petrophysical and geotechnical characteristics.

4.1. Grain size Analysis

Grain size analysis, also known as particle-size analysis or granulometric analysis, is perhaps the most basic sedimentological technique to characterize and interpret sediments and sedimentary rocks. The purpose of this analysis is to determinete the respective quantity of different elements composing sediments such as gravels, sands, muds, and clays or silt and product of the mode of transportation by rolling, salutation and suspension, and indicative of the distance of transportation; the finer the size, the greater the distance (Howari, et al., 2007). Depict the grain size distribution as a grain size histogram provides a brief description of the shape of the sediments samples (Hyperbrick, 2006).

4.1.1. Textural Analyses

A total numbers of eighteen selected samples collected from the studied dams were subjected to grain size analysis, and the textural classes of the samples are tabulated in Table (4.1). In addition, the average of grain size distributions for the studied areas were represented as histograms. A ternary diagram with a gravel-sand-mud classification triangle by Folk (1974) shown in Figure (4.1), was used to classify and visualize the sediment samples of each dam, and the results were plotted in Figure (4.2), as well as in Appendices (III-1- III-4). From Table (4.1) generally, it can be deduced that most samples can be described as sandy gravel to gravely sand to a lesser extent muddy sand. According to the values listed in Table (4.1), the sediment samples collected from Al-Shuweib dam can be classified as gravely sand, silty sand and sandy gravel, whereas, selected sediments samples from Al-Bih dam characterized by sandy silt, sandy gravel and silty sand. Al-Tawiyeen and Ham dams selected sediments samples are classified as silty sand and gravelly sand respectively.

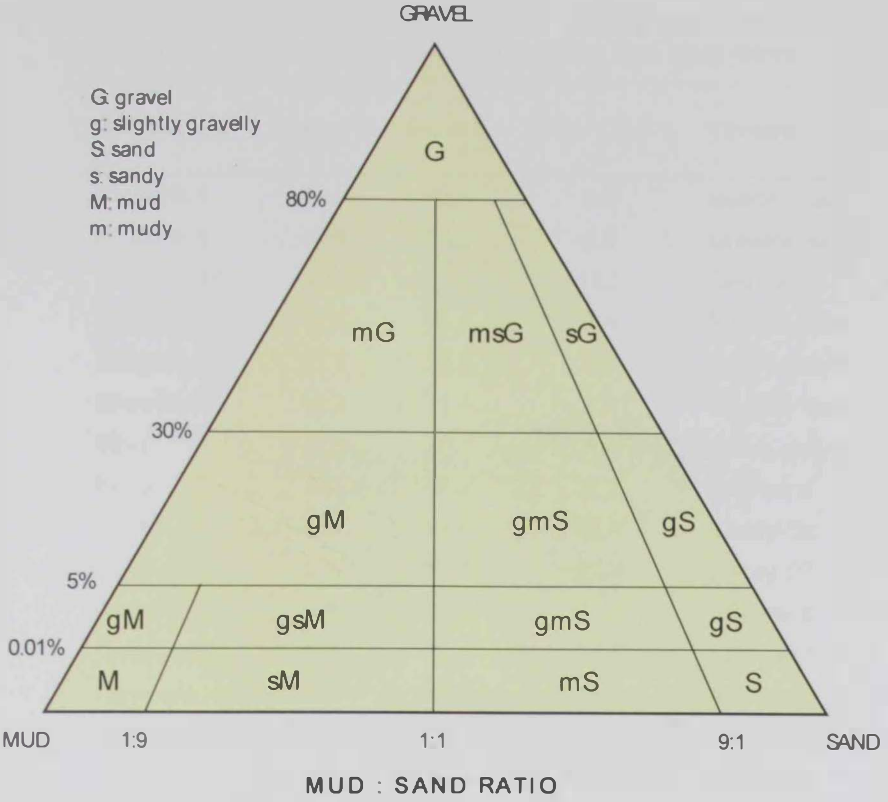


Figure 4.1. Textural Classification Triangle of the sediments samples according to grain size distribution (Folk, 1974).

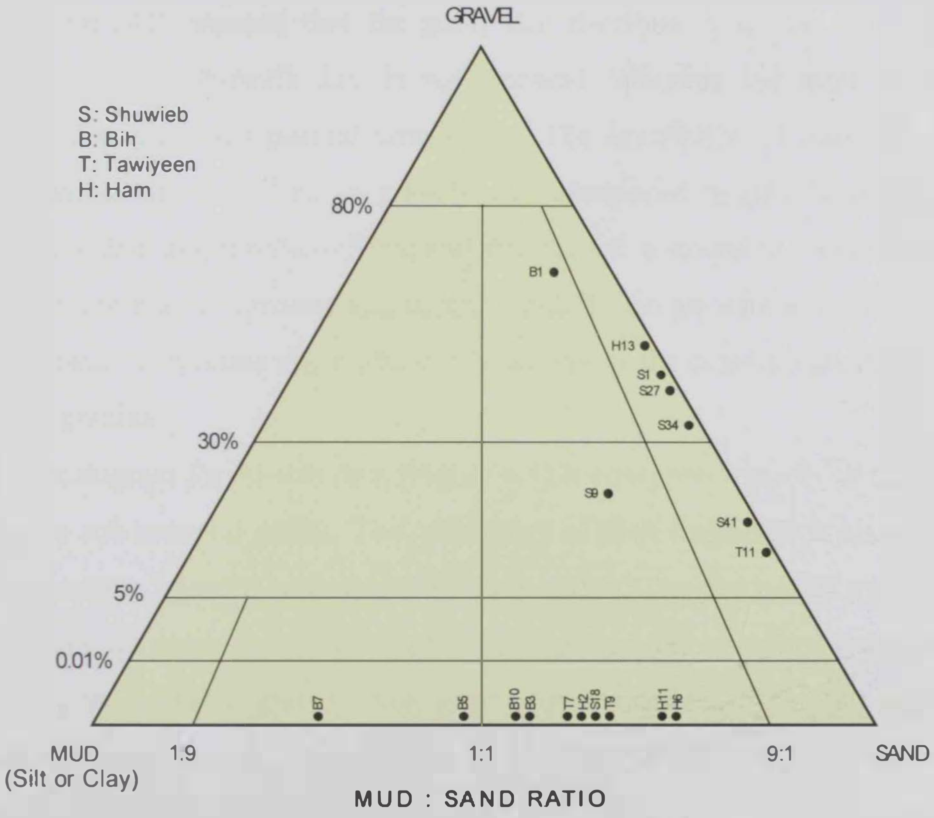


Figure 4.2. Plotted histogram showing the textural classification of the sediment samples of Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams.

Table 4 1 Textual analyses values in percentage of gravel, sand and mud for the selected samples from Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams.

Samples No	Gravel %	Sand %	Silt or Clay %	Texture
Shuweib-1	37.0	62.4	0.6	Sandy Gravel
Shuweib-9	19.9	70.2	9.8	Gravelly sand
Shuweib-18	0.0	80.8	19.2	Silty sand
Shuweib-27	36.5	61.0	2.4	Sandy gravel
Shuweib-34	30.1	66.5	3.3	Sandy gravel
Shuweib-41	16.2	81.4	2.4	Gravelly sand
Bih-1	70.6	25.1	4.3	Sandy gravel
Bih-3	0.0	72.2	27.8	Silty sand
Bih-5	0.0	17.6	82.4	Sandy Silt
Bih-7	0.0	17.6	82.4	Sandy Silt
Bih-10	0.0	68.5	31.5	Silty sand
Tawiyeen-7	0.0	78.2	21.8	Silty sand
Tawiyeen -9	0.0	82.4	17.6	Silty sand
Tawiyeen -11	12.0	86.8	1.3	Gravelly sand
Ham-2	0.0	79.8	20.2	Silty sand
Ham-6	0.0	86.3	13.7	Silty sand
Ham-11	0.0	86.0	14.0	Silty sand
Ham-13	45.6	50.2	4.2	Sand gravel

Figure (4.3) showed that the grain size distribution for the different samples obtained from Al-Shuweib dam is not identical. Whereas, the most of the samples followed skewed to not normal distribution. The description of insoluble residue for these samples are very fine to gravely size composed mainly of quartz, which is mostly abundant about 65% to 85%, and showed sub rounded to rounded grains. Rock fragments are mainly igneous and metamorphic in origin with abundance of 10% to 30%. Gypsum consistute about 5% and is present as the cement materals between the different granins.

The histogram for Al-Bih dam (Figure 4.4) is composed mainly of quartz with sub angular to sub rounded grains. The percentage of rock fragments is about 50% where they are mainly igneous and metamorphic in origin. The percent of gypsum found to be in form of cement is about 30%. The rest of the samples were also similar exhibiting very fine to gravely size, grey color, composed 50%, sub angular to sub rounded grains of quartz, 40% gypsum in form of cement and grains about 40% and approximately 10% marl.

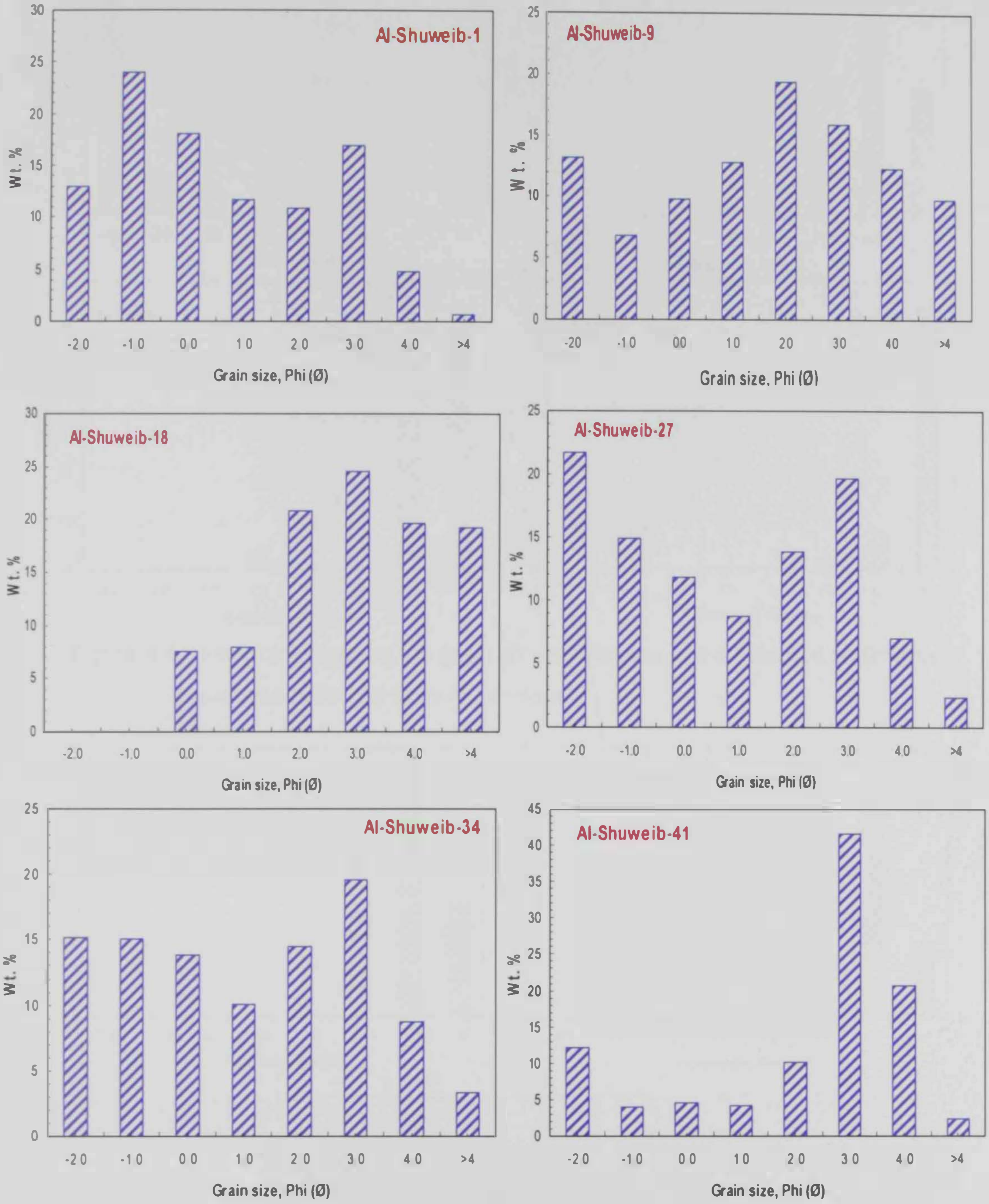


Figure 4.3. Histogram showing the grain size distribution of the selected sediment samples collected from Al-Shuweib dam.

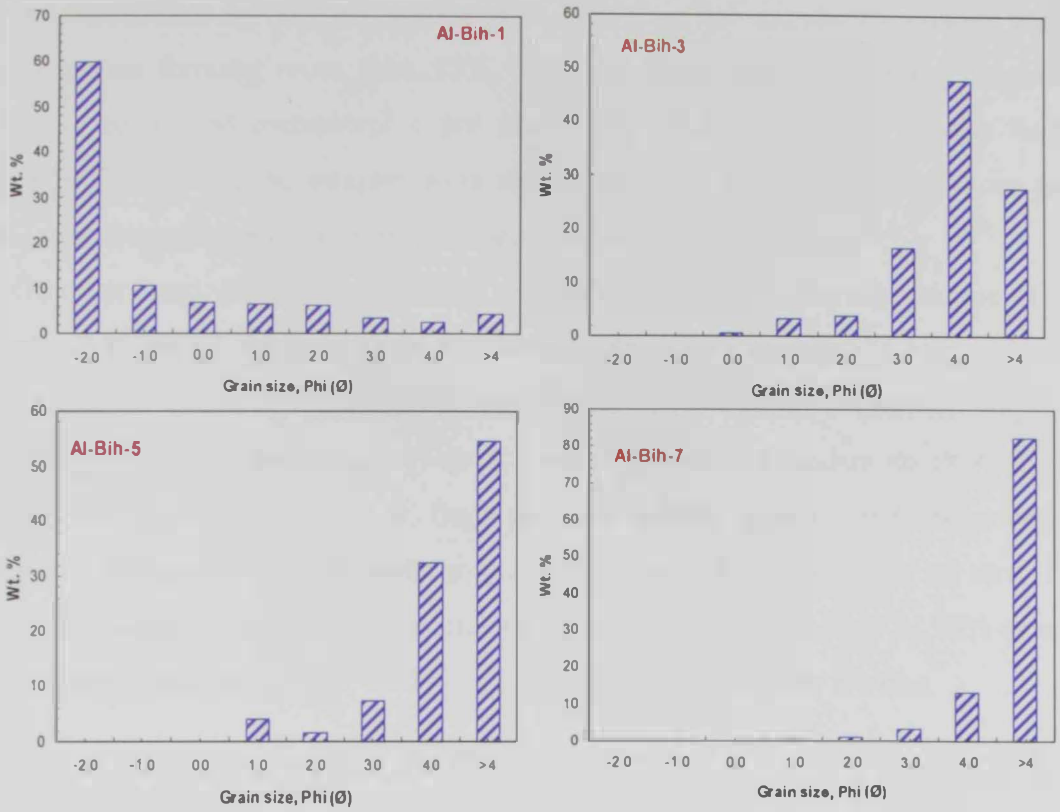


Figure 4.4. Histogram showing the grain size distribution of the selected sediments samples collected from Al-Bih dam.

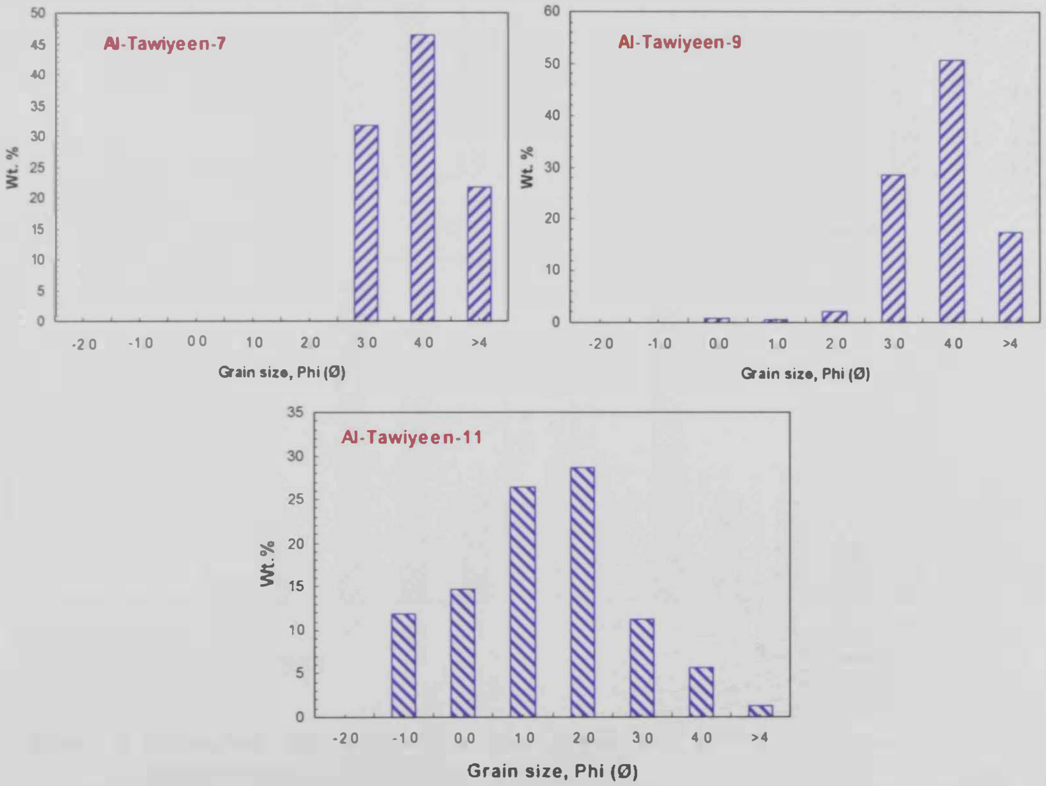


Figure 4.5. Histogram showing the grain size distribution of the selected sediment samples collected from Al-Tawiyeen dam.

In Al-Tawiyeen dam (Fig. 4.5), the grain size distribution followed skewed and normal distribution mode. The samples were dark grey, sub angular to rounded grains quartz grains forming more than 85%, feldspars form about 8%, rock fragments mainly igneous and metamorphic are about 5%, while the rest is opaque heavy minerals. The rest of the samples were clay or silt size, quartz grains are more than 95%, rock fragments are about 3% and heavy minerals are very rare.

On other hand, Ham dam histogram showed that the grain size distribution of the samples 2, 6 and 13 follow skewed distribution and sample number 11 follow normal distribution as shown in Figure (4.6). These samples were yellowish brown, very fine to gravely size composed mainly of quartz, which is mostly abundant about 95%, sub angular to rounded grains. Rock fragments are mainly igneous and metamorphic about 2%, feldspars about 2% while gypsum and opaque heavy minerals are rare. The rest of the samples were grey color, clay or silt size composed mainly of 98% quartz, sub angular to rounded grains, while gypsum and opaque minerals are rare.

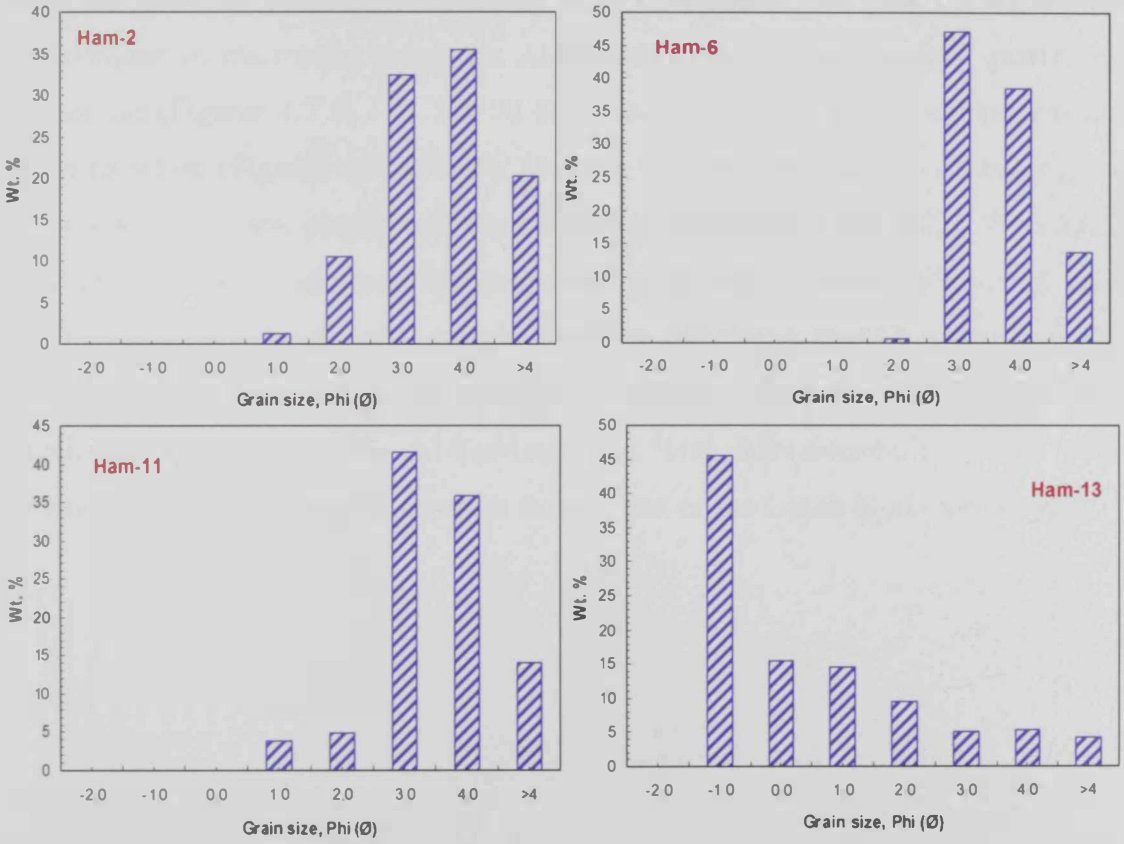


Figure 4.6. Histogram showing the grain size distribution of the selected sediments samples collected from Ham dam.

4.2. Mineralogical Analyses

Clay minerals are an important group of minerals because they are among the most common products of chemical weathering, and thus are the main constituents of the fine-grained sedimentary rocks (mudstones, claystones, and shales). Generally, the clay minerals occur as such small mineral grains that they cannot be easily distinguished in either hand specimen or thin section. X-ray techniques, are thus usually required to identify the clay minerals (Stephen, 2006).

4.2.1. Microscopic study

The microscopic examination of the sediments particles of various grain sizes, using the microscope suggests a rather limited effect of chemical weathering. The mineral composition of the sediments particles reflects their derivation from different sources, including; igneous and metamorphic rocks. The relative abundance of these clastics varies from one place to another, depending on the prevailing source rocks in the hinterland. Microphotographs of normal and polarized light microscope were used to study the non-clay minerals in sand-size fraction of major four dam's samples. The observations of microphotograph for Al-Shuweib dam showed calcite, quartz, and plagioclase (Figures 4.7 & 4.8). For Al-Bih dam, it observed quartz, calcite, gypsum and plagioclase (Figures 4.9 & 4.10). Moreover, in Al-Tawiyeen dam tabular grain, subrounded grain and plagioclase were observed (Figures 4.11 & 4.12). Whereas in Ham dam calcite, plagioclase, and iron oxid grain were observed (Figures 4.13 & 4.14). The collected sediments samples, without exception, contain quartz that may point to the important role of the aeolian transportation from the surrounding desert. Aeolian sediments in Al-Bih, Al-Tawiyeen and Ham dams accumulate in the wadis between the high and rough mountains that are part of the Oman Mountain range.

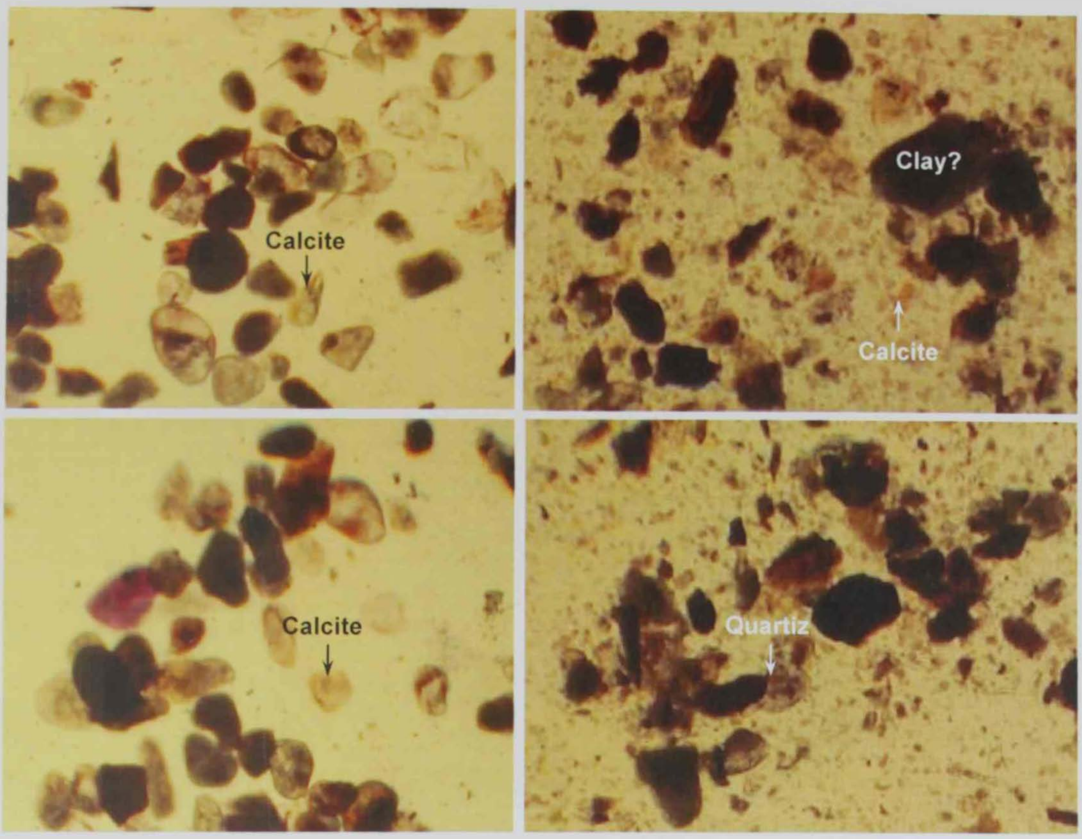


Figure 4.7. Microphotograph with normal light showing calcite grain, quartz and some clay mineral grain in Al- Shuweib dam – (x–25).

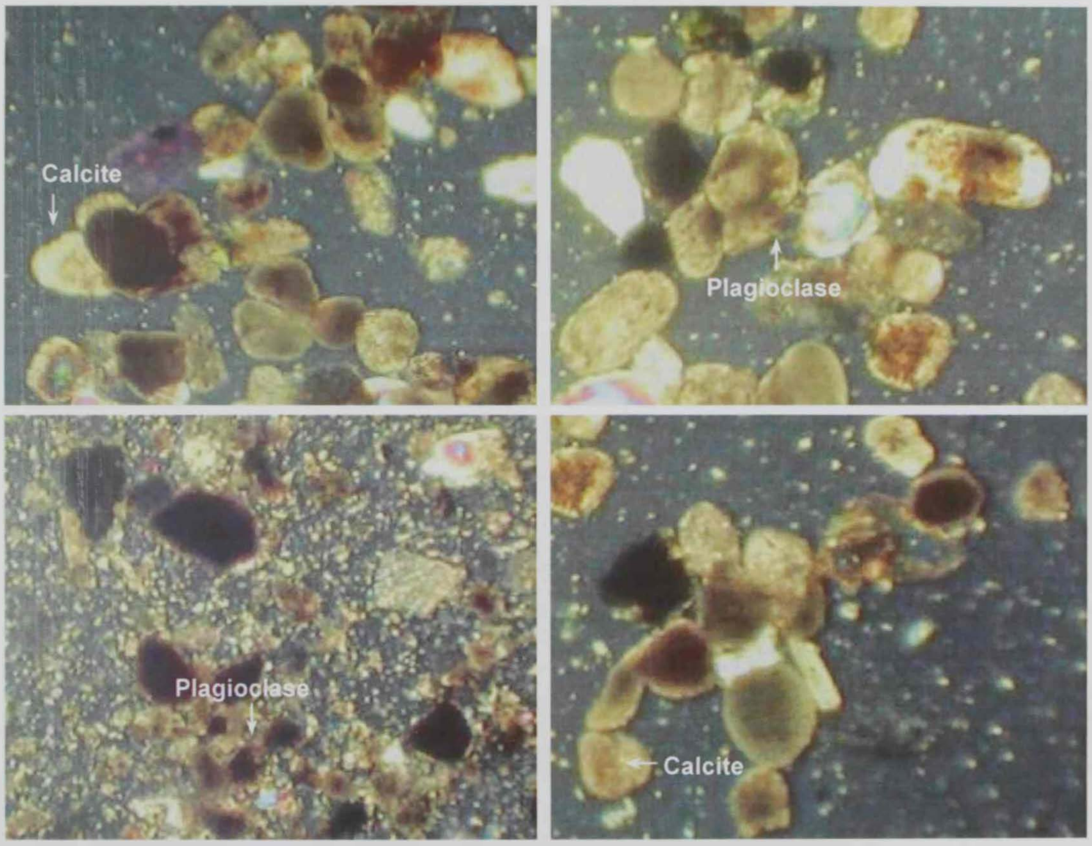


Figure 4.8. Microphotograph with polarized light showing calcite and plagioclase grain in Al-Shuweib dam – (x–25).

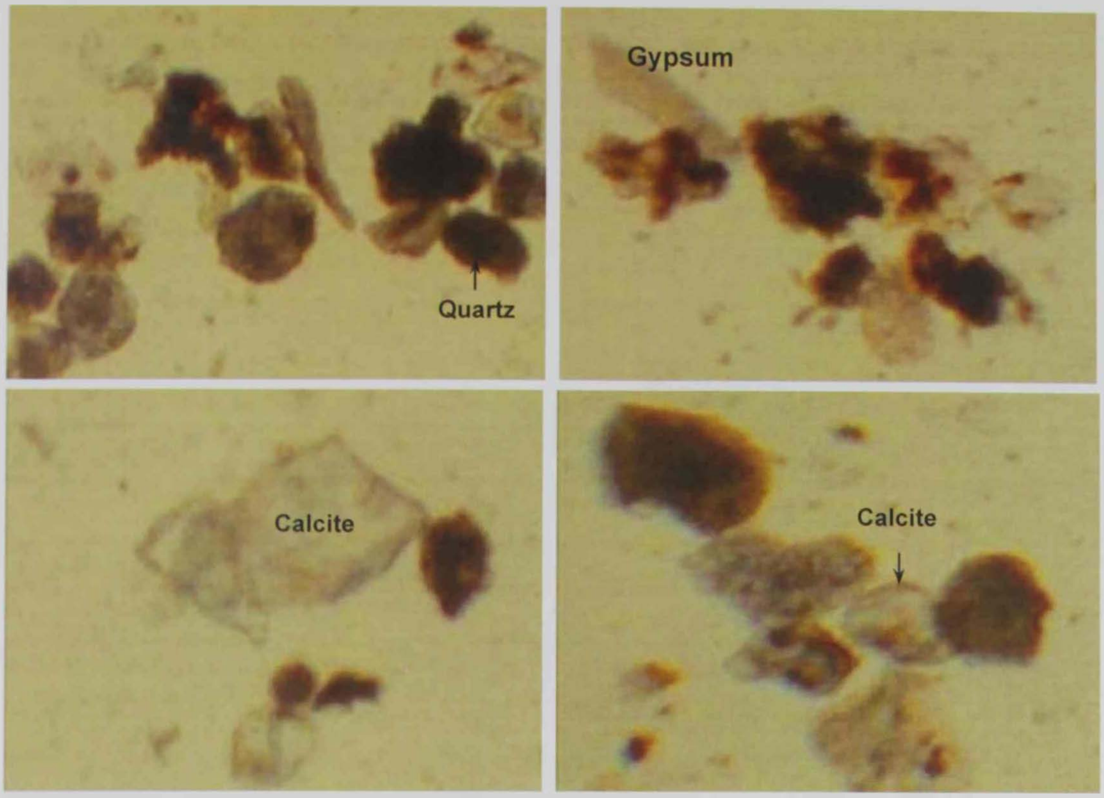


Figure 4.9. Microphotograph with normal light showing rectangular shape of calcite grain, quartz, and gypsum in Al-Bih dam – (x–25).

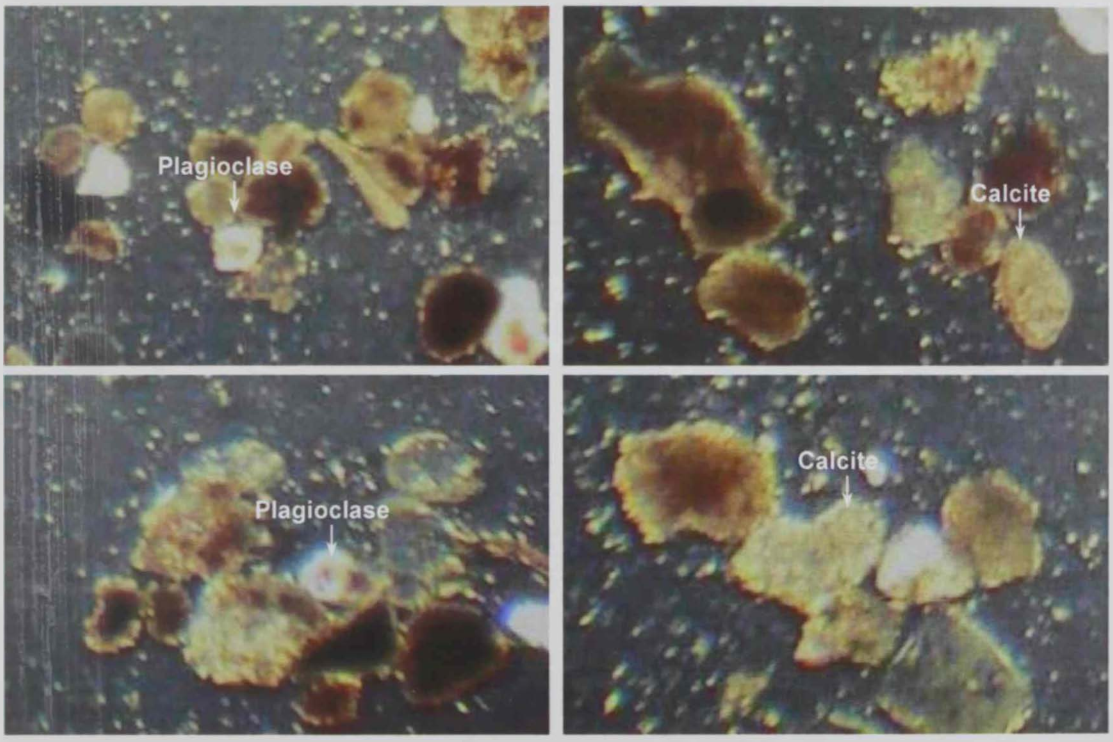


Figure 4.10. Microphotograph with polarized light showing calcite and palogiclase in Al-Bih dam (x–25).

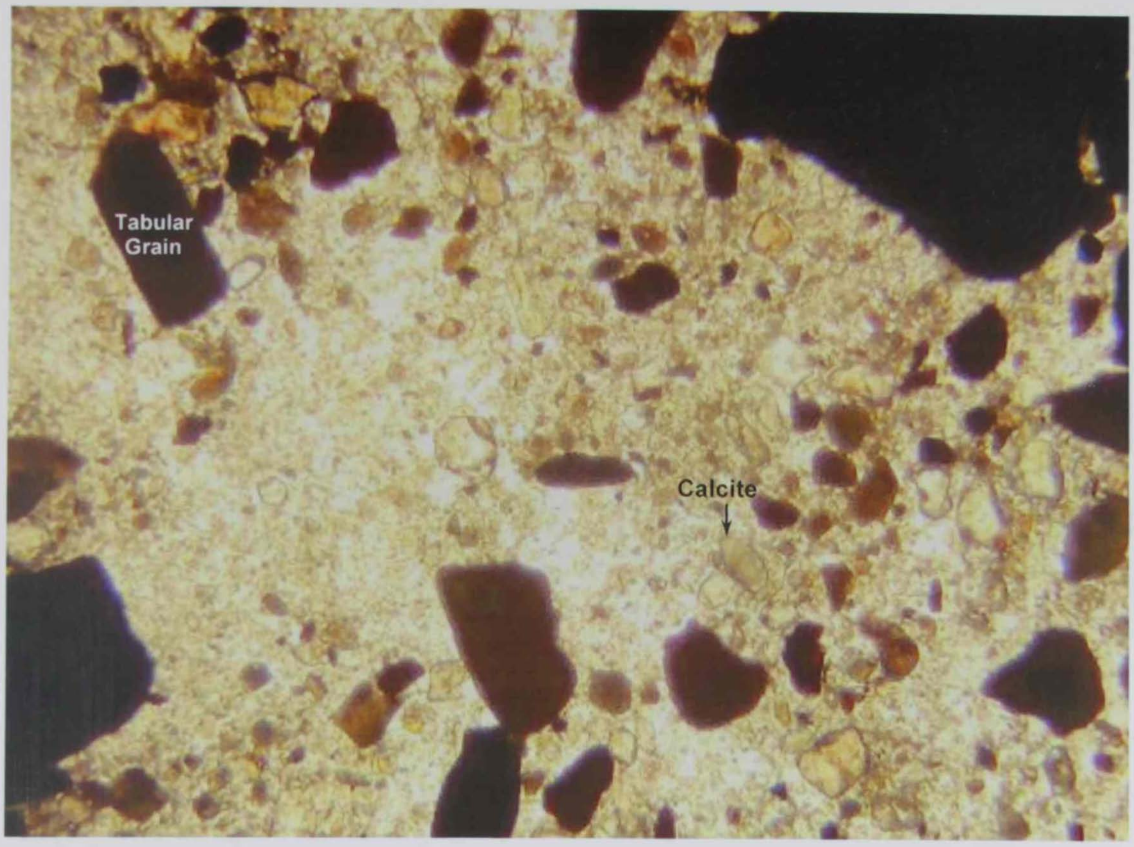


Figure 4 11. Microphotograph with normal light showing tabular grain and calcite grain in Al-Tawiyeen dam – (x–25).

Figure 4.12. Microphotograph with polarized light showing plagioclase grain in Al-Tawiyeen dam (x–25).

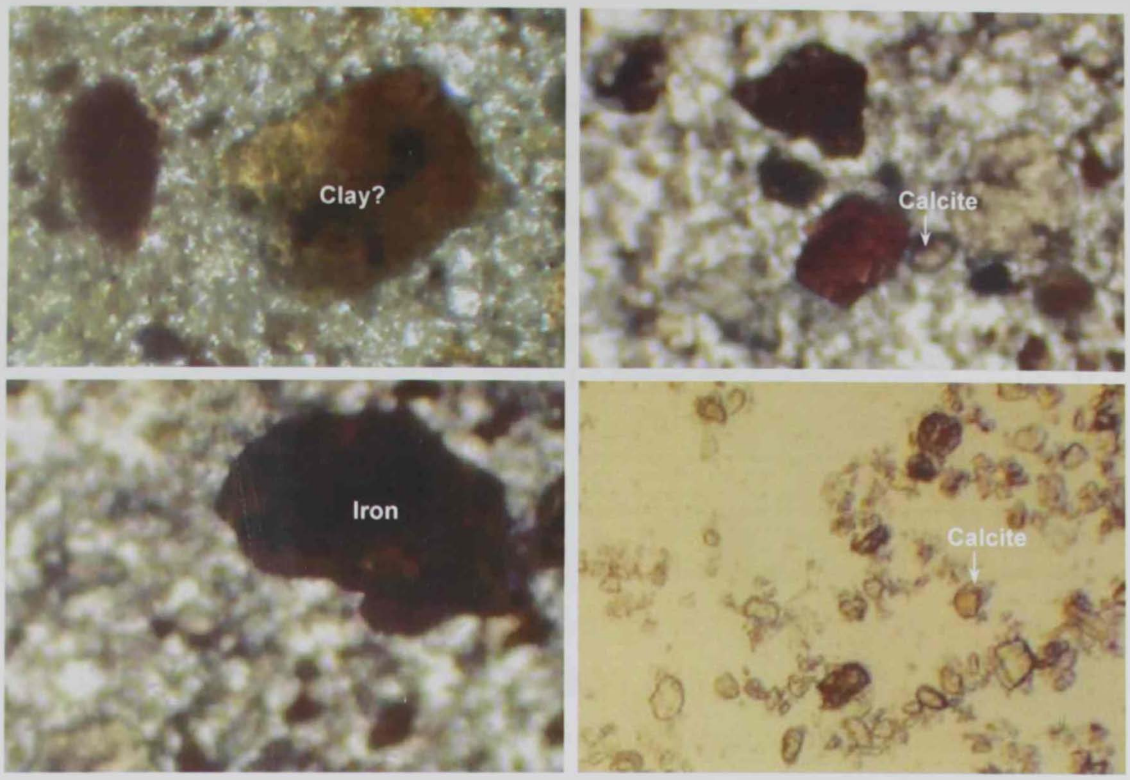


Figure 4.13. Microphotograph with normal light showing iron and calcite grain in Ham dam – (x–25).

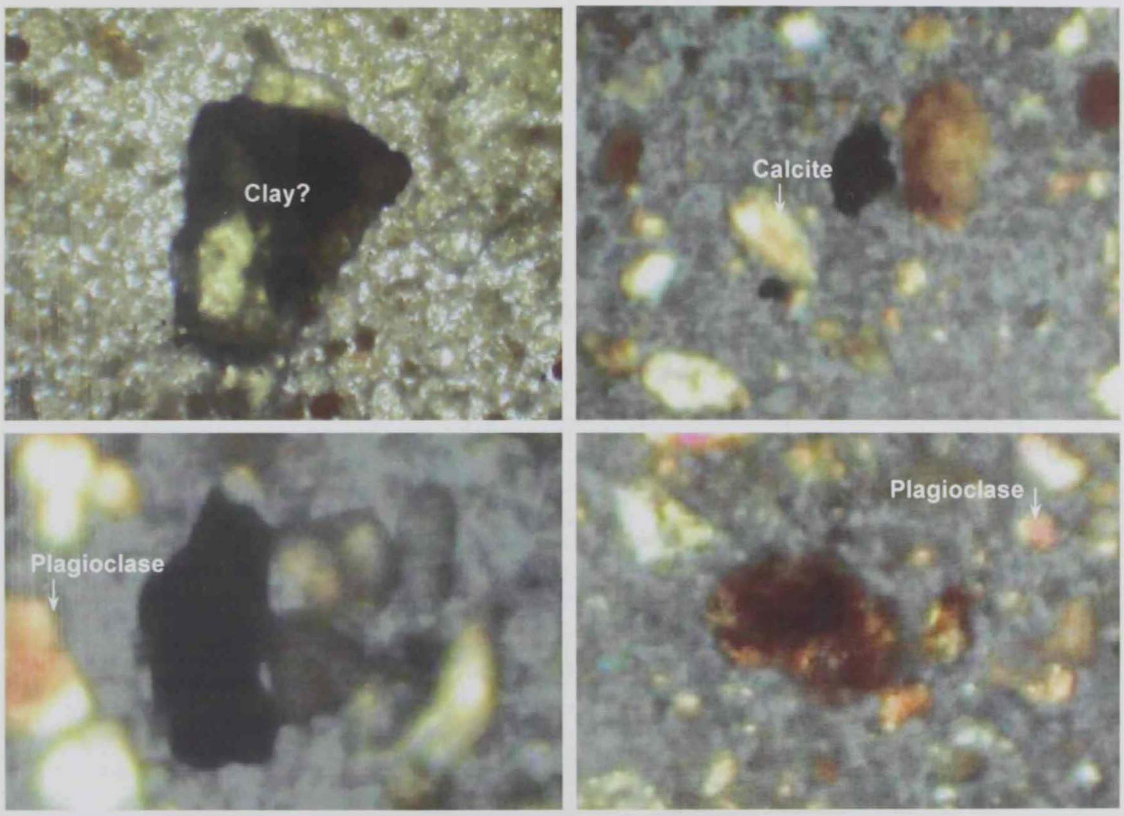


Figure 4.14. Microphotograph with polarized light showing grain in Ham dam – (x–25).

4.2.2. X-ray diffraction analysis

X-ray powder diffraction analysis is the best available technique for the identification and quantification of all minerals present in the sediments. X-rays of a known wavelength are passed through a sample in order to identify the crystal structure. The wave nature of the X-rays means that they are diffracted by the lattice of the crystal to give a unique pattern of peaks of 'reflections' at differing angles of different intensity, just as light can be diffracted by a grating of suitably spaced lines (Brindley, 1980; Reynolds, 1989; Snyder and Bish, 1989; McManus, 1991; Moore and Reynolds, 1997 and Jan Środoń, 2001).

X-Ray diffraction for clay minerals: The identification of clay minerals in the clay size (<2μm) of the total number of nine sediment samples collected from the studied area by X-ray diffraction instrument showed the extent of d-spacing expansion and contraction indicative of certain clay minerals during subsequent treatments. These treatments include air-drying, glycolation with ethylene glycol and heating to 550°C. The relative abundance of clay minerals was determined in account of the height and width of the basel reflection (Brown, 1961 and Reynolds, 1989).

Table (4.2) identifies clay minerals in Al-Shuweib, Al-Bih and Al-Tawiyeen dams and showed similar distribution with the same clay minerals (Figures 4.15, 4.16 & 4.17). The minerals identified assemblage of quartz as major mineral, Illite as subordinate mineral and chlorite as minor mineral. Whereas, in Ham dam (Figure 4.18), Illite showed as major mineral, quartz as subordinate and chlorite remains as minor mineral in collected sediment samples.

Table 4.2. The identified mineral composition of selected samples as detected from the X-ray diffractograms for clay size fraction arranged according to their decreasing abundance.

Samples No.	Major Mineral(s)	Subordinate Mineral(s)	Minor Mineral(s)
Shuweib-3	Quartz	Illite	Chlorite
Bih-10	Quartz	Illite	Chlorite
Tawiyeen-7	Quartz	Illite	Chlorite
Tawiyeen -9	Quartz	Illite	Chlorite
Tawiyeen -11	Quartz	Illite	Chlorite
Ham-2	Illite	Quartz	Chlorite
Ham-6	Illite	Quartz	Chlorite
Ham-11	Illite	Quartz	Chlorite
Ham-13	Illite	Quartz	Chlorite

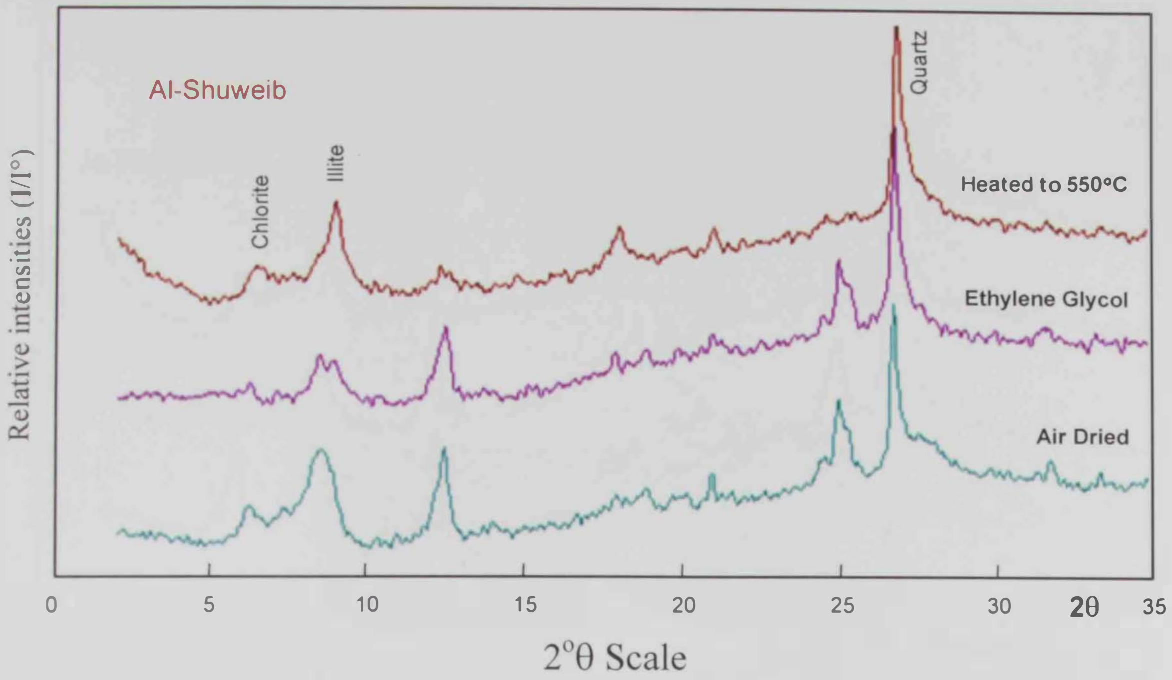


Figure 4.15. X-ray diffraction pattern of clay size fractional minerals of the selected sample from Al-Shuweib dam.

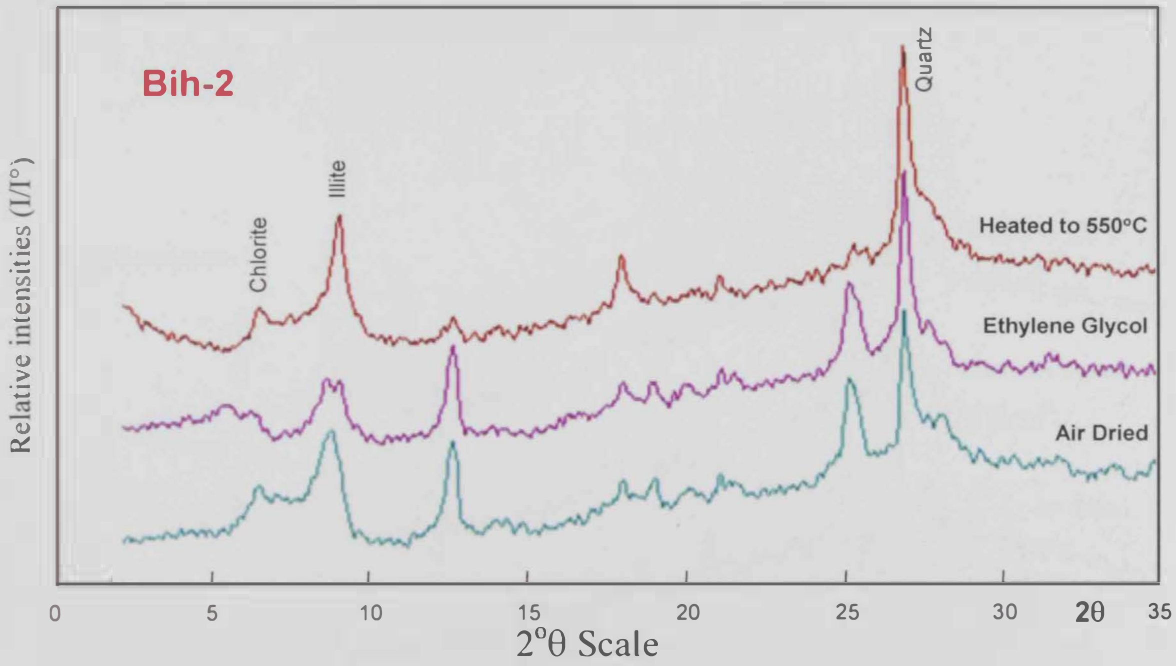


Figure 4.16. X-ray diffraction pattern of clay size fractional minerals of the selected sample from Al-Bih dam.

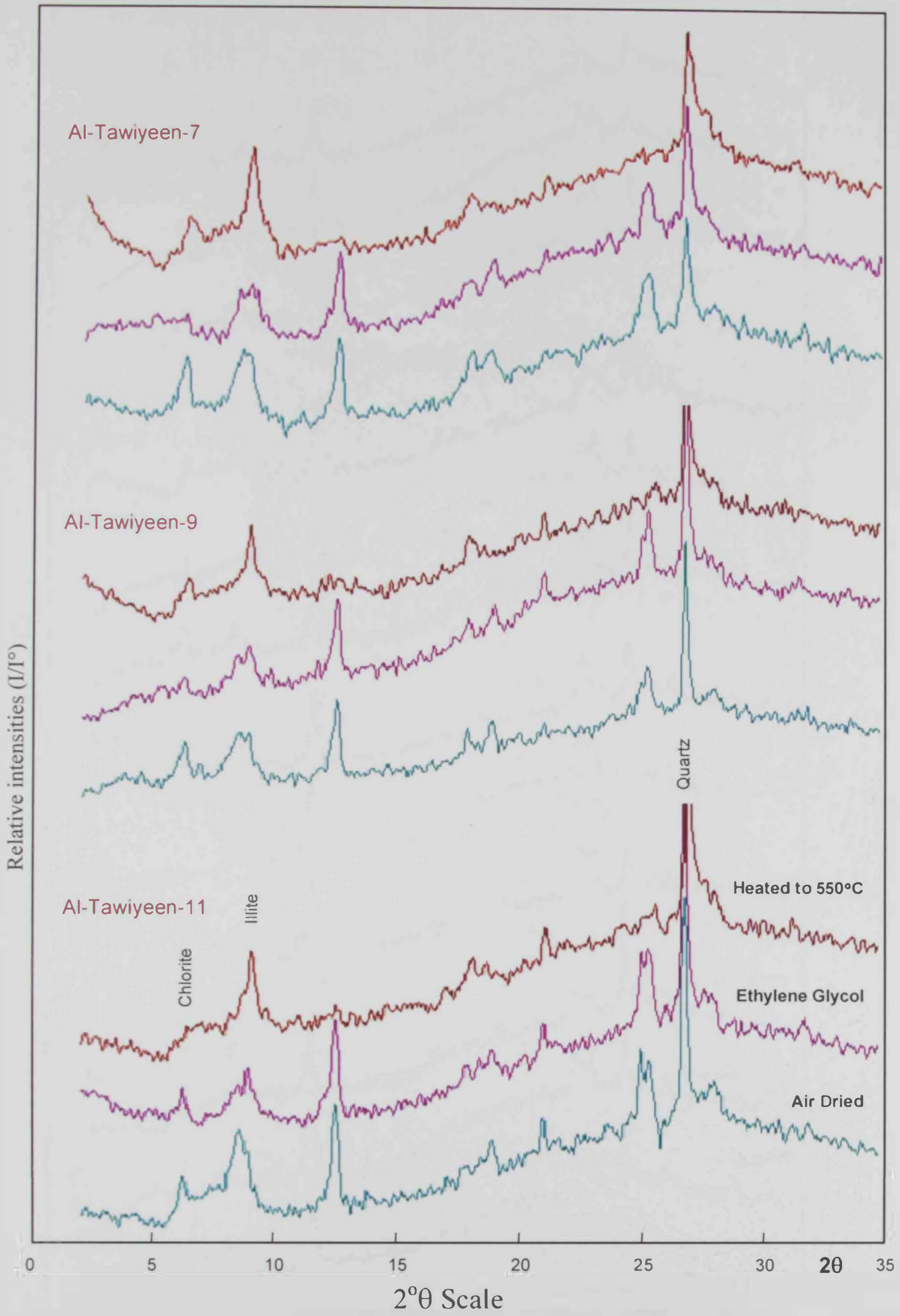


Figure 4.17. X-ray diffraction pattern of clay size fractional minerals of the selected samples from Al-Tawiyeen dam.

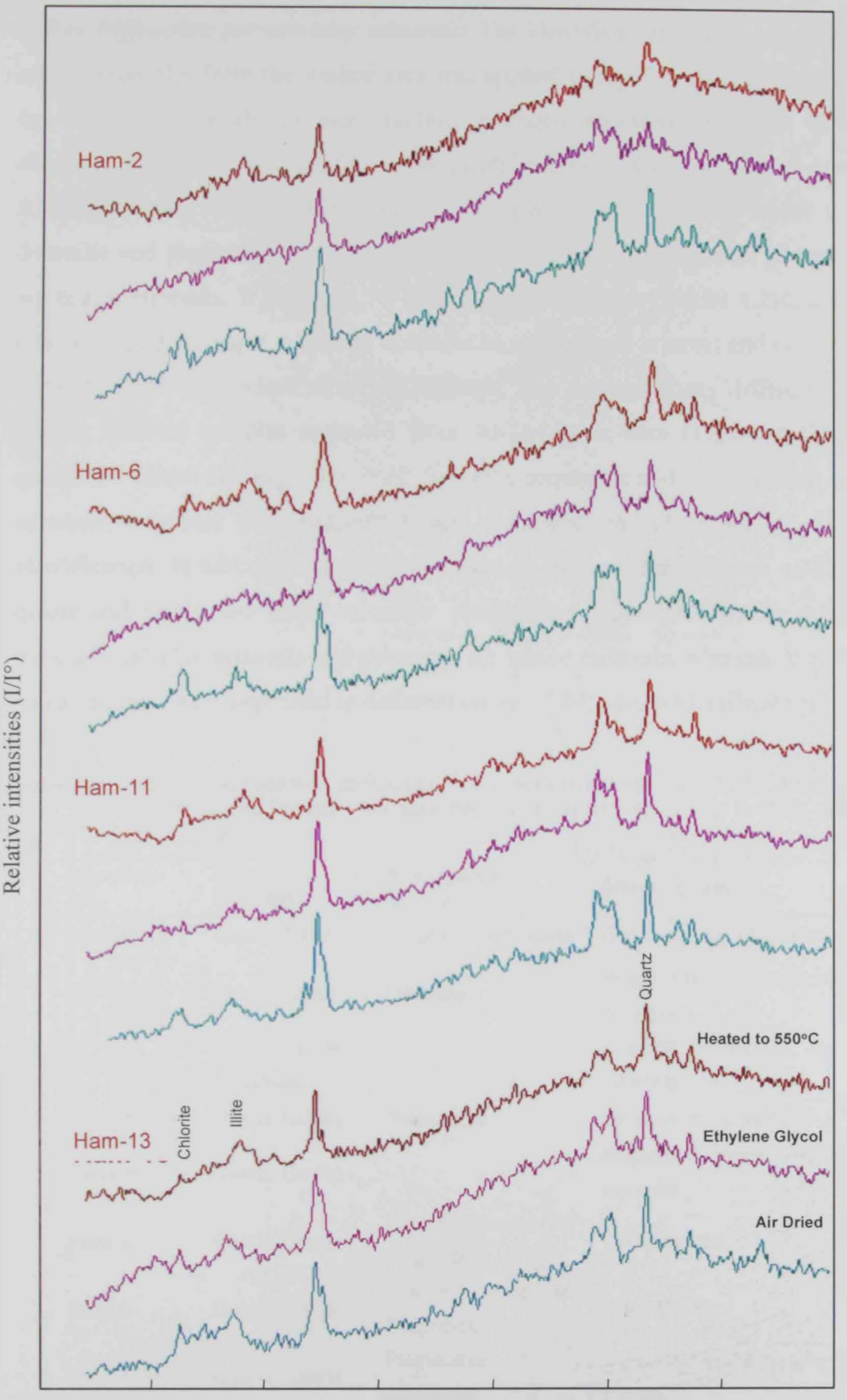


Figure 4.18. X-ray diffraction pattern of clay size fractional minerals of the selected samples from Ham dam.

X-Ray Diffraction for non-clay minerals: The identification of total number of nine selected samples from the studied area was applied using X-ray diffraction technique on non-clay minerals in size fraction arranged according to their decreasing abundance are listed in Table (4.3). The identification of X-ray diffraction pattern for Al-Shuweib dam (Figure 4.19), showed the quartz and calcite are major minerals; dolomite and plagioclase are subordinate minerals and clay minerals and serpentine are minor minerals. Whereas in Al-Bih diffraction pattern (Figure 4.20), quartz and calcite present as major minerals; dolomite as subordinate mineral and clay minerals, serpentine and plagioclase as minor minerals. The average X-ray diffraction pattern for the selected samples collected from Al-Tawiyeen dam (Figure 4.21) showed quartz and calcite are major minerals; dolomite, serpentine and clay minerals as minor minerals, whereas, the plagioclase was presented in all group of diffraction identification. In addition, the diffraction pattern of Ham dam (Figure 4.22) showed quartz and calcite are major minerals; plagioclase and amphibole are subordinate minerals and clay minerals and pyroxene are minor minerals, whereas, the dolomite and serpentine were presented in different group of diffraction identification.

Table 4.3. The identified mineral composition of selected samples as detected from the X-ray diffractograms for non-clay size fraction arranged according to their decreasing abundance

Samples No.	**Major Mineral(s)**	**Subordinate Mineral(s)**	**Minor Mineral(s)**
Shuweib-3	Quartz, Calcite	Dolomite, Plagioclase	Clay minerals, Serpentine
Bih-10	Quartz, Calcite	Dolomite	Plagioclase, Clay minerals, Serpentine
Tawiyeen-7	Quartz, Calcite, Plagioclase	-	Dolomite, Serpentine, Clay minerals
Tawiyeen -9	Quartz, Calcite	Plagioclase	Serpentine, Dolomite
Tawiyeen -11	Quartz, Calcite	-	Plagioclase, Serpentine, Clay minerals
Ham-2	Quartz, Calcite	Dolomite, Serpentine, Plagioclase	Clay minerals
Ham-6	Quartz, Calcite	Dolomite, Serpentine, Plagioclase	Clay minerals
Ham-11	Quartz, Calcite	Plagioclase, Serpentine	Dolomite, Pyroxene, Clay minerals
Ham-13	Quartz, Calcite, Serpentine	Dolomite, Plagioclase, Amphibole	-

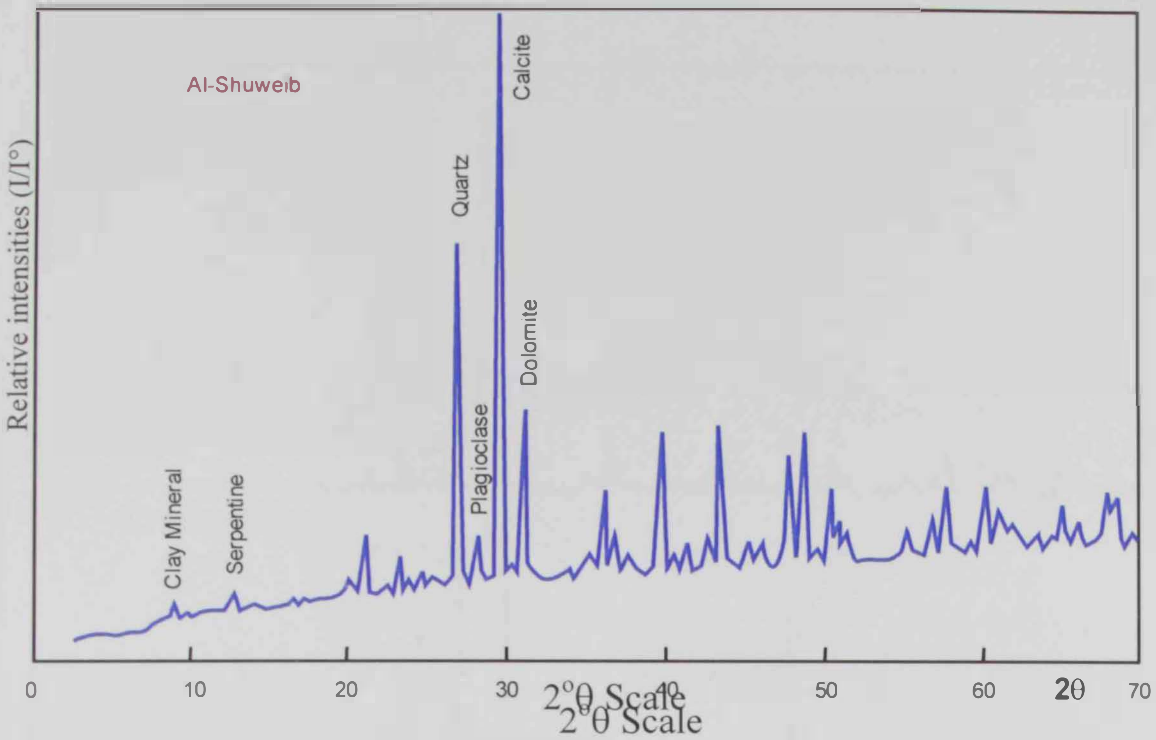


Figure 4.19. X-ray powder diffraction pattern of non-clay size fractional minerals of the selected samples from Al-Shuweib dam.

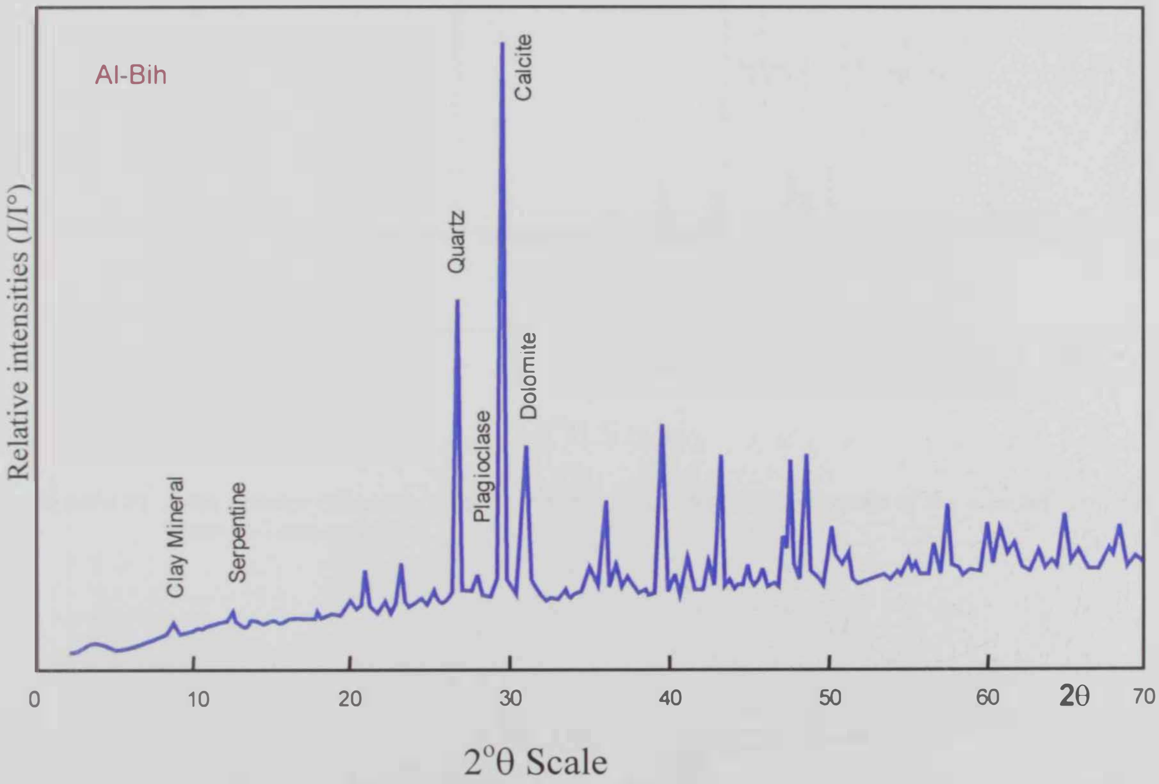


Figure 4.20. X-ray powder diffraction pattern of non-clay size fractional minerals of the selected samples from Al-Bih dam.

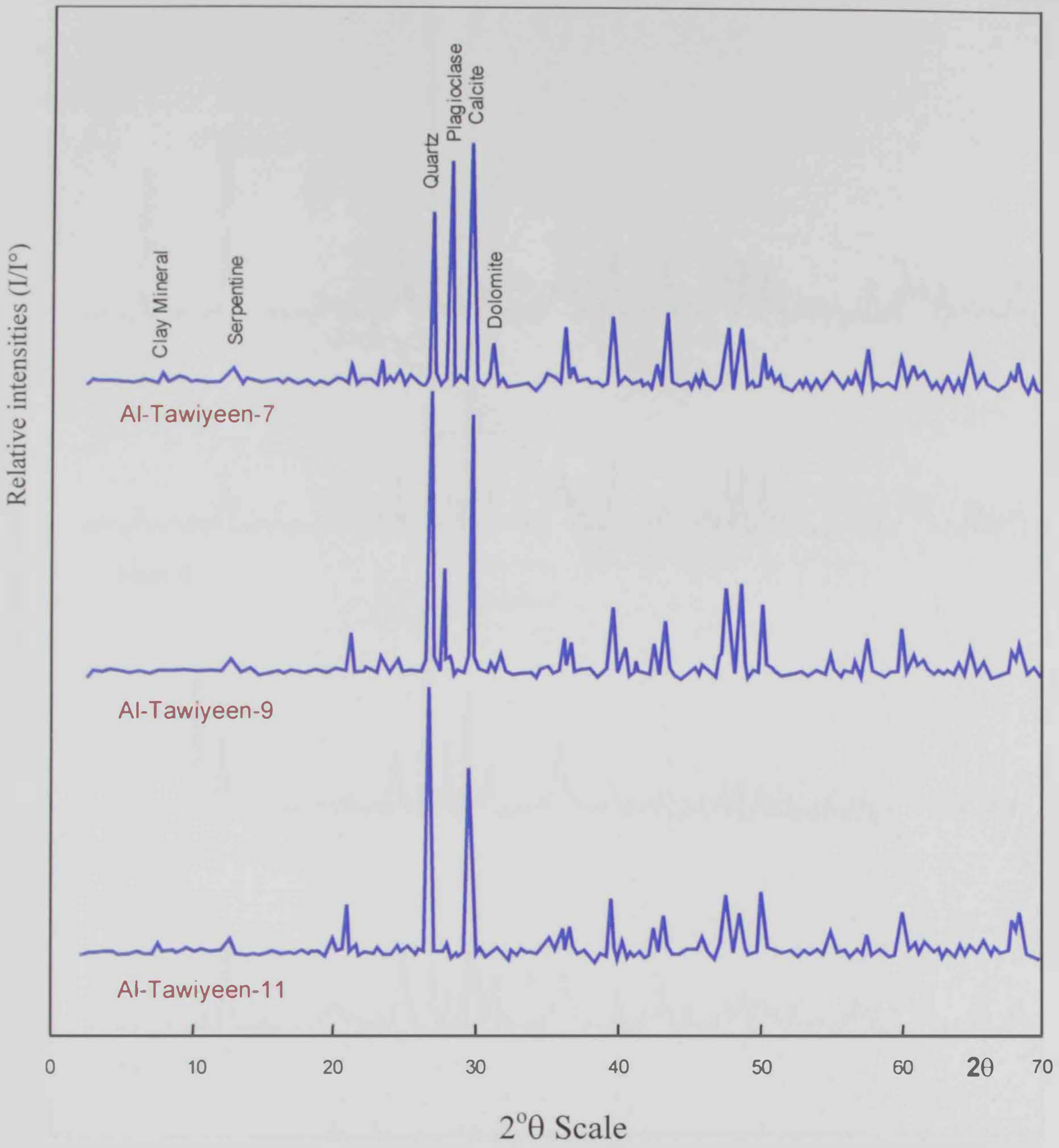


Figure 4.21. X-ray powder diffraction pattern of non-clay size fractional minerals of the selected samples from Al-Tawiyeen dam.

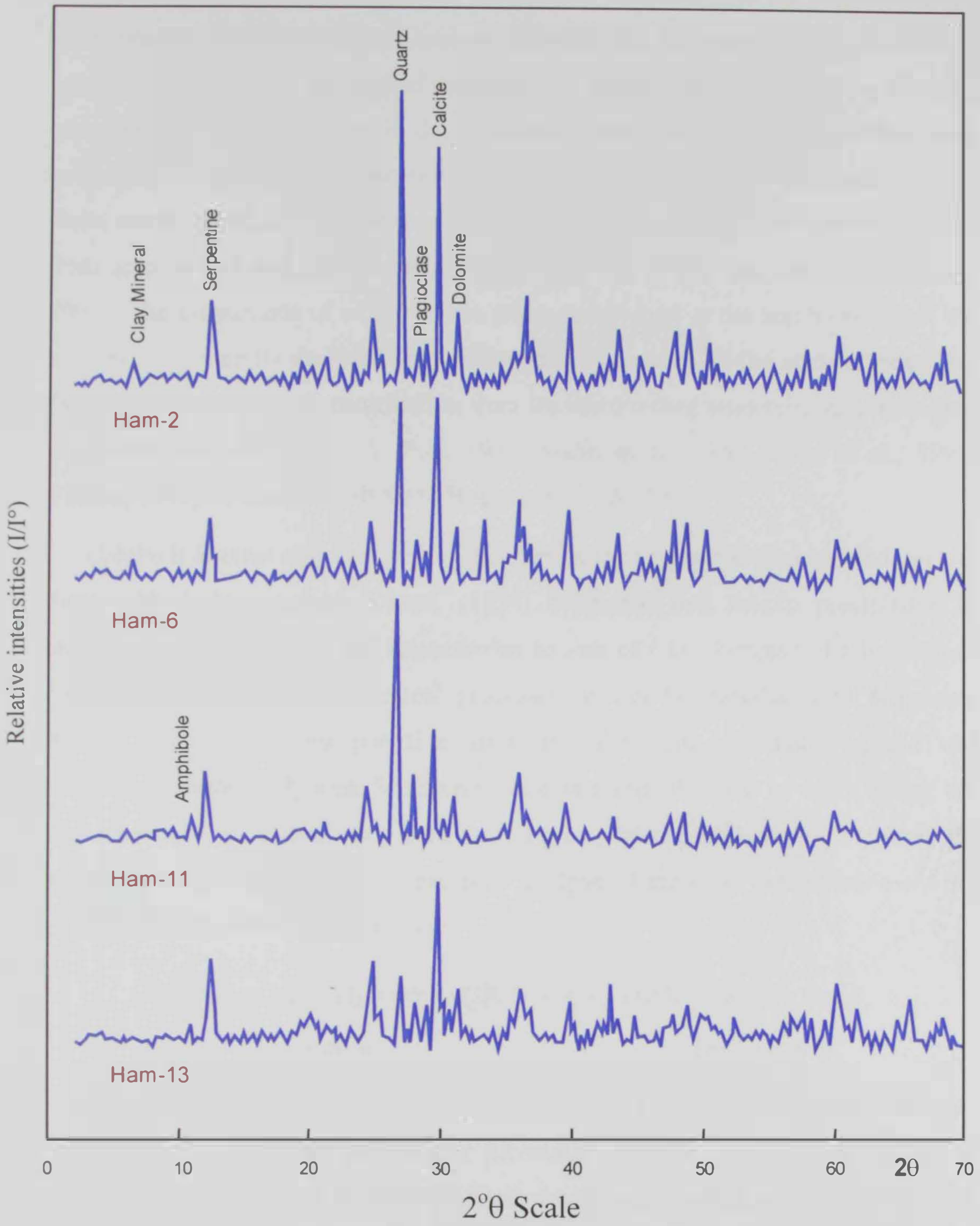


Figure 4.22. X-ray powder diffraction pattern of non-clay size fractional minerals of the selected samples from Ham dam.

The sedimentological analyses for the samples collected from the studied area for granulometric and mineralogical analyses revealed that the quartz is a major mineral constituent of most of the studied samples. The marked dominance of single quartz grain with uniform extinction in the Al-Shuweib dam sediments indicates that these sediments are considerable mineralogical maturity. This suggests that major part of these sands passes through several sedimentary cycles rather than derived directly from igneous rock and metamorphic rocks (Ehlers and Baltt, 1982 and Howari, et al., 2007). The proportions of single quartz grains are highest at the south eastern of the country but generally decrease toward the northern eastern of the studied area. This fact is related to the local contribution from the surrounding mountains and of aeolian sediments from the desert (Yaalon, 1987; Stahr, et al., 1989; Jahn, et al., 1991; Yaalon, 1997; Al-sheriani, 1998 and Howari, et al., 2007).

Calcite is another major mineral constituent in investigated sediments, and imparts them with a limy nature. Dioxn, (1994) suggested that calcite precipitates in sediments by evaporation, pH increase due to loss of CO_2, increase of temperature, common ion effect and biological processes. It can be introduced to sediments through the eaolian transportation from the limestone mountains spread out everywhere in the study area. Sediments can concentrate the flow of water during the very short and occasional rainy periods and precipitates $CaCO_3$ during the long dry season to form solidified and impervious hardpan (duricrust). This reaction can be expressed by the following equations:

$$CaCO_3 + CO_2 + H_2O \leftrightarrow Ca(HCO_3)_2 \leftrightarrow CaCO_3 + CO_2\uparrow + H_2O\uparrow$$

Rainy Season *Dry Season*

Calcite, as such, precipitates as intergranular fillings, cement, and pocket fillings. Although its contents are persistently substantial, and its vary from one place to another, under the control of drain direction, ground slope and plant/microbial growth (Callot, et al., 1985; Folk, 1993; and Newman, et al., 1997). It is unclear whether the laths of calcite originally grew as organic material and later replaced by calcite or whether they originally grew as calcite (Newman, et al., 1997). Therefore, calcite as well as other carbonate minerals may be present in sediments detrital particles, coatings over or between other particles.

Carbonate coatings in sediments matrix may form in layers from impeded water movement. Limestone and dolomite are the two major types of carbonate rocks. Dolomite ($CaMg(CO_3)_2$) is detected in most of the analyzed sediments samples, but with higher viability in the sediments of the eastern mountains (Al-Bih, Al-Tawiyeen and Ham dams), as the ophiolite sequence is the potential source of magnesium. Feldspare are generally of plagioclases present in many types of metamorphic rocks; which showed slight alteration due to weathering process, particularly along fractures and cleavage planes. However, the specific climate in our region, which is typical arid moisture regime, does not allow significant breakdown of the aeolian plagioclases transported from desert. The reliable identification of minerals such as amphiboles mineral that possess sediments solution and possibilities of alteration is a rather difficult task (Al-sheriani, 1998). Amphiboles and feldspars disappear from sediments after approximately one Ma of weathering under humid climate. Longer laps of time must be required for complete weathering of amphiboles and feldspars under the arid moisture regime (Bullen, et al., 1997). Amphiboles, serpentines and pyroxenes are minerals of either igneous or metamorphic rocks (Hurlbut et al., 1985 and Stephen, 2006). The minerals constitute pyroxenes especially toward the northeastern parts of the study area where the Oman Mountains are located. Pyroxenes are orthopyroxenes (enstatite–hypersthene) and subordinate amounts of clinopyroxenes (diopside–augite). Illite occurs as an alteration product of muscovite and feldspar in weathering and hydrothermal environments. It is common as sediments, soils, and argillaceous sedimentary rocks as well as in some low grade metamorphic rocks (Mitchell, 1993). The X-ray diffrection illustrates that illite presented in most of the sediment samples in studied area. Chlorite presents as a minor mineral in the studied sediments and it is commonly found in igneous rocks. However, it can be generalized that the studied area sediments consist of three major inorganic constituents, namely; carbonates, such as calcite and dolomite; silicates, such pyroxenes and serpentines; free silica, which is mostly in the form of detrital quartz. The identified minerals can not be considered as a source of heavy metal.

CHAPTER FIVE

GEOCHEMICAL ANALYSES

5. GEOCHEMICAL ANALYSES

One of the most important fields of geochemistry is to examine the distribution and movements of elements in different parts of the earth (crust, mantle, hydrosphere etc.) and in minerals with the goal to determine the underlying system of distribution and movement. Therefore, ninety-three samples were collected in a systematic fashion from the major dams of UAE. These samples are distributed as follow: forty-one sediments samples from Al-Shuweib dam, twenty-three sediments samples from Al-Bih dam, eleven sediments samples from Al-Tawiyeen dam and eighteen sediments samples from Ham dam. These samples were subjected to geochemical analysis that included pH, TDS, CO_3%, TOM%, P_2O_5%, and CEC, as well as bulk metals analysis and sequential heavy metals analysis.

5.1. Determination of pH

The values of pH of the sediments samples were determine for Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams (Table 5.1 and Appendix II.1). Generally, the values of pH for Al-Bih, Al-Tawiyeen and Ham dams are almost equal and there is slight increase of pH value in Al-Shuweib dam.

Table 5.1. Average, minimum, maximum and standard deviation of pH values for the major four dams.

	Al-Shuwieb	Al-Bih	Al-Tawiyeen	Ham
Samples "N"	41	23	11	18
Average	7.85	7.41	7.47	7.46
Minimum	7.2	6.98	7.30	7.23
Maximum	8.6	8.11	7.78	7.82
STD	0.4	0.30	0.13	0.17

"N" . No. of samples collected from each dam.

5.2. Total Dissolved Solid Content (TDS)

The values of TDS (ppm) of the collected sediment samples from Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams were presented (Table 5.2 and Appendix II.2). It can be observed that the TDS values in Al-Bih sediment samples is higher than other dams.

Table 5.2. Average, minimum, maximum and standard deviation of (TDS, ppm) values for the major four dams.

	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
Samples "N"	41	23	11	18
Average	227.1	744.5	564.9	337.8
Minimum	104.3	246.8	183.0	190.1
Maximum	610.6	1813.8	935.0	447.2
STD	107.8	495.4	228.1	76.14

"N" No. of samples collected from each dam

5.3. Total Carbonate Content (CO_3 %)

The analytical result values for carbonate content percentage (CO_3%) of the sediments samples collected from Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams were presented in Table (5.3) and Appendix (II.3). It can be observed from the values recorded that Al-Shuweib and Ham dams values are almost similar, whereas, there is an increase in percentage value of carbonate in Al-Bih and Al-Tawiyeen dams.

Table 5.3. Average, minimum, maximum and standard deviation of total carbonate content (CO_3 %) values for the major four dams.

	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
Samples "N"	41	23	11	18
Average	19.20	32.58	28.10	16.81
Minimum	12.06	23.45	24.21	12.07
Maximum	27.40	49.27	37.31	21.99
STD	3.52	6.58	3.80	2.92

"N" : No. of samples collected from each dam.

5.4. Total Organic Matter Content (TOM %)

The values of total organic matter content (TOM %) of the sediments samples collected from the investigated dams were presented in Table (5.4) and Appendix (II.4). The measured values showed a very low percentage of total organic matter content in sediments samples collected from investigated.

Table 5.4. Average, minimum, maximum and standard deviation of total organic matter content (TOM %) values for the major four dams.

	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
Samples "N"	41	23	11	18
Average	2.22	5.00	5.36	4.58
Minimum	0.22	2.49	3.81	2.32
Maximum	6.35	7.41	7.33	7.04
STD	1.43	1.42	0.92	1.63

"N" : No. of samples collected from each dam.

5.5. Total Phosphate Content (P_2O_5 %)

The percentage values of total phosphate content (P_2O_5%) of the sediments samples of Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams were listed in Table (5.5) and Appendix (II.5). The values of P_2O_5 content are low in four dams sediment samples.

Table 5.5 Average, minimum, maximum and standard deviation of total phosphate content (P_2O_5 %) values for the major four dams.

	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
Samples "N"	41	23	11	18
Average	2.49	4.35	8.94	5.53
Minimum	1.15	2.23	4.79	2.27
Maximum	5.95	5.58	11.38	8.33
STD	1.31	1.07	1.71	1.80

"N" No. of samples collected from each dam.

5.6. Cation Exchange Capacity (CEC)

The cation exchange capacity of the sediments samples in Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams were listed in Table (5.6) and Appendix (II.6).

Table 5.6. Average, minimum, maximum and standard deviation of cation exchange capacity (CEC m.eq./100 g soil) values for the major four dams.

	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
Samples "N"	41	23	11	18
Average	29.1	49.0	57.9	45.0
Minimum	9.1	20.9	16.6	20.0
Maximum	71.2	72.5	82.3	85.4
STD	12.5	13.3	18.7	19.1

5.7. Bulk Metals analysis of Al, Fe, Cu, Cd, Cr, Pb and Zn

The concentrations of the analyzed metals (Al, Fe, Cu, Cd, Cr, Pb and Zn) in the sediments samples collected from Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams were measured in clay size sediments (>2μm). Table (5.7) and Appendix (II.7) showed the concentration values of analyzed metals from sediment samples collected in Al-Shuweib dam, Table (5.8) and Appendix (II.8) for Al-Bih dam, Table (5.9) and Appendix (II.9) for Al-Tawiyeen dam, and Table (5.10) and Appendix (II.10) for Ham dam.

Table 5.7 Average, minimum, maximum and standard deviation of bulk trace elements analysis in ppm for 41 sediment samples collected from Al-Shuweib dam

	Al	Fe	Cu	Cd	Cr	Pb	Zn
Average	23.6	41.0	0.03	0	0.3	0.02	0.1
Minimum	18.1	20.8	0.01	0	0	0.01	0.03
Maximum	28.5	72.8	0.07	0	0.5	0.03	0.4
STD	2.1	12.0	0.02	0	0.1	0.01	0.06

Table 5.8 Average, minimum, maximum and standard deviation of bulk trace elements analysis in ppm for 23 sediment samples collected from Al-Bih dam

	Al	Fe	Cu	Cd	Cr	Pb	Zn
Average	26.8	44.1	0.03	0	0.1	0.03	0.1
Minimum	22.6	24.4	0.01	0	0.1	0.03	0.06
Maximum	28.3	58.7	0.05	0	0.2	0.06	0.17
STD	1.61	8.3	0.01	0	0.03	0.007	0.02

Table 5.9. Average, minimum, maximum and standard deviation of bulk trace elements analysis in ppm for 11 sediment samples collected from Al-Tawiyeen dam

	Al	Fe	Cu	Cd	Cr	Pb	Zn
Average	28.8	64.7	0.1	0.0003	0.3	0.04	0.2
Minimum	27.7	56.9	0.1	0	0.3	0.03	0.1
Maximum	30.8	80.9	0.1	0.002	0.4	0.04	0.6
STD	0.8	6.8	0.02	0	0.03	0.005	0.1

Table 5.10. Average, minimum, maximum and standard deviation of bulk trace elements analysis in ppm for 18 sediment samples collected from Ham dam

	Al	Fe	Cu	Cd	Cr	Pb	Zn
Average	28.1	73.3	0.1	0.0004	0.9	0.03	0.2
Minimum	26.7	56.9	0.1	0.0	0.7	0.02	0.1
Maximum	29.5	85.2	0.2	0.003	1.5	0.04	0.5
STD	0.8	7.0	0.04	0.0009	0.2	0.006	0.1

5.8. Sequential Heavy Metals Analysis (Chemical speciation)

Sequential extractions procedure described by Tessier, et al. (1979) was employed with slight modifications (Kirk, et al., 2003) on five samples from each dam. Various analytical techniques were used to quantify Cu, Cd, Cr, Pb and Zn following a sequential extraction by using two instruments; the Inductive Coupled Plasma Optical Emission Spectrometry (ICP-OES) and Flame Atomic Absorption Spectrometry (FAAS). Briefly, Tessier's procedure extracts metals associated with five fractions: (F1) exchangeable, (F2) carbonates, (F3) Fe/Mn oxides, (F4) organic matter, and (F5) residual. The values of the selected metal elements liberated by the five fractions for Al Shuweib dam listed in Table (5.11), Table (5.12) for Al-Bih dam, Table (5.13) for Al-Tawiyeen dam and Table (5.14) for Ham dam.

Table 5.11. List of sequential heavy metals analysis (speciation) Al-Shuweib dam in ppm.

Samples No.	Fraction	Cu	Cd	Cr	Pb	Zn
S 2	F1	0.6	0	0.1	0.5	0.3
	F2	0.9	0	0	0	3.4
	F3	7.3	0	0.1	1.5	10.4
	F4	4.1	0	0.4	0	1.3
	F5	0.6	0.05	1.8	0.3	5.7
S 10	F1	0.25	0	0.006	0.2	0.2
	F2	1.6	0	0	0	4.6
	F3	6	0.1	0.4	1.2	5.6
	F4	4.2	0	0.5	0	1.1
	F5	0.8	0.05	1.4	0.2	6.1
S 20	F1	0.1	0	0.02	0.05	0.1
	F2	3	0	0.1	0	4.6
	F3	2.6	0	0.1	0	3.7
	F4	3.1	0	0.4	0	1.8
	F5	0.6	0.04	1.2	0.2	5.6
S 30	F1	0.25	0	0.05	0.35	0.1
	F2	1.5	0	0	0	4.3
	F3	1.4	0	0.2	0	2.6
	F4	3.1	0	0.6	0	0.7
	F5	0.6	0.08	2.1	0.2	6.2
S 40	F1	0.4	0	0.006	0.2	0.3
	F2	3	0	0	0	5.2
	F3	3.5	0	0.3	2.3	4.8
	F4	3.7	0	0.6	0	0.6
	F5	1.3	0.1	2.9	0.4	7.1

Table 5.12. List of sequential heavy metals analysis (speciation) Al-Bih dam in ppm.

Samples No.	Fraction	Cu	Cd	Cr	Pb	Zn
B 3	F1	0.8	0	0.006	0.2	0.1
	F2	0.9	0	0.3	0.1	4
	F3	2.7	0	0.1	0.5	2.1
	F4	3.8	0	0.3	0	0.6
	F5	0.8	0.04	0.8	0.2	6.1
B 9	F1	0.25	0	0.006	0.1	0.1
	F2	1.6	0	0.2	0.2	2.7
	F3	3.4	0	0.1	0.4	3
	F4	3.7	0	0.4	0	0.6
	F5	1.1	0.06	0.8	0.3	6.5
B 15	F1	0.3	0	0.006	0.2	0.06
	F2	1.4	0	2.4	0	2.7
	F3	5.6	0	0.2	0.2	3
	F4	3.9	0	0.4	0	1.5
	F5	0.8	0.2	0.8	0.2	5.1
B 20	F1	0.1	0	0.04	0.1	0.04
	F2	0.8	0	0.2	0.3	3.6
	F3	5.1	0	0	0.4	3.2
	F4	4.5	0	0.6	0	1.6
	F5	0.22	0.005	0.06	0.06	4.4
B 23	F1	0.2	0	0.02	0.2	0.06
	F2	2.5	0	1.2	0.7	4.8
	F3	2.3	0	0.3	0.1	1.8
	F4	3.9	0	0.5	0	1.6
	F5	0.4	0.02	0.4	0.1	3

Table 5.13. List of sequential heavy metals analysis (speciation) Al-Tawiyeen dam in ppm.

Samples No.	Fraction	Cu	Cd	Cr	Pb	Zn
T 1	F1	0.3	0	0.001	0.1	0.1
	F2	1.5	0	0.1	1.1	5.1
	F3	4.2	0	0.2	0	1.9
	F4	3.7	0	1.4	0	0.7
	F5	1.3	0.07	1.6	0.3	7.3
T 4	F1	0.2	0	0.001	0.3	0.18
	F2	0.7	0	1	0.2	3.3
	F3	4.2	0	0.3	0	2.4
	F4	3.9	0	0.8	0	0.6
	F5	1.5	0.1	2.1	0.4	7.8
T 7	F1	0.3	0	0.001	0.26	0.1
	F2	0.6	0	0.4	2.2	3.5
	F3	4.3	0	0.6	0	2.3
	F4	4	0	0.3	0	0.9
	F5	0.8	0.03	0.9	0.1	2.3
T 9	F1	0.4	0	0.001	0.2	0.1
	F2	1.3	0	0.3	0.1	3.2
	F3	4.2	0	0.2	0.1	5.2
	F4	4	0	0.4	0	0.7
	F5	0.5	0.03	1.7	0.1	2.1
T 11	F1	0.1	0	0.002	0.1	0.1
	F2	3.3	0	0.4	0	3.6
	F3	3.9	0	0.1	0	2
	F4	3.9	0	0.6	0	0.8
	F5	0.1	0.04	3.1	0.1	0.6

Table 5.14. List of sequential heavy metals analysis (speciation) Ham dam in ppm.

Samples No.	Fraction	Cu	Cd	Cr	Pb	Zn
H 1	F1	0.1	0	0.002	0.2	0.04
	F2	1.2	0	0.7	0	4.3
	F3	4.4	0	0.5	0	2
	F4	4.1	0	0.7	0	0.8
	F5	3.5	0.1	2.8	0.2	4.2
H 5	F1	0.2	0	0.002	0.2	0.04
	F2	1.4	0	1.4	0	4.5
	F3	4.1	0	0.9	0	2.3
	F4	4.1	0	0.5	0	0.8
	F5	1.8	0.1	3.5	0.2	4.6
H 10	F1	0.2	0	0	0.3	0.1
	F2	4.8	0	0.3	0	4.5
	F3	4	0	0.7	0	2.2
	F4	2.8	0	0.3	0	0.7
	F5	2.3	0.3	4	0.3	4.7
H 15	F1	0.1	0	0.001	0.4	0.2
	F2	1.5	0	0.2	0.2	4.3
	F3	4.2	0	0.8	0	3.6
	F4	2.6	0	0.4	0	0.6
	F5	2.1	0.2	6.4	0.2	4.5
H 18	F1	0.1	0	0.002	0.7	0.2
	F2	9	0	0.6	0.1	5.4
	F3	4.1	0	0.3	0	3.6
	F4	2.9	0	0.6	0	0.8
	F5	2.4	0.2	4.9	0.2	5.5

CHAPTER SIX

DISCUSSION

6. DISCUSSION

The concentration of trace elements in sediments can be influenced by variation in their texture, composition, reduction/oxidation reactions, adsorption/desorption, and physical transport or sorting in addition to anthropogenic metal input (Förstner and Wittman, 1983; Dang, et al., 2002 and Ma, et al., 2002). Those factors affect the availability of metal concentration in time and space.

6.1. Geochemistry and Distribution of Analyzed Metals

Trace metals may be distributed among several sediments components and may be associated with these components in different ways and strengths (Kersten and Förstner, 1989 and Ract, et al., 2003). The concentrations of selected analyzed metals (Cu, Cd, Cr, Pb, and Zn) in total number of ninety-three sediment samples collected from Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams were almost similar distribution among the dams. By taking into account the effect of the physico-chemical processes with regard to metal accumulation and the concentrations of measured heavy metals in the clay fraction.

From the measured results listed in Tables (5.7 – 5.10), it can be revealed that the Cu, Zn, Cr, Pb, and Cd contents have almost similar average concentration values among the investigated sediment samples. The average of the Copper (Cu) concentration is around 0.03 ppm in both Al-Shuwieb and Al-Bih dams, whereas in Al-Tawiyeen and Ham dams have higher concentration value, which are equal to 0.1 ppm. The increase of Cu concentration in analyzed sediments samples could be due to ultramafic igneous and metamorphic rocks exposed near ophiolites of the Oman Mountains which may be derived near the dams through the weathering process (Mason, et. al., 1982; Al-sheriani, 1998). Generally, Cu is a naturally occurring element, which can be found in all environmental media: air, soil, sediment, and water (Alloway, 1990). The average value of Cu in the earth's curst is equal to 45 ppm (Turkian and Wedphole, 1961 and Alloway, 1990). It may be present in sediments as soluble compounds including nitrates, sulfates and chlorides, and insoluble compounds such as oxides, hydroxides, carbonates and sulfides (Bodek, et al., 1988 and Budavari, 1996). Soluble Cu compounds strongly sorbs to particles of organic matter, clay sediments, or sand, and demonstrate low mobility in sediments (Bodek, et al., 1988). Insoluble Cu compounds are effectively immobile in sediments.

The concentration of Zinc (Zn) in analyzed sediments samples collected from the investigated dams showed the average values of 0.1 ppm in Al-Shuwieb and Al-Bih dams, and 0.2 ppm in both Al-Tawiyeen and Ham dams. These average values are very low compared with the average concentration of zinc value in the earth`s crust, which equal to 75 ppm (Adriano, 1986; Turkian and Wedphole, 1961 and Alloway, 1990). As the Copper, the Zn indicates a very close proximity to their ultramafic igneous source rocks (Mason, et. al., 1982). Zinc and Copper in the sediments are generally good indicators of anthropogenic input (Förstner and Wittman, 1979). Zinc is an essential trace element for organisms where it plays a vital role in the physiological and metabolic processes of many organisms, but at high concentrations zinc can be toxic to the organisms (Varshney, 1983; Moore and Ramamoorthy, 1983; Alloway, 1990 and Keikens, 1990).

From the measured results of collected sediment samples, it can be observed that the Chromium (Cr) concentration is slightly increasing in the northern region such as in Ham dam, where the average value is equal to 0.9 ppm. Whereas, Cr content showed similar average value in the sediment samples collected from both Al-Shuwieb and Al-Tawiyeen dams which is equal to 0.3 ppm, and 0.1 ppm in Al-Bih dam. This metal is derived from the weathering process of ophiolitic rocks exposures of Oman Mountains, which are dominated by olivine, pyroxene and serpentine (Guilbert et. al., 1986; Al-sheriani, 1998). The average Cr content in earth's crust is equal to 100 ppm (Turkian and Wedephole, 1986; Alloway, 1990), this value is much higher than the value presented in this study sites.

The recorded value of the average concentration for Lead (Pb) in both Al-Bih and Ham dams sediment samples is equal to 0.03 ppm, whereas in Al-Tawiyeen dam the average value equal to 0.04 ppm and in Al-Shuwieb dam, the average concentration of Pb equal to 0.02 ppm. The present of Pb in the analyzed sediment samples indicates a close proximity to metamorphic rocks source, which is also derived from the ophiolitic rock exposures (David et al., 1973). Lead belongs to the more abundant trace elements in the earth crust; and it average value in shale is equal to 20 ppm (Turkian and Wedephole, 1961; Adriano, 1986; Alloway, 1990).

In sediments, lead is relatively immobile and persistent whether added to the sediments as halides, hydroxides, oxides, carbonates or sulfates (US-EPA, 1997). When released to sediments, Pb is normally converted from soluble lead compounds to relatively insoluble sulfate or phosphate derivatives. It also forms complexes with organic matter and clay minerals, which limits its mobility. However, leaching of lead can be relatively rapid from some sediment, especially at high-contaminated sites or landfills (Kayser, et al., 1982). Concentration of lead in sediments solution reaches a minimum between pH 5 and 6 because metal organic complexes form in this pH range. In addition, other factors may affect the uptake of lead including cation exchange capacity, organic matter content, calcium content, metal concentrations, precipitation, light, temperature and low pH (US EPA, 1997).

There was no significant values of Cadmium (Cd) concentration appeared in the collected sediments samples of studied areas except very slight values appeared in both Al-Tawiyeen and Ham dams. Cadmium is naturally occurring rare elements that does not have any known essential or beneficial biological function (Eisler, 1985). Even though, the average cadmium concentration in the earth's crust is generally placed between 0.1 and 0.5 ppm, much higher levels may accumulate in sedimentrary rocks (Turkian and Wedphole, 1961 and Alloway, 1990). Cadmium can be adsorbed to sediments but to a much lesser extent than most other heavy metals. The most important sediments properties influencing adsorption are pH and organic content. Therefore, leaching is more likely to occur under acid conditions in sandy sediments. Pickering (1980) found that with increasing the value of pH, the Cd concentrations in the solution decreased due to increases in hydrolysis, and adsorption density (Alloway, 1990; US-EPA, 2005).

The relashionship between the grain size and the analyzed metal can be examined from the values of analyzed metals showed in Appendix (II.7) to (II.10) for the four dams and the values of the grain size analysis in Appendix (II.11) and (II.12). It can be revealed that the value of the analyzed metals increased with the increaseing the surface layer of sediment, where the highest values presented in the sandy sediment samples for the investigated sediment samples. Fine-grained sediments tend to have relatively high metal contents, due to the high specific surface of smaller particles. This enrichment is mainly due to surface adsorption and ionic attraction (McCave, 1984; Horowitz and Elrick, 1987).

It may be concluded that the concentrations of trace metals in the studied area are controlled almost exclusively by the mineralogy of the land derived fragments and the effect of human impact upon the absolute concentration is minimal. The samples collected from investigated sediment samples consist primarily of olivine, serpentine, pyroxene and amphibole that were derived most probably from nearly ophiolitic exposures. The Oman Mountains are mainly composed of less stable minerals such as pyroxenes and olivine. The X-ray diffraction patterns analyses support the results from chemical analyses. The observation of the measurement concentrations values of sediments samples collected from investigated dams compared with elemental background compositions (Turekian and Wedepohl, 1961; Mason, 1966; Bown, 1979 and Salomons and Förstner, 1984) indicated that surface sediments were observed to be not contaminated with Cu, Zn, Cr, Pb and Cd, however, Cr observed to be slightly high in the northern region.

6.2. Spatial Distribution of Analyzed Metals

The visualization of spatial data is made by preparing distribution maps of heavy metal concentration in sediments and co-relation diagrams. These results highlight the need for instituting a systematic and continuous monitoring of the study area for analyzed metals Cu, Zn, Cr, and Pb. The absent of Cd concentration from the spatial distribution maps due to zero value of cadmium concentration in the measured sediments collected along the tested stations.

6.2.1. Cu, Zn, Cr, and Pb in Al-Shuweib Dam

It can be observed from Figure (6.1) that the elements of Pb and Cu in Al-Shuwieb dam displayed quite similar histogram of distributions. The Cr and Zn content increases from the bottom of the dam toward the north side, where a marked increase of Cr concentration is recorded near a road highway close to the dam. This can be explained due to extent of weathering process and transportation distance of the Ophiolitic exposures from the Oman Mountains in the east side of the dam toward the west and north sides.

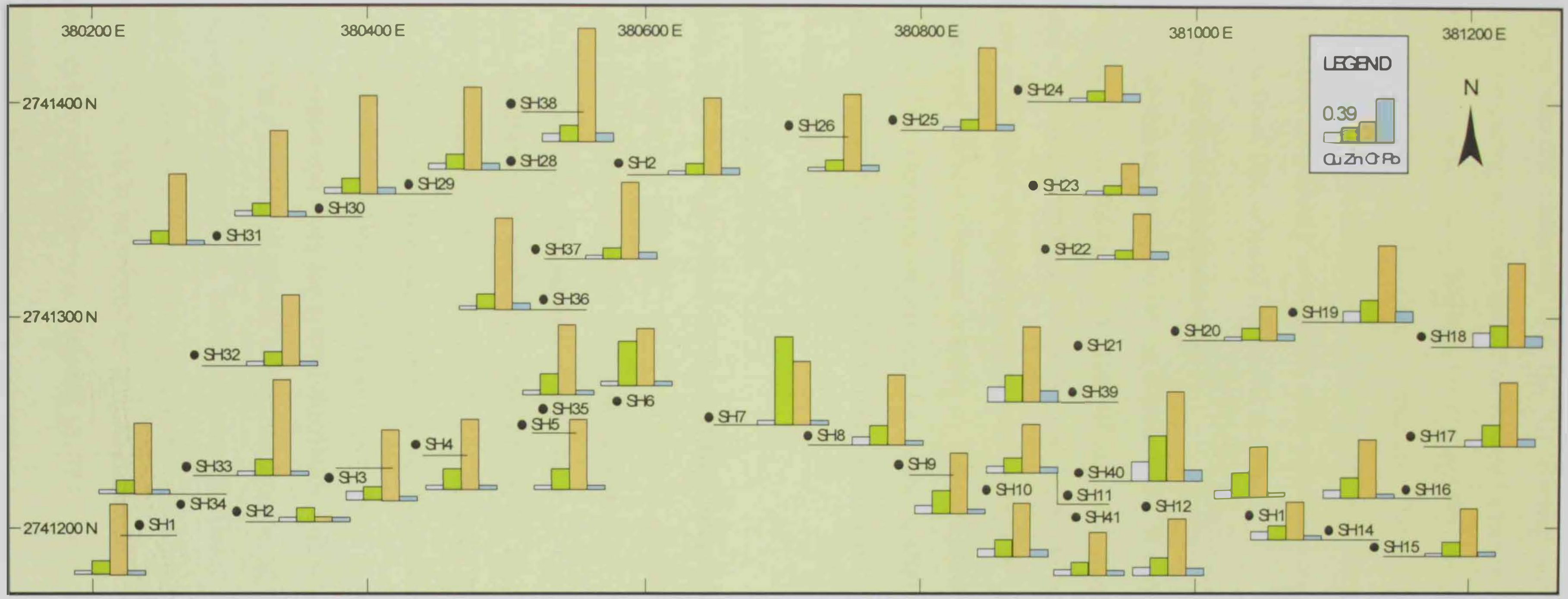


Figure 6.1. Spatial distribution of heavy metals Cu, Zn, Cr and Pb concentrations in Wadi Al-Shuweib dam.

6.2.2. Cu, Zn, Cr, and Pb in Al-Bih Dam

From Figure (6.2), it can be observed that the Cr content showed the highest concentration values comparing with the rest of considered elements. However, Zn is the second highest content in this dam, whereas the Cu and Pb content displayed quite similar histogram distribution in the dam. Generally, the metals contents are increasing from the bottom of the dam toward the north side where surrounded by mountains. These metals are closely associated with ophiolitic rocks and therefore they are mainly derived from Ophiolite of Oman Mountains.

6.2.3. Cu, Zn, Cr, and Pb in Al-Tawiyeen Dam

From the distribution of the analyzed metals in Figure (6.3), it can be observed that the Cu content showed the highest concentration values comparing with the rest of considered analyzed elements, which could be derived from the ultramafic igneous and metamorphic rocks exposed of ophiolitic rock exposures. The Chromium content considered as the second highest element content in the dam with highest increase shown in station no.4. The elements of Zn and Pb in the spatial distribution map displayed quite similar histogram. Most of the metals are increasing from the bottom toward the western north side of the dam.

6.2.4. Cu, Zn, Cr, and Pb in Ham Dam

By examining Figure (6.4), it can be observed that the Cr content showed the highest concentration values comparing with the rest of considered elements. The analyzed metals of Cu, Zn and Pb content displayed quite similar histogram of distribution and slight increase of Zn content in the bottom side of the dam.

From the spatial distribution of analyzed metals of Cu, Cr, Pb and Zn in the four selected dams, it can be revealed that the Cr and Zn are the main dominant elements in Al-Shuweib and Al-Bih dams, whereas Cr is the main dominant element in Ham dam, and Cu is the main dominant element in Al-Tawiyeen dam.

Generally, it can be observed from the spatial distribution of analyzed metals that the concerned elements are present obviously in northern region of UAE as examined in Al-Bih, Al-Tawiyeen and Ham dams, which are close to Oman Mountains where the level of elements decreased in the eastern region as in Al-Shuweib dam, which is open in desert area. This is might be related to several parameters such as size range in the source rocks, extent of weathering, distance of transportation and the energy variation of the depositing agents.

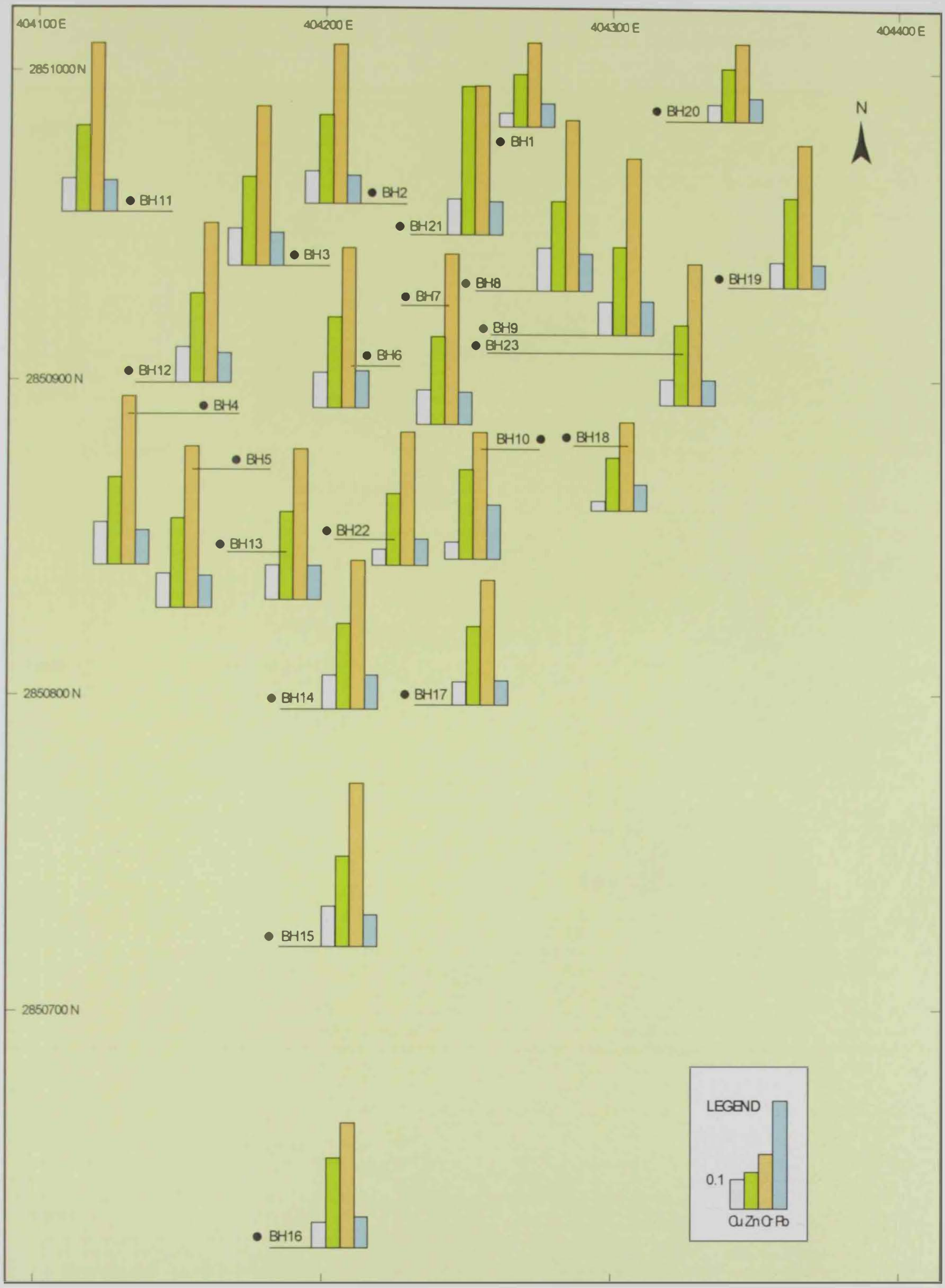


Figure 6.2. Spatial distribution of analyzed metals Cu, Zn, Cr and Pb concentrations in Al-Bih dam.

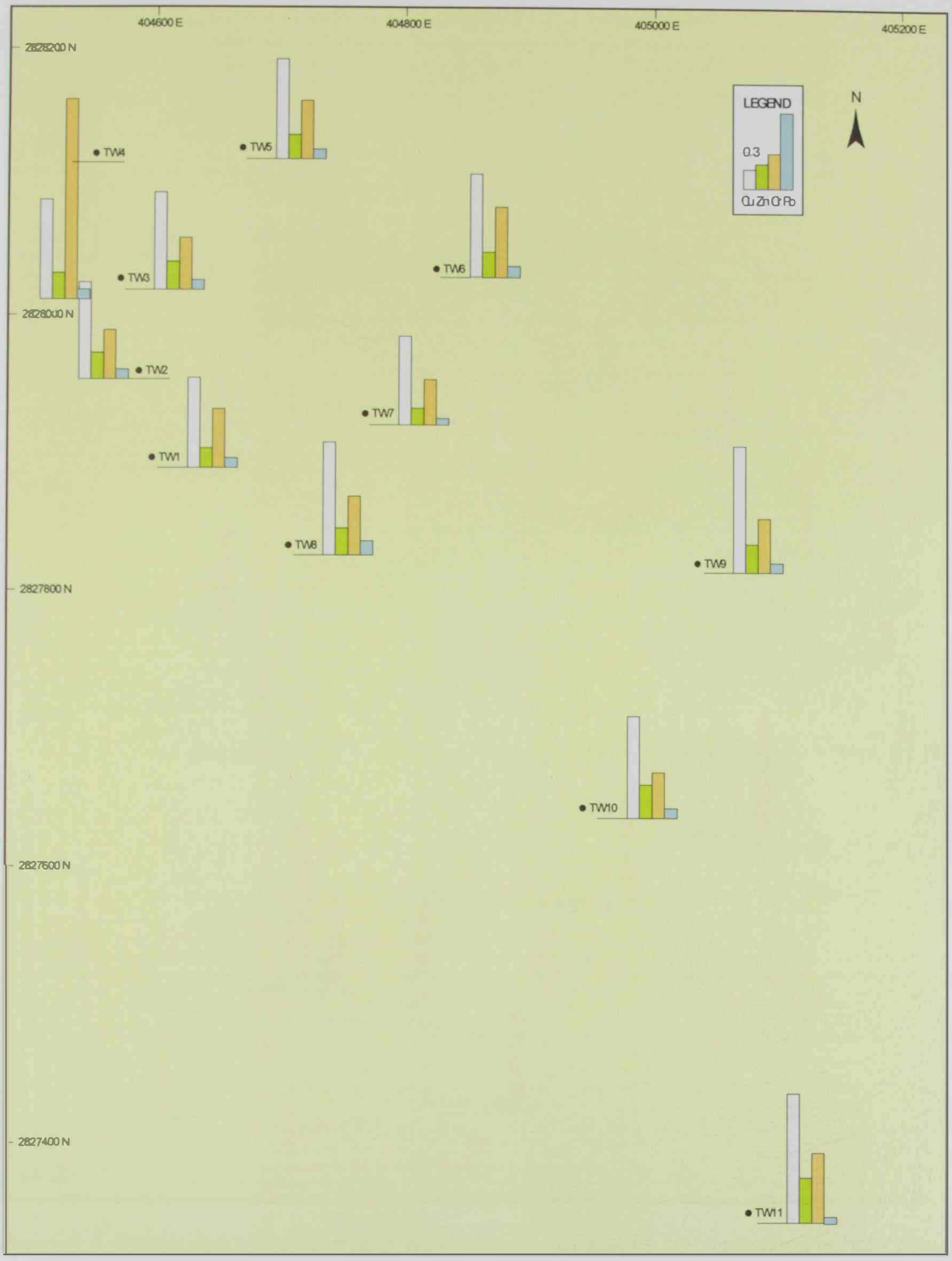


Figure 6.3. Spatial distribution of analyzed metals Cu, Zn, Cr and Pb concentrations in Al-Tawiyeen dam.

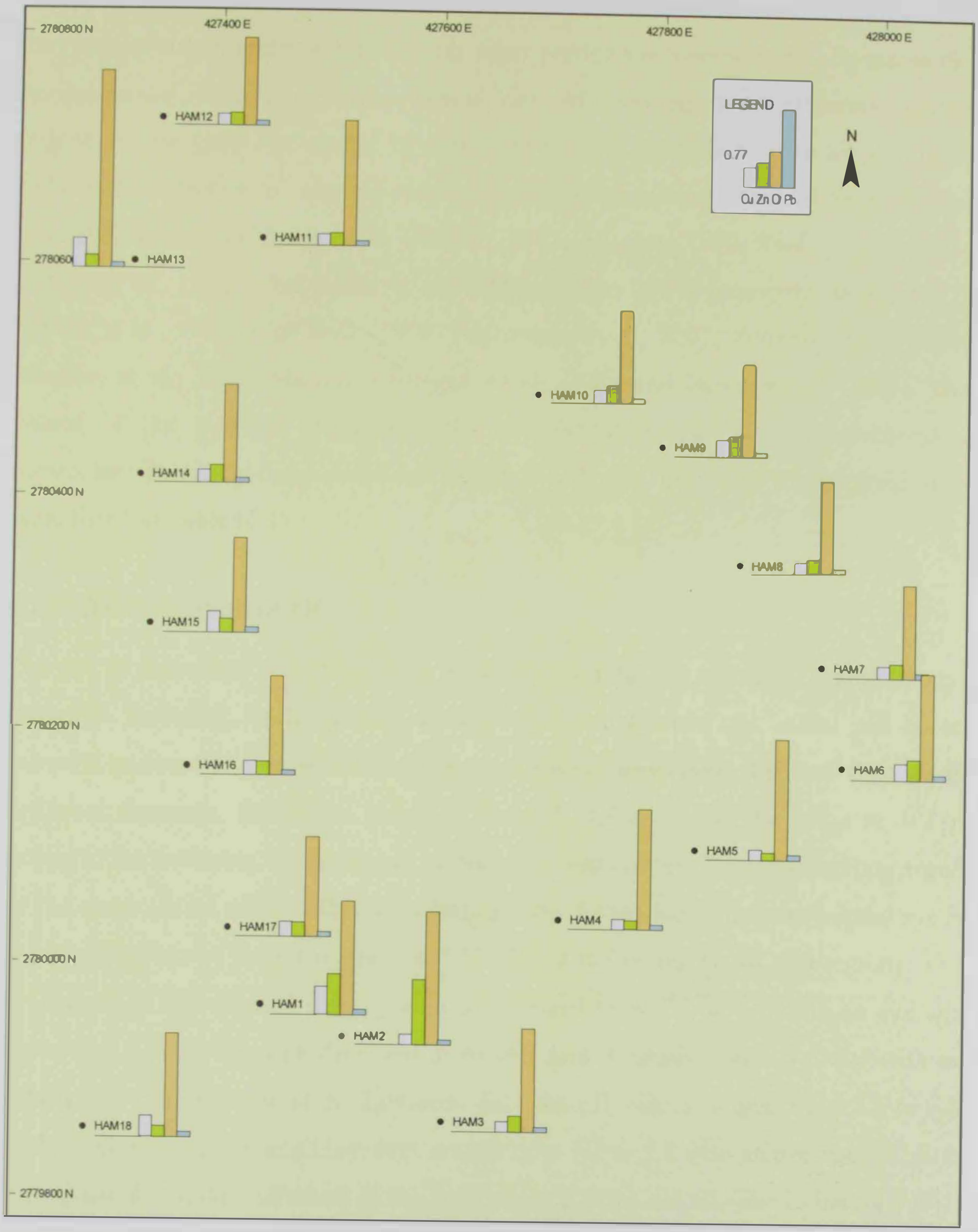


Figure 6.4. Spatial distribution of heavy metals Cu, Zn, Cr and Pb concentrations in Ham dam.

6.3. Controlling Physico-Chemical Parameters and their Impact on Metal Distribution

Metal distribution depends on the characteristics of the sediments, corresponds to the place of origin and association with other particles or compounds. To assess the environmental behavior and ecological risk of selected trace elements in the sediments, the good knowledge of certain sediments properties: such as pH, TDS, carbonate content, total organic matter, phosphours contents, and cation exchange capacity is required (Förstner and Wittman, 1983; Alloway, 1990; Szefer, et al., 1995; Loring et al., 1992; Chakrapani et al., 1993; Gabler, 1997; Izquierdo, et al., 1997; Patrick et al., 1998; Wen et al., 1999; Bachmann, et al., 2001; Zounnis, et al., 2001; Morillo, et al., 2002; Martinez-Villegas, et al., 2004 and Banat, et al., 2005). The values of the average, range and standard deviation for the physico-chemical parameters in ninety-three sediment samples collected from the investigated sites were listed in Table (6.1).

6.3.1. Determination of pH

The pH of sediments is controlled by many complex factors including microbiology, chemical buffering, hydrothermal activity and temperature. As such, pH is an essential parameter in understanding biogeochemical processes, chemical fluxes and sediment digenesis. Sediments generally have pH values within the range of 4–8.5, owing to the buffering by aluminum at the lower end and by $CaCO_3$ at the upper end of the range (Wild, 1988; Alloway, 1990). Brady (1984) stated that the normal pH is 5-7 in sediments of humid regions, and pH 7-9 in the sediments of arid regions. The pH values in investigated dams (Table 6.1) ranged from 7.2 to 8.6 with an average value of 7.8 in Al-Shuwieb dam, and in Al-Bih dam it ranges from 6.9 to 8.1 with an average of 7.4. Whereas in Al-Tawiyeen dam the pH values ranged from 7.3 to 7.8 with an average of 7.5, and Ham dam ranged from 7.2 to 7.8 with an average of 7.4. It can revealed that the sediments in the four selected dams are alkaline in nature due to $CaCO_3$ content which is not leached through the sediments because of the limited rainfall in the country. The sediments in UAE usually alkaline when pH is more than 7.0, normally ranges from 7.5 to 8.5 (Al-sheriani, 1998 and Al-Barshmgy, 2007).

Table 6.1. Average, range and standard deviation values for the major four dams

Dam	**Al-Shuwieb**			**Al-Bih**			**Al-Tawiyeen**			**Ham**		
	Average (N=41)	**Range**	**STD**	**Average** (N=23)	**Range**	**STD**	**Average** (N=11)	**Range**	**STD**	**Average** (N=18)	**Range**	**STD**
pH	7.8	7.2 – 8.6	0.4	7.4	6.9 – 8.1	0.3	7.5	7.3 – 7.8	0.1	7.4	7.2 – 7.8	0.2
TDS (ppm)	227.1	104.3 – 610.6	107.8	744.5	246.8 – 1813.8	495.4	564.9	183 - 935	228.1	337.8	190 – 447.2	76.1
$CaCO_3$ %	19.2	12.1 – 27.4	3.5	32.6	23.4 – 49.3	6.6	28.1	24.2 – 37.3	3.8	16.8	12.1 – 21.9	2.9
TOM %	2.22	0.2 – 6.3	1.4	5.0	2.5 – 7.4	1.4	5.4	3.8 – 7.3	0.9	4.6	2.3 – 7.0	1.6
P_2O_5 %	2.5	1.1 – 5.9	1.3	4.3	2.2 – 5.6	1.1	8.9	4.8 – 11.4	1.7	5.5	2.3 – 8.3	1.8
CEC	29.1	9.1 – 71.2	12.5	49.0	20.9 – 72.5	13.3	57.9	16.6 – 82.3	18.7	45.0	20 – 85.4	19.1

N : No. Of samples collected from each dam

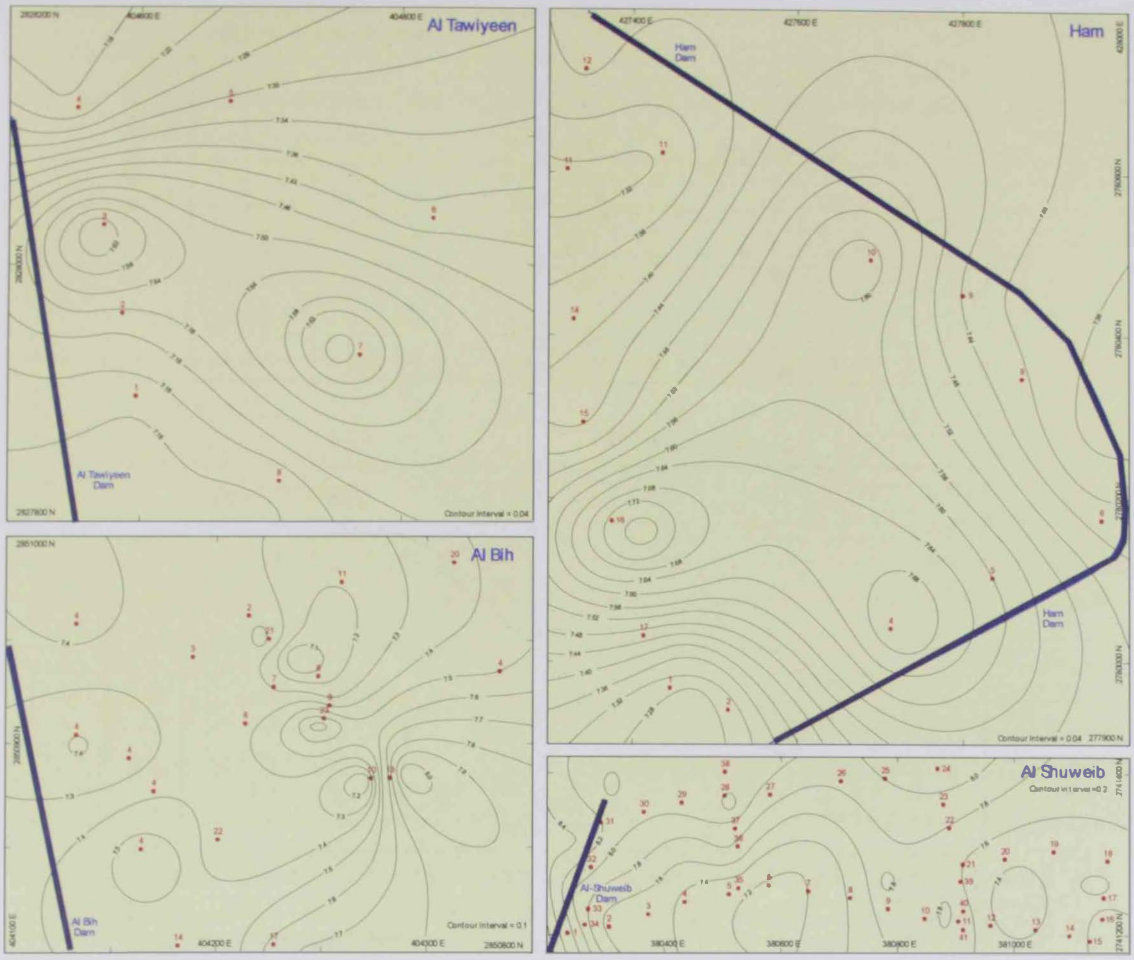


Figure 6.5. Geochemical maps of pH measured in sediments samples of the four dams.

The geochemical maps of pH distribution in collected sediment samples of the four dams as presented in Figure (6.5), showed that the pH values in Al-Shuweib dam increase from the east side toward the north side near the dam, whereas the rest of the dams its increase in the center of the dam. The pair wise correlations coefficients anlysis of the pH value with the analyzed metals in investigated dams are listed in Tables (6.2 – 6.5). It can revealed that the pH values has a negative correlation with the most analyzed metals, except a weak positive correlation with Cr in Al-Shuweib and Al-Tawiyeen dams, which seems that there is no effect of pH on the distribution of the analyzed metals. This might be ascribed to the alkaline nature of the investigated sediments samples where the most of trace metals occur in acidic nature (Alloway, 1990). By illustrating the relationship between the pH values and analyzed metals in Figure (6.6), it can be observed that most of the metals concentrated in the pH values ranged from 7.0 to 8.6. There is a slight increasing in the Cr trend with the increasing of pH values in Al-Shuweib and Al-Tawiyeen dams, where is no effect of pH values on the rest of analyzed metals.

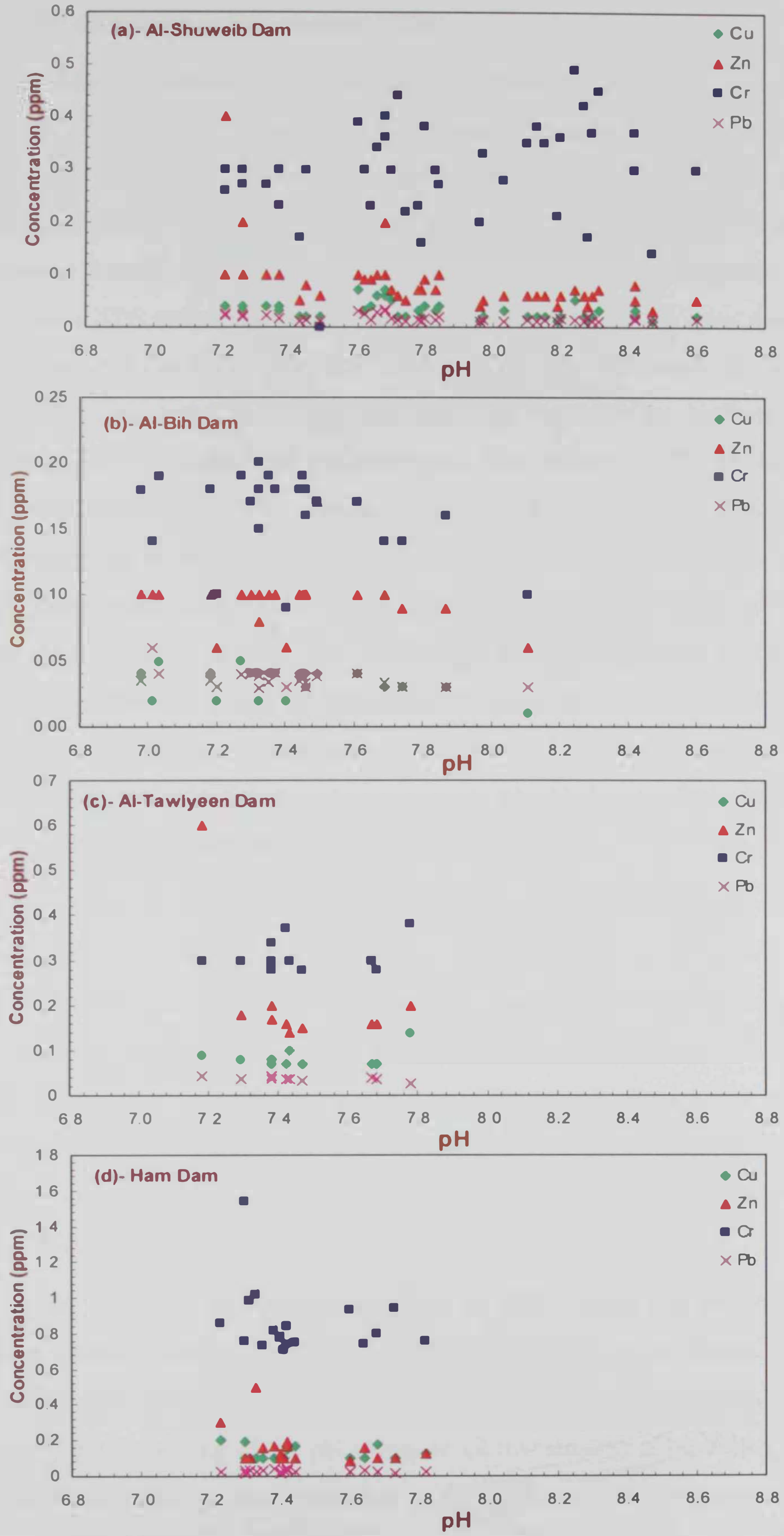


Figure 6.6. Relationship betweem the pH values and the analyzed metals in investigated dams.

6.3.2. Total dissolved solids content (TDS)

The TDS values in sediments collected from Al-Shuweib dam (Table 6.1) range from 104.3 to 610.6 ppm with an average of 227.1 ppm. The observation of low measuring values of TDS could be due to the characteristic of the sediments and grain size, which is gravely sand, silty sand and sandy gravel. This type of sediments accelerates the filtration process, thus decreases the pounding water, and consequently decreases the sediments TDS value. Moreover, the amount of the rain in the open desert area is rarely, which reduces the evaporation process. From the measured data among the investigated areas, it can be revealed that the TDS values in the northern region of UAE are higher compared with eastern region. The values of TDS in the sediment samples collected from Al-Bih dam ranged from 246.8 to 1813.8 ppm with an average of 744.5 ppm and in Al-Tawiyeen dam ranged from 183 to 935 ppm with an average of 564.9 ppm, while in Ham dam the values of TDS ranged from 190.1 to 447.2 ppm with an average of 337.8 ppm. This increase of TDS values could be explained by high amount of the rain during the year in the northern region, which is close to Oman Mountains. The sedimentological analyses support this explanation, where the sandy silty sand grain size and clay minerals are more presented in northern region, which reduce the filtration process and increase the evaporation process of the rainwater.

The display of TDS values in geochemical map (Figure 6.7) showed that the high range of TDS values distributed is concentrated in the southwest side of Al-Bih dam and decreased toward the north where the rain water is remain near the dam (Figure 1.3). In Al-Tawiyeen dam, the value of TDS concentrated in the northern side and reduced near the dam side as also the rain water remain closer to the dam (Figure 1.4). Whereas, in Ham dam, the measured values of TDS presented in the bottom side and in Al-Shuwieb dam increase from the east side and decreased in the west side closer to the dam.

In Figure (6.8), the relationship between the TDS values and pH values of the sediments samples collected from the investigated dams has been plotted to examine the effect of each other. It can be observed that there is a clear decreasing of the TDS values with the increasing of the pH values in all investigated sites, which seems that there is an effect of pH on the distribution of TDS values in the measured samples.

In Tables (6.2 – 6.5), pair wise correlations coefficient analysis has been applied on the values of the TDS measured in sediments samples to examine the effect of the TDS parameter on the distrubiton of the analyzed metals. It revealed that there is a weak positive correlation with most of measured metals in the investigated samples, which indicates that there is a slight TDS effect on the distribution of these metals. By plloting the relationship of TDS values with analyzed metals in Figure (6.9), it can illustrate that most of the metals concentrated in the range of 100 – 500 ppm in all investigated dams except in Al-Bih dam, which has the highest TDS content. There is no significant effect of the TDS values on the ternd of analyzed metals.

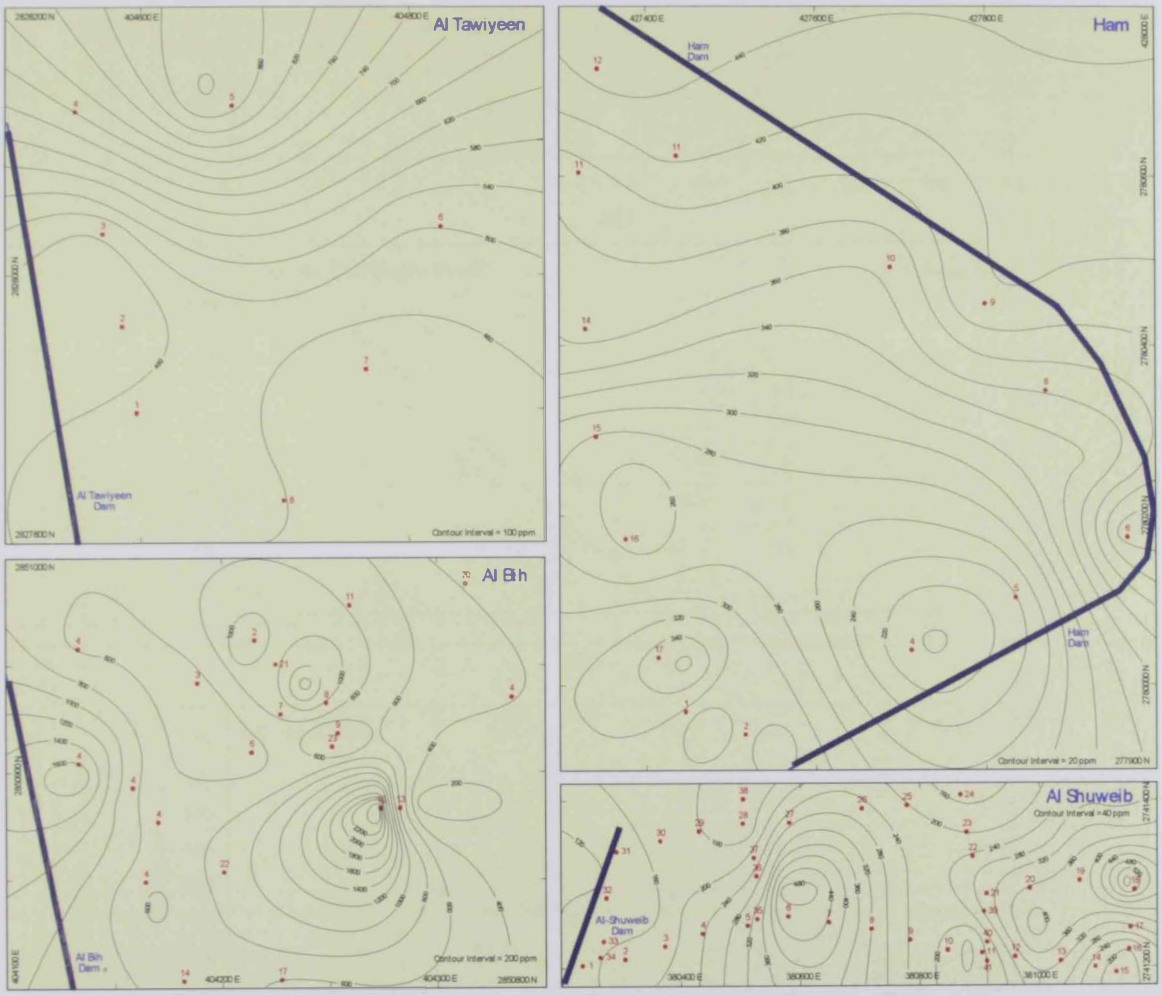


Figure 6.7. Geochemical maps of TDS measured in sediments samples of the investigated dams.

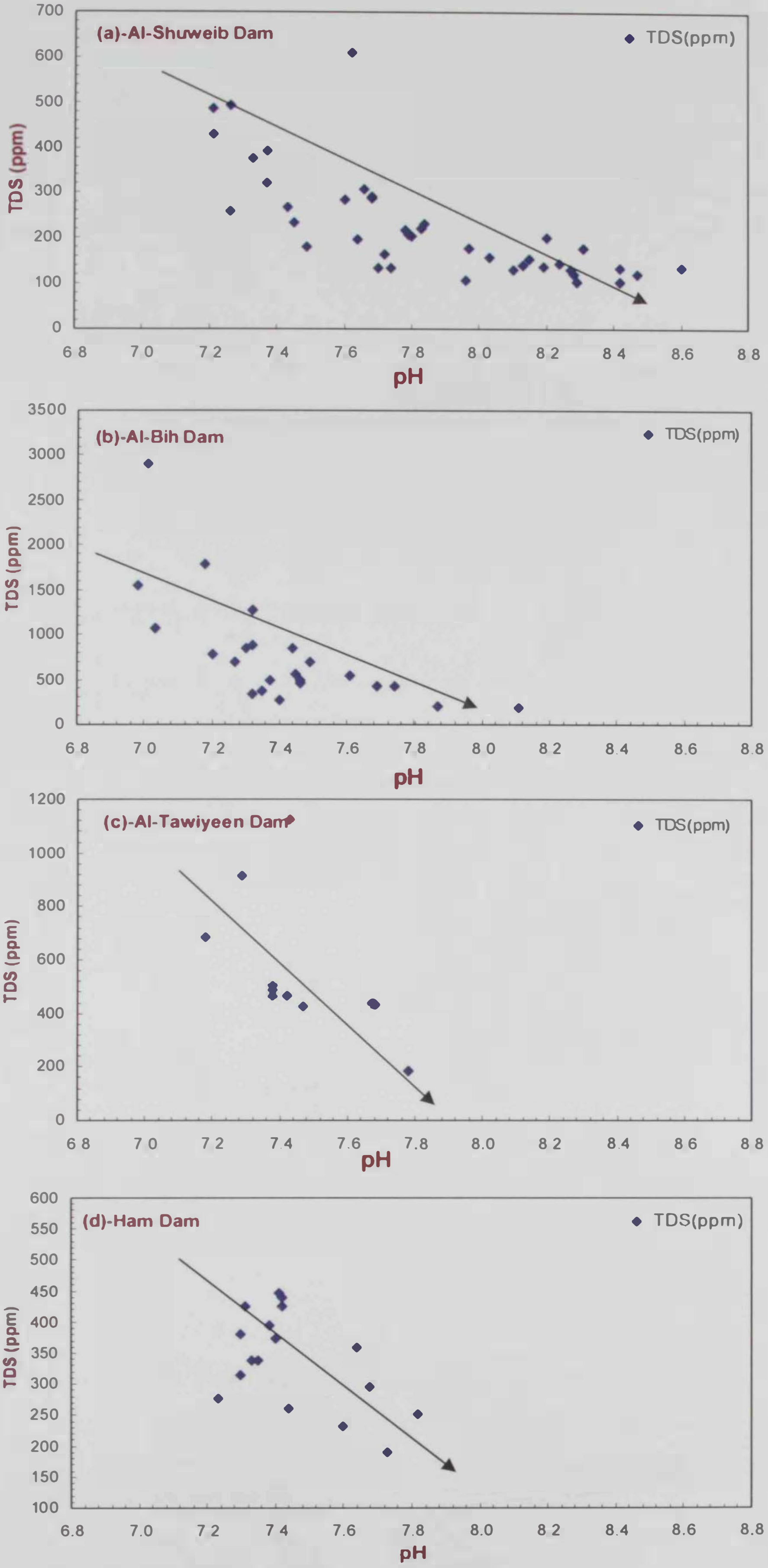


Figure 6.8. Relationship betweem the pH values and the TDS values in investigated dams.

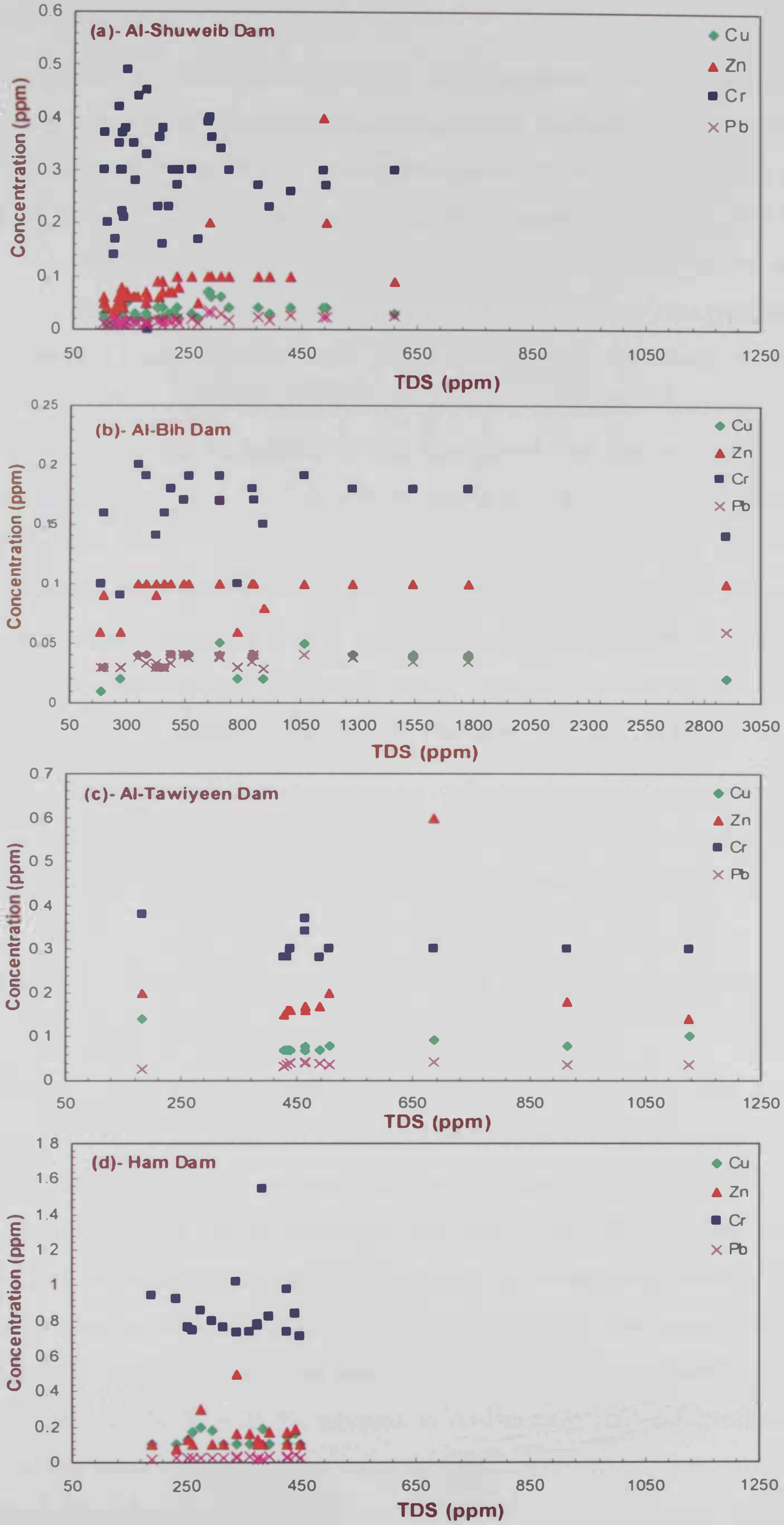


Figure 6.9. Relationship betweem the TDS values and the analyzed metals in investigated dams.

6.3.3. Total carbonate content (CO_3%)

Carbonates occur as a major component in the fine-grained fraction of sediments (Förstner and Wittman, 1983). The carbonate content in the sediments of Al-Shuweib dam ranged from 12.1% to 27.4% with an average of 19.2%, in Al-Bih dam ranged from 23.4% to 49.3% with an average of 32.6%, whereas, in Al-Tawiyeen ranged from 24.2% to 37.3% with an average of 28.1%, and from 12.1% to 21.9% with an average of 16.8%, in Ham dam as listed in Table (6.1). Generally, the percentage of calcium carbonate ($CaCO_3$) content is very high in UAE and ranges between 25-40% (Al-Barshmgy, 2007) mainly due to the natural carbonate based lithological formation. For example, Al-Belushi (1998) mentioned that the aeolian carbonate particles are presumed to have been derived during former high latitude glaciations from an exposed shallow sea floor beyond the present Oman coast. The calcium carbonate content can be derived as calstics of pre-existing limestones, such as in Al-Shuweib dam, reprecipitated as surface sediments due to evaporation of bicarbonate-rich groundwater, and broken calcareous shells, especially in sediments along the landstretch of Oman Mountains in Al-Bih, Al-Tawiyeen and Ham dams.

From the geochemical map in Figure (6.7) for the ($CaCO_3$) content, it can observe that Al-Bih dam has the highest of ($CaCO_3$) content and increase in the east side of the dam. Whereas, in Al-Shuweib dam the ($CaCO_3$) content distribution increase around the dam and concentrated near the dam. In Al-Tawiyeen the ($CaCO_3$) content increase in the east side and in Ham dam it concentrated in the west side of the dam.

The pair wise correlations coefficient analysis of ($CaCO_3$) values listed in Tables (6.2 – 6.5). The correlations showed a negative correlation with all analyzed metals in investigated dams except a very weak positive correlation of Pb in Al-Shuweib sediment samples, which can be concluded that there is no effect of $CaCO_3$ on the distribution of the analyzed metals. The result of the correlations analysis can be supported by plotting the relationship between the $CaCO_3$ and the analyzed metals in Figure (6.11). It can illustrate that the analyzed metals in Al-Shuweib and Ham dams concentrate between 10 % – 25 %, whereas in Al-Bih and Al-Tawiyeen dams, it is above 25%, and there is no significant effect of the $CaCO_3$ content on the distribution trend of the analyzed metals.

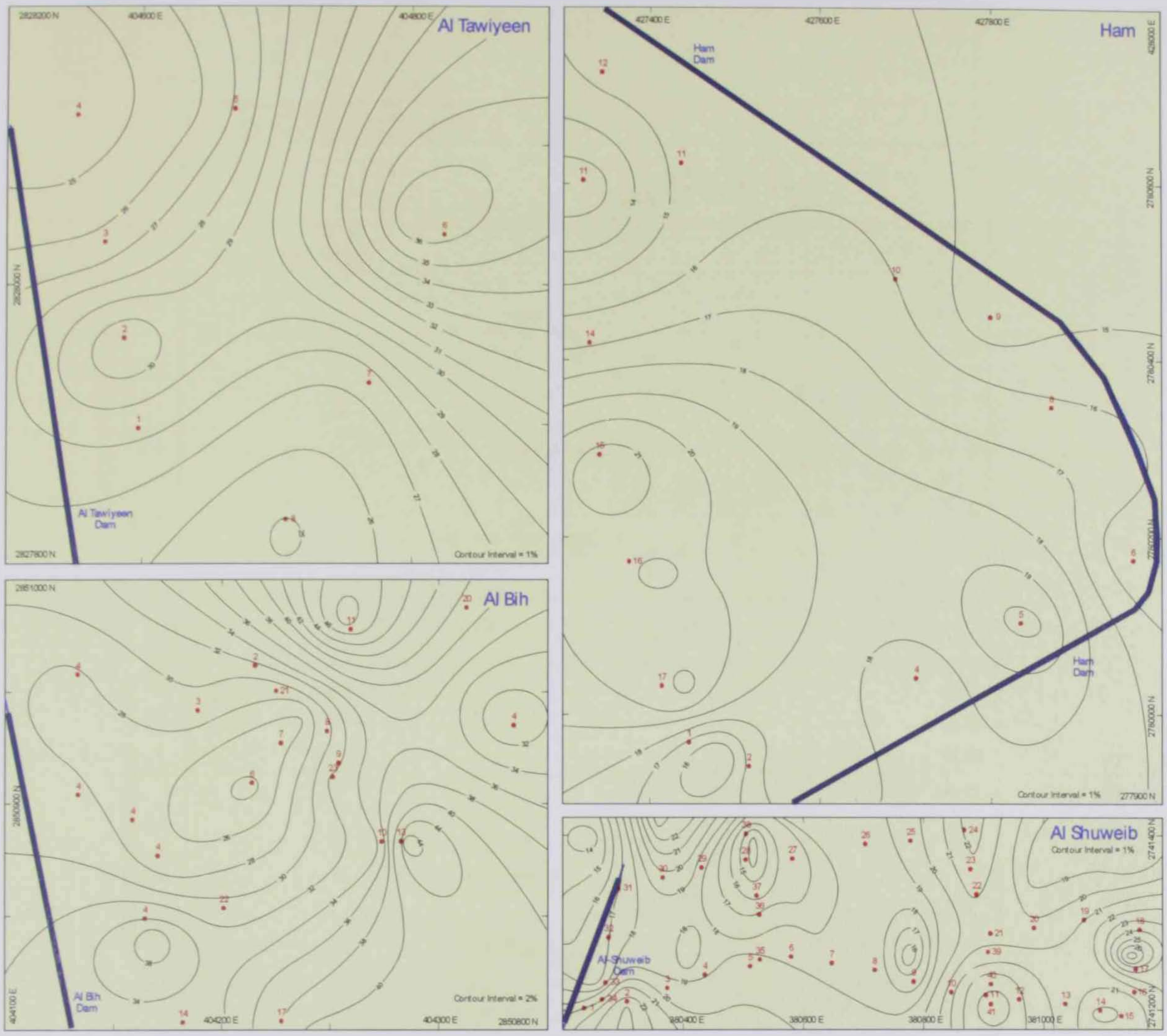


Figure 6.10. Geochemical maps of (CO_3%) measured in sediments samples of the investigated dams.

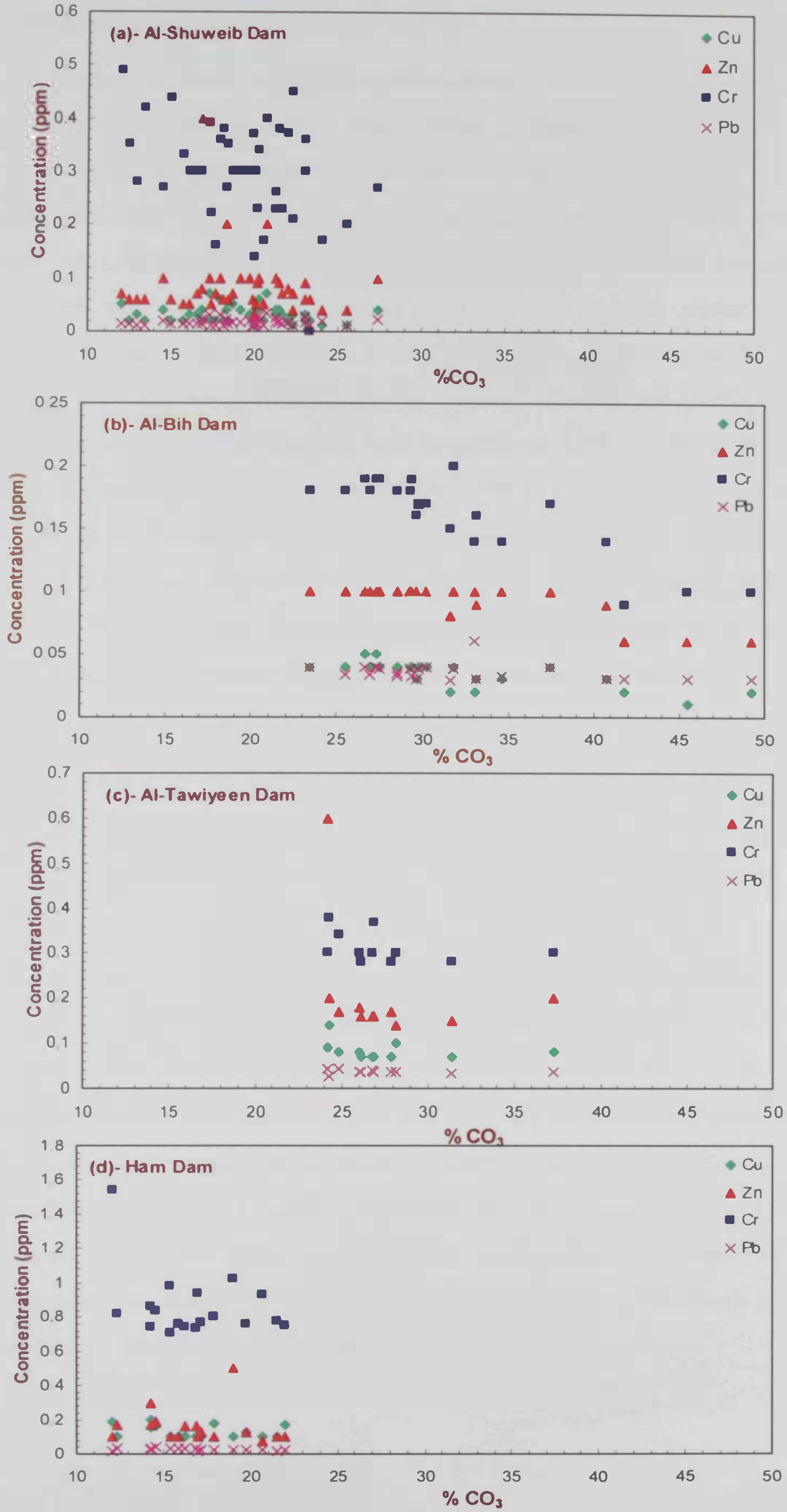


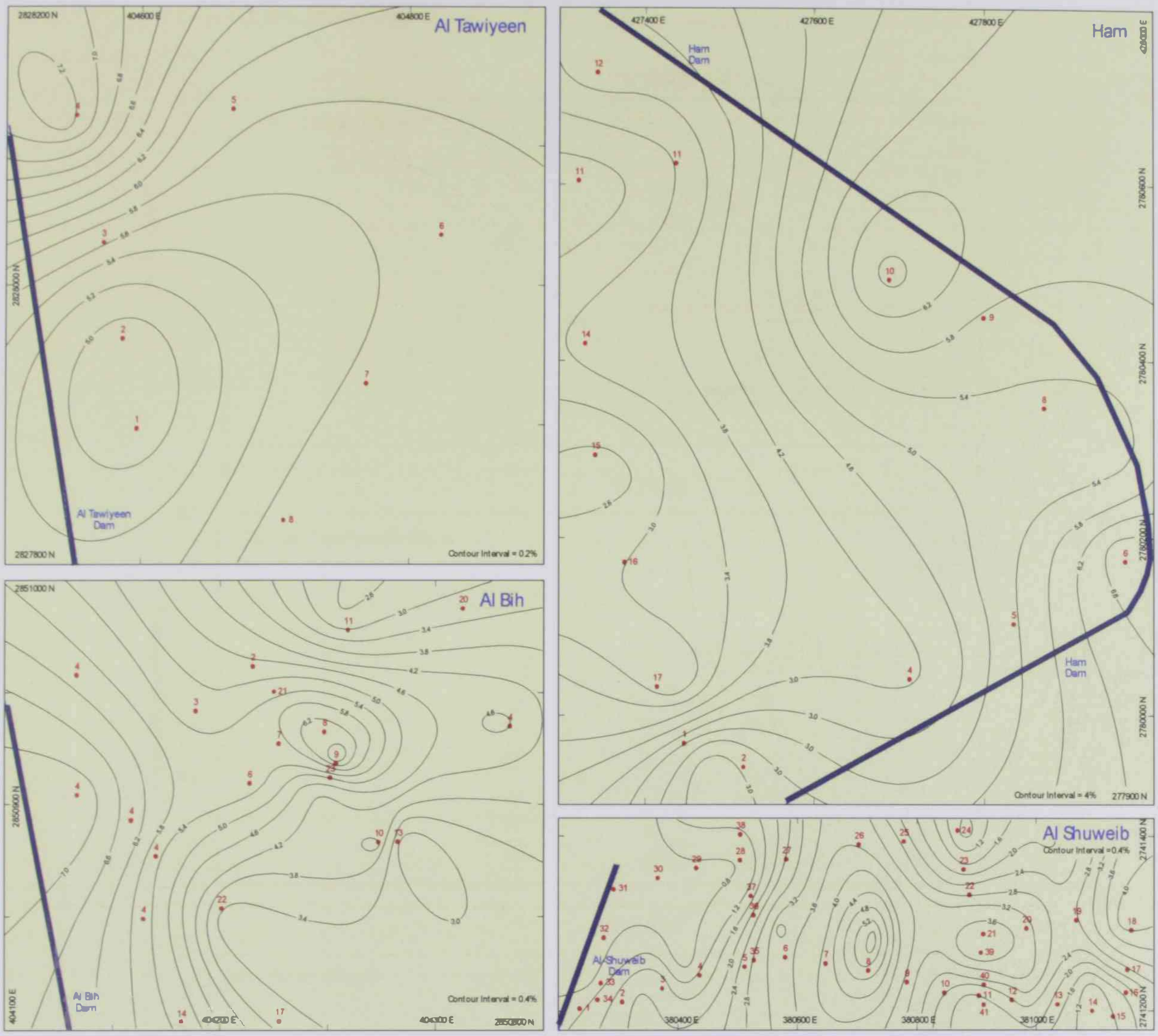
Figure 6.11. Relationship betweem the (CO_3%) values and the analyzed metals in investigated dams.

6.3.4. Total organic matter content (TOM %)

Organic matter contributes to the physical condition of sediments by holding moisture and by affecting structure. It is a direct source of plant nutrient elements and the release of which depends upon microbial activity and the organic matter is directly involved in the availability of nutrient elements due to the effect of cation exchange capacity. All soils and sediments contain organic matter, although the amount and the type maybe vary considerably (Alloway, 1990). The organic matter content is determined to assess the played role of organic faction of sediment in the transport, deposition and retention of trace metals (Loring and Rantalia, 1992). The percentage of total organic matter of Al-Shuweib dam ranged from 0.2% to 6.3% with an average of 2.2%. Whereas in Al-Bih dam ranged from 2.5% to 7.4% with an average of 5.0%, moreover, in Al-Tawiyeen dam the TOM% ranged from 3.8% to 7.3% with an average of 5.4%, and from 2.3% to 7.0%, with the average of 4.6% in Ham dam (Table 6.1). The percentage of organic substance in UAE sediments is very low due to hot climate and quick decomposition of organic substance (Al-Barshmgy, 2007).

The display of TOM values in geochemical map (Figure 6.12) showed the highest distribution of the TOM content in Al-Shuwieb dam in the center of the dam whereas, in Al-Bih dam and Al-Tawiyeen dams it increase in the northern side of the dam. Moreover, in Ham dam most of the TOM values concentrated along the dam side.

Tables (6.2 – 6.5) showed the pair wise correlation coefficient analysis of the TOM values with the analyzed metals in the investigated dams. It can revealed that there is a positive correlations coefficient of TOM values with most analyzed metals among the dams samples, which indicate that there is a TOM effect on the distribution of these metals. This result can be observed clearly from the relationship between the parameter and the analyzed metals in Figure (6.13). The Zn and Pb showed increasing trend in all investigated dams, whereas the Cr increase in Al-Bih dam and has no effect in other investigated dams. The Copper increased in Al-Shuweib and Al-Bih dams whereas, there is no effect in both Al-Tawiyeen and Ham dams.



Al Tawiyeen

Ham

Al Bih

Al Shuweib

Figure 6.12. Geochemical maps of (TOM%) measured in sediments samples of the investigated dams.

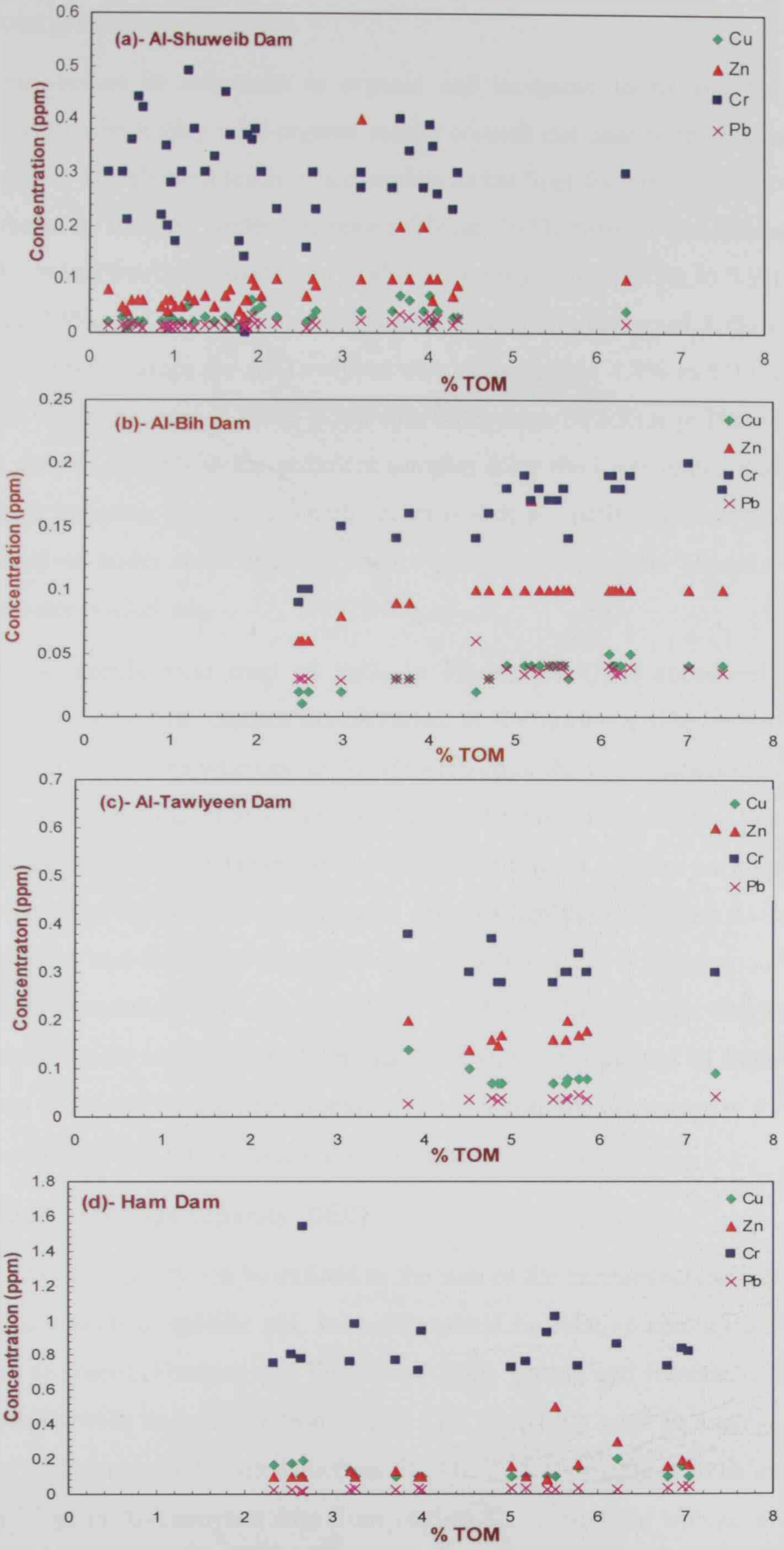


Figure 6.13. Relationship betweem the (TOM%) values and the analyzed metals in investigated dams.

6.3.5. Total phosphate (P_2O_5 %)

Phosphorus occurs in sediments in organic and inorganic forms and the relative proportions of which vary with organic matter content but usually the organic forms predominated. The element tends to accumulate in the finer fractions of sediments and thus increases as the clay content increases (Hesse, 1972; Norrish and Rosser, 1983). The P_2O_5 content in Al-Shuweib dam (Table 6.1), ranged from 1.1% to 5.9% with an average of 2.5%, and ranged from 2.2% to 5.6% with an average of 4.3% in Al-Bih dam. The P_2O_5 % values for Al-Tawiyeen dam ranged from 4.8% to %11.4 with an average of %8.9 and from 2.3% to 8.3% with an average of 5.53% in Ham dam. The deficient content of P_2O_5 in the sediment samples from the investigated dams would be related to inorganic phosphate which occurs mainly as apatite (calcium phosphate), which dissolves under acidic medium, hence plant can not uptake phosphates when sediment water is alkaline.

From the geochemical map of P_2O_5 in Figure (6.14), it aboserved that the distribution of phosphate content concentrated in the northern side of Al-Bih, Al-Tawiyeen and Ham dams whereas, in Al-Shuwieb dam, the P_2O_5 increased in the east side of the dam and concentrated in the middle of the dam. The pair wise correlations of P_2O_5 values listed in the Tables (6.2 – 6.5) and showed a positive correlation with the most analyzed metals in all investigated dams except the Cr in both Al-Tawiyeen and Ham dams and Cu in Al-Tawiyeen dam, which showed a negative correlation. The positive correlation indicates that there is a P_2O_5 effect on the distribution of these metals, which is observed clearly in the relationship plotted in Figure (6.15) where most of the metals showed increasing in trend with the increasing of P_2O_5 value except the Cr in both Al-Tawiyeen and Ham dams.

6.3.6. Cation exchange capacity (CEC)

Cation exchange capacity can be defined as the sum of the exchangeable cations that a mineral can adsorb at specific pH. It is determined by relative amount of different colloids in sediment (Förstner and Wittmann, 1983; Loring and Rantala, 1992). The CEC in Al-Shuweib dam varied from 9.1 to 71.2 meq/100g with an average of 29.1 meq/100g; and ranges in Al-Bih dam from 20.9 to 72.5 meq/100g with an average of 49.0 meq/100g, in Al-Tawiyeen dam from 16.6 to 82.3 meq/100g with an average of 57.9 meq/100g, and in Ham dam varied from 20.0 to 85.4 meq/100g with an average of 45.0 meq/100g as listed in Table (6.1).

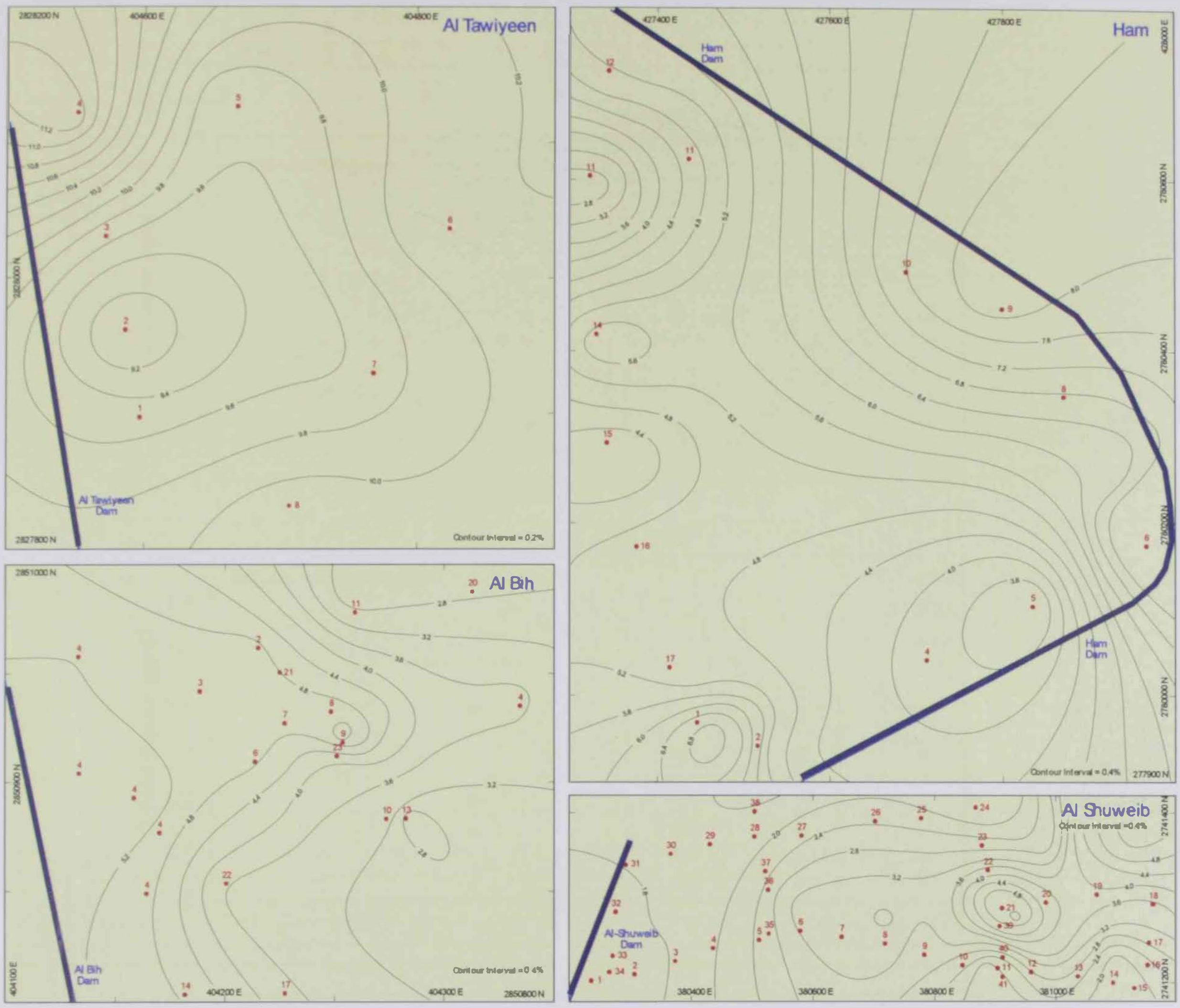


Figure 6 14. Geochemical maps of (P_2O_5%) measured in sediments samples of the investigated dams.

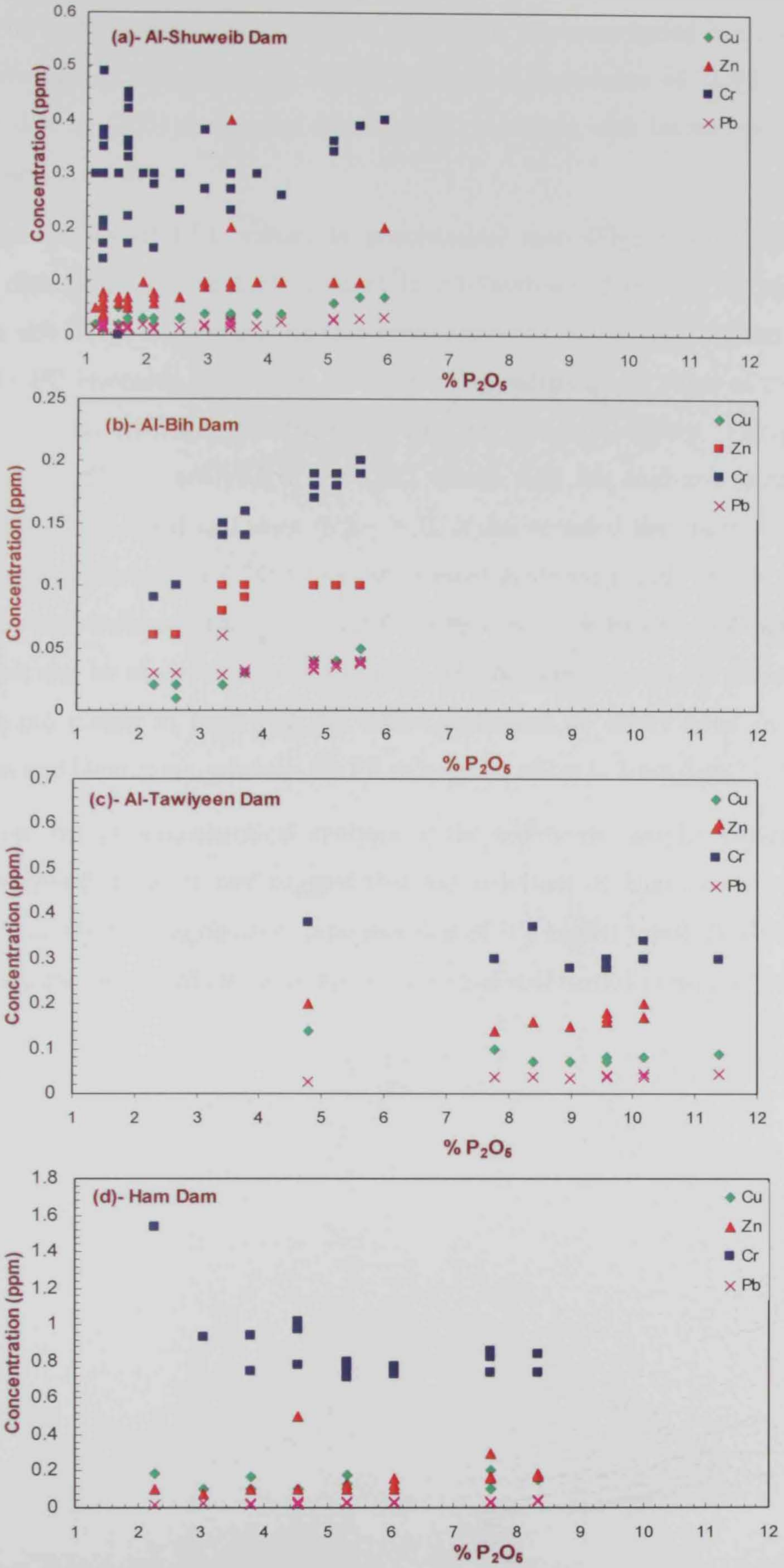


Figure 6.15. Relationship betweem the (P_2O_5%) values and the analyzed metals in investigated dams.

The CEC values along the tested stations in the investigated dams sediments has a low values, which may be related to the less abundance of TOM content as Brady and Weil (2001) suggested that the CEC increases with increasing pH, TOM and calcium content.

The display of CEC values in geochemical map (Figure 6.16) showed the highest distribution of the CEC content in Al-Tawiyeen dam and increase in the northern side of the dam where the rain water remains (Figure 1.4). In Ham dam, the value of CEC increased in the west side of the dam whereas, the value of the CEC in Al-Shuwieb and Al-Bih concentrated in the east side of the dam. The pair wise correlation coefficient analysis of the CEC values with the analyzed metals in the investigated dams listed in Tables (6.2 – 6.5). It can revealed that there is a positive correlations coefficient of CEC values with most analyzed metals among the dams samples, which indicates that there is a CEC effect on the distribution of these metals. This result can be observed clearly from the relationship between the parameter and the analyzed metals in Figure (6.17). The Cr showed no effect trend in both Al-Tawiyeen and Ham dams, whereas the Pb showed no effect in Ham dam.

From the physico-chemical analysis of the sediments samples collected from the investigated dams, it can suggest that the sediment of Ham dam is the most suitable sediments for agriculture purposes due of it's higher value of Total organic content and the present of clay menials as a result of sedimentological analysis.

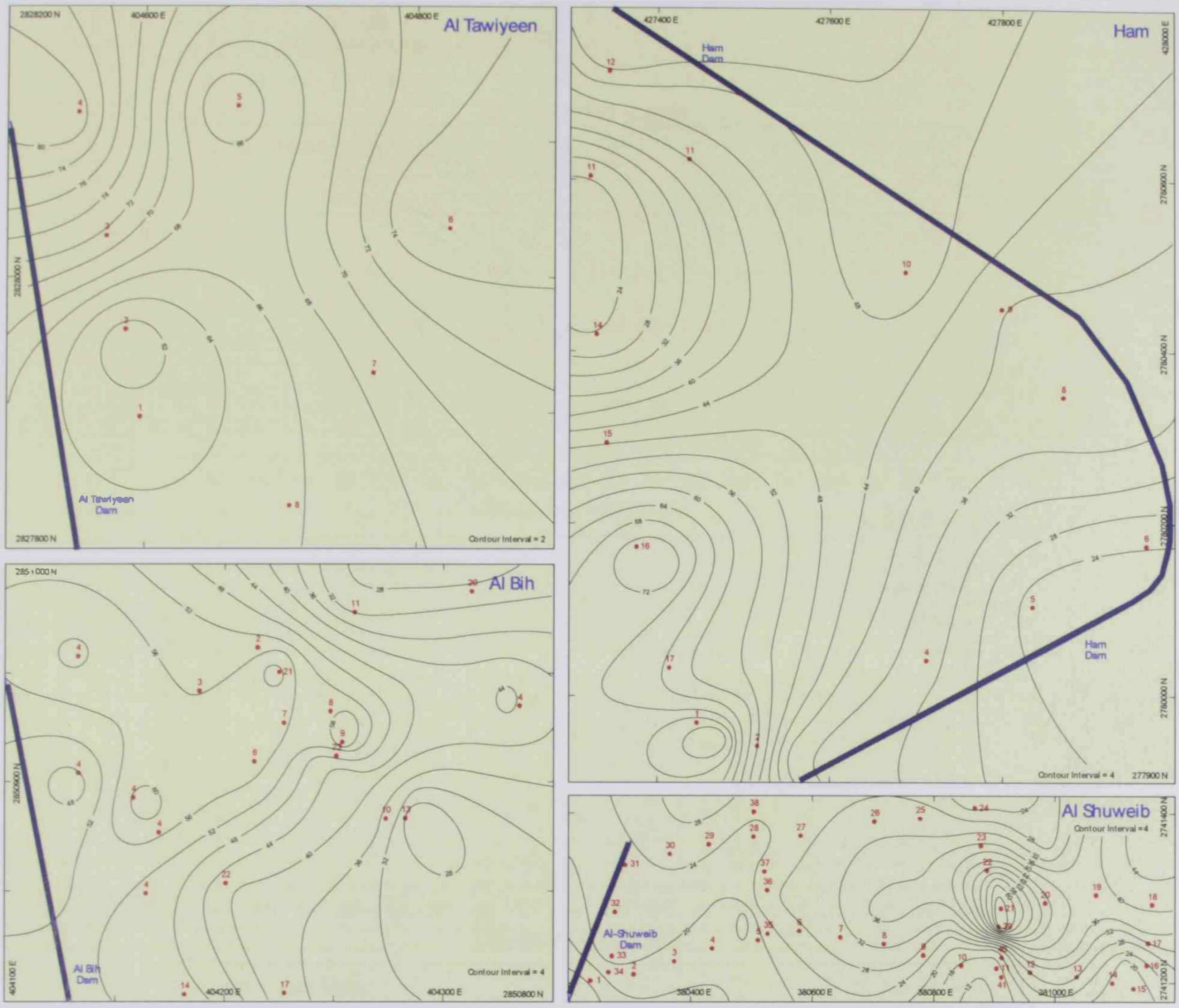


Figure 6.16. Geochemical maps of (CEC) measured in sediments samples of the investigated dams.

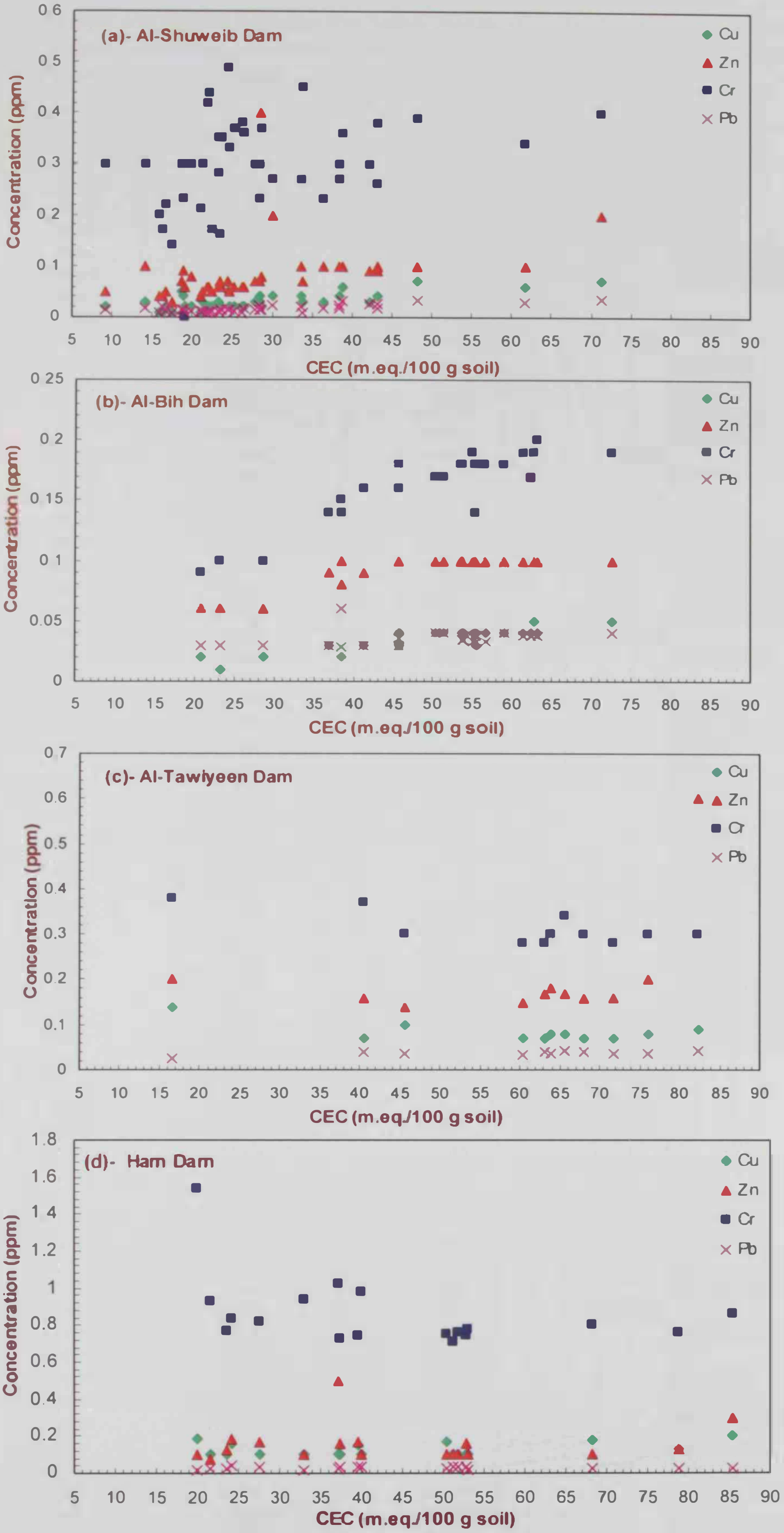
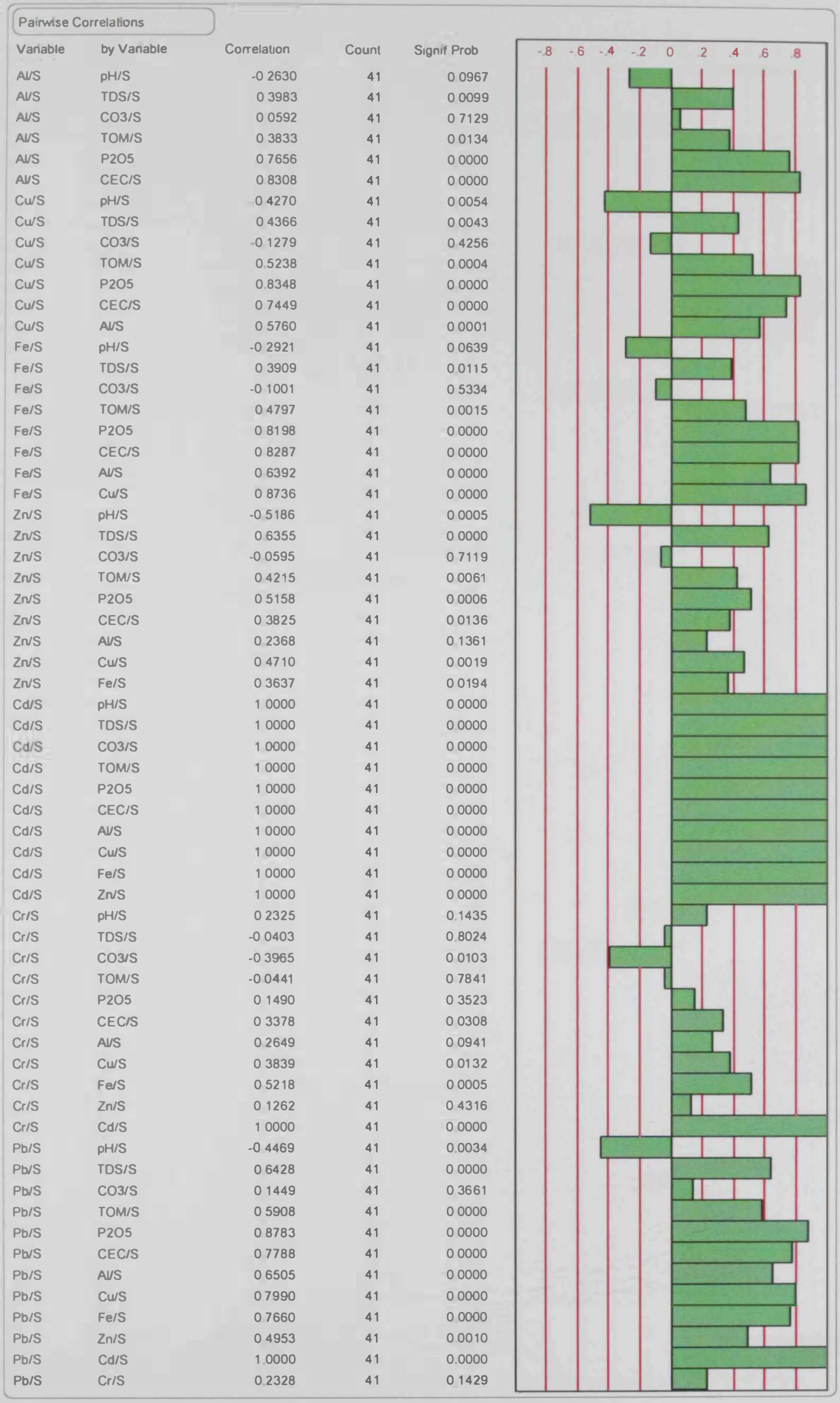


Figure 6.17. Relationship betweem the (CEC) values and the analyzed metals in investigated dams.

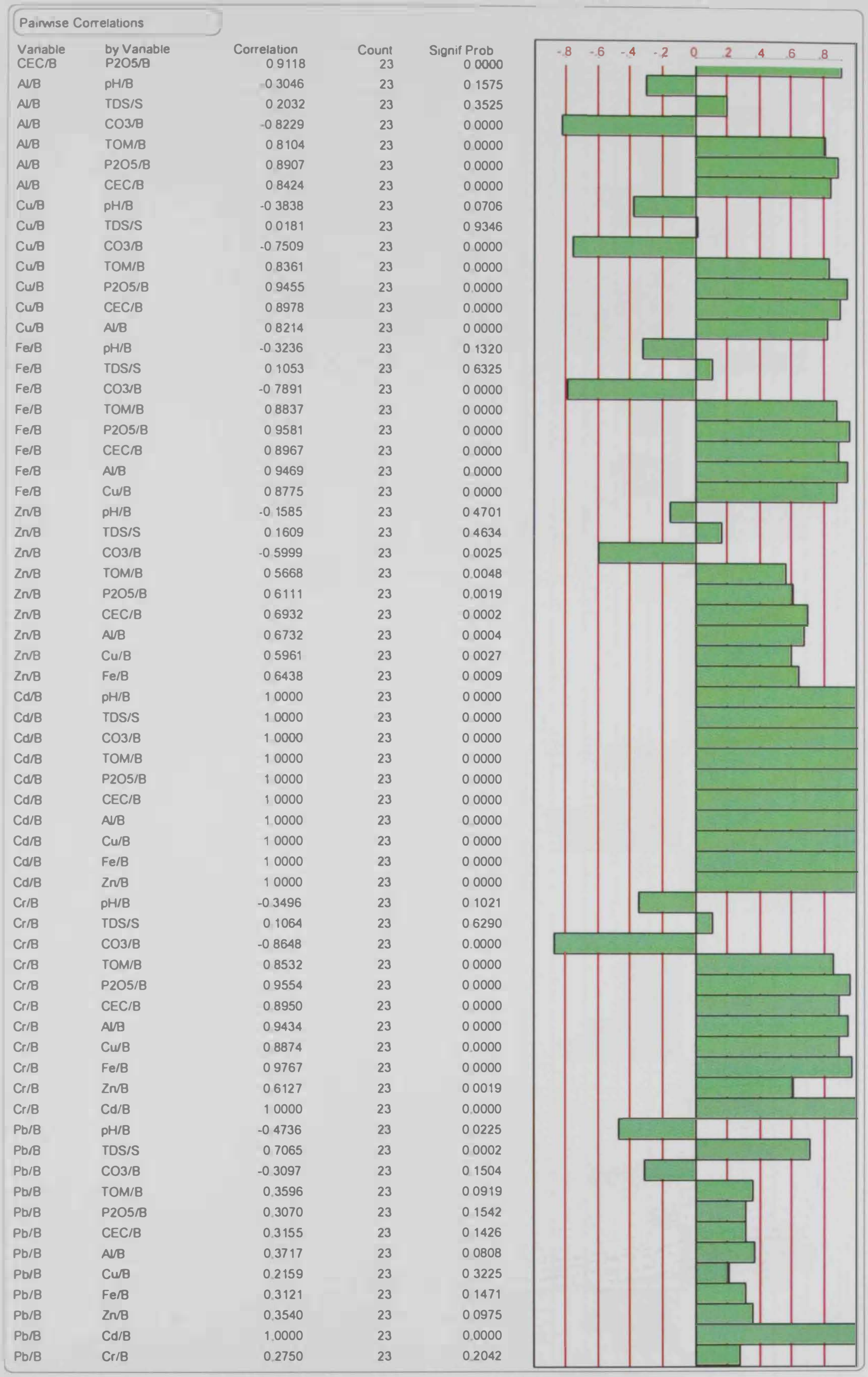
Table 6.2. Pair wise correlation between the heavy metals (Cu, Zn, Cd, Cr and Pb) with the pollution controlling parameters (pH, TDS, $CaCO_3$, TOM, P_2O_5 and CEC) for Al Shuweib dam S: Shuweib



Pairwise Correlations

Variable	by Variable	Correlation	Count	Signif Prob
Al/S	pH/S	-0.2630	41	0.0967
Al/S	TDS/S	0.3983	41	0.0099
Al/S	CO3/S	0.0592	41	0.7129
Al/S	TOM/S	0.3833	41	0.0134
Al/S	P2O5	0.7656	41	0.0000
Al/S	CEC/S	0.8308	41	0.0000
Cu/S	pH/S	-0.4270	41	0.0054
Cu/S	TDS/S	0.4366	41	0.0043
Cu/S	CO3/S	-0.1279	41	0.4256
Cu/S	TOM/S	0.5238	41	0.0004
Cu/S	P2O5	0.8348	41	0.0000
Cu/S	CEC/S	0.7449	41	0.0000
Cu/S	Al/S	0.5760	41	0.0001
Fe/S	pH/S	-0.2921	41	0.0639
Fe/S	TDS/S	0.3909	41	0.0115
Fe/S	CO3/S	-0.1001	41	0.5334
Fe/S	TOM/S	0.4797	41	0.0015
Fe/S	P2O5	0.8198	41	0.0000
Fe/S	CEC/S	0.8287	41	0.0000
Fe/S	Al/S	0.6392	41	0.0000
Fe/S	Cu/S	0.8736	41	0.0000
Zn/S	pH/S	-0.5186	41	0.0005
Zn/S	TDS/S	0.6355	41	0.0000
Zn/S	CO3/S	-0.0595	41	0.7119
Zn/S	TOM/S	0.4215	41	0.0061
Zn/S	P2O5	0.5158	41	0.0006
Zn/S	CEC/S	0.3825	41	0.0136
Zn/S	Al/S	0.2368	41	0.1361
Zn/S	Cu/S	0.4710	41	0.0019
Zn/S	Fe/S	0.3637	41	0.0194
Cd/S	pH/S	1.0000	41	0.0000
Cd/S	TDS/S	1.0000	41	0.0000
Cd/S	CO3/S	1.0000	41	0.0000
Cd/S	TOM/S	1.0000	41	0.0000
Cd/S	P2O5	1.0000	41	0.0000
Cd/S	CEC/S	1.0000	41	0.0000
Cd/S	Al/S	1.0000	41	0.0000
Cd/S	Cu/S	1.0000	41	0.0000
Cd/S	Fe/S	1.0000	41	0.0000
Cd/S	Zn/S	1.0000	41	0.0000
Cr/S	pH/S	0.2325	41	0.1435
Cr/S	TDS/S	-0.0403	41	0.8024
Cr/S	CO3/S	-0.3965	41	0.0103
Cr/S	TOM/S	-0.0441	41	0.7841
Cr/S	P2O5	0.1490	41	0.3523
Cr/S	CEC/S	0.3378	41	0.0308
Cr/S	Al/S	0.2649	41	0.0941
Cr/S	Cu/S	0.3839	41	0.0132
Cr/S	Fe/S	0.5218	41	0.0005
Cr/S	Zn/S	0.1262	41	0.4316
Cr/S	Cd/S	1.0000	41	0.0000
Pb/S	pH/S	-0.4469	41	0.0034
Pb/S	TDS/S	0.6428	41	0.0000
Pb/S	CO3/S	0.1449	41	0.3661
Pb/S	TOM/S	0.5908	41	0.0000
Pb/S	P2O5	0.8783	41	0.0000
Pb/S	CEC/S	0.7788	41	0.0000
Pb/S	Al/S	0.6505	41	0.0000
Pb/S	Cu/S	0.7990	41	0.0000
Pb/S	Fe/S	0.7660	41	0.0000
Pb/S	Zn/S	0.4953	41	0.0010
Pb/S	Cd/S	1.0000	41	0.0000
Pb/S	Cr/S	0.2328	41	0.1429

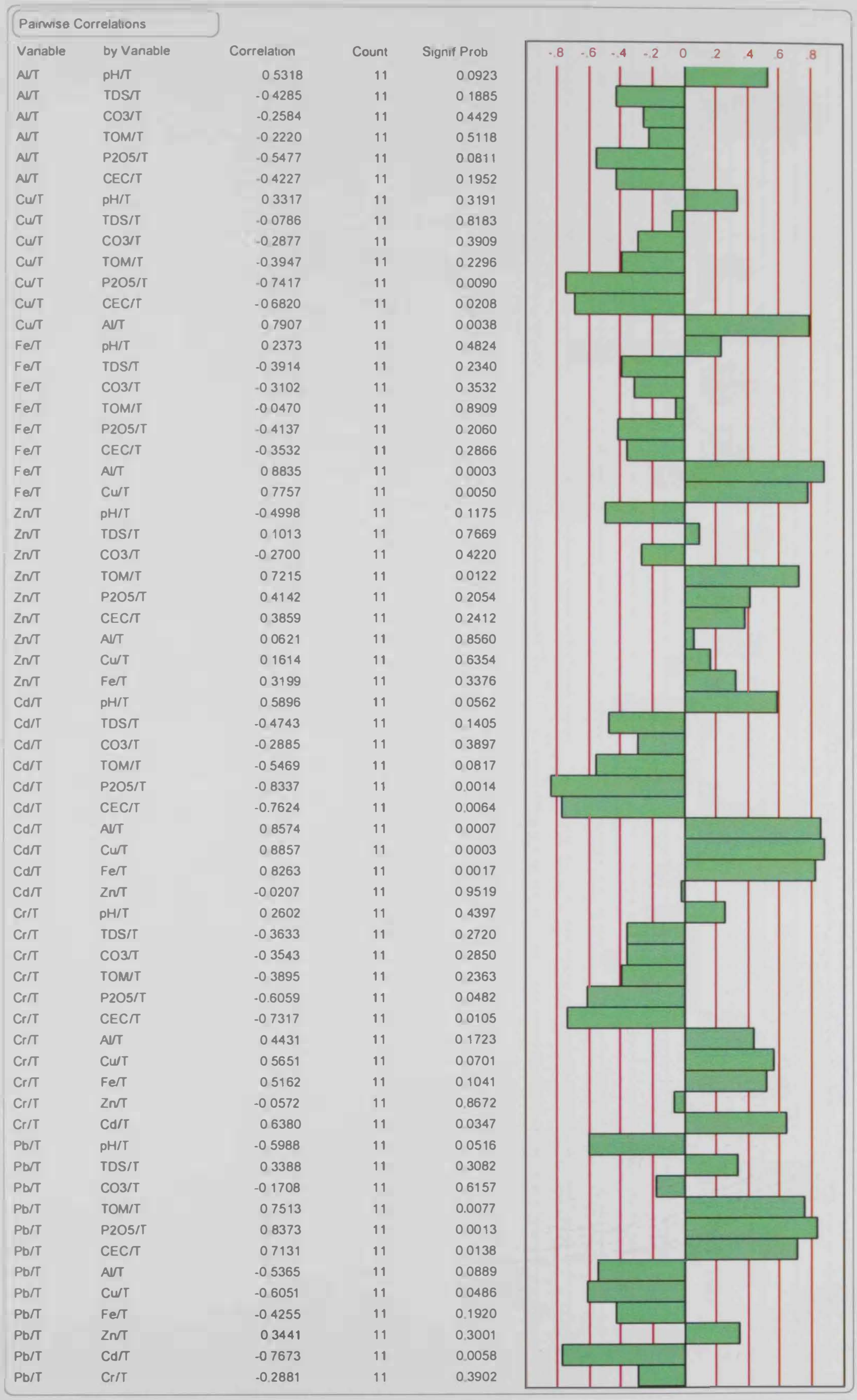
Table 6.3 Pair wise correlation between the heavy metals (Cu, Zn, Cd, Cr and Pb) with the pollution controlling parameters (pH, TDS, Ca CO_3, TOM, P_2O_5 and CEC) for Al Bih dam B Bih



Pairwise Correlations

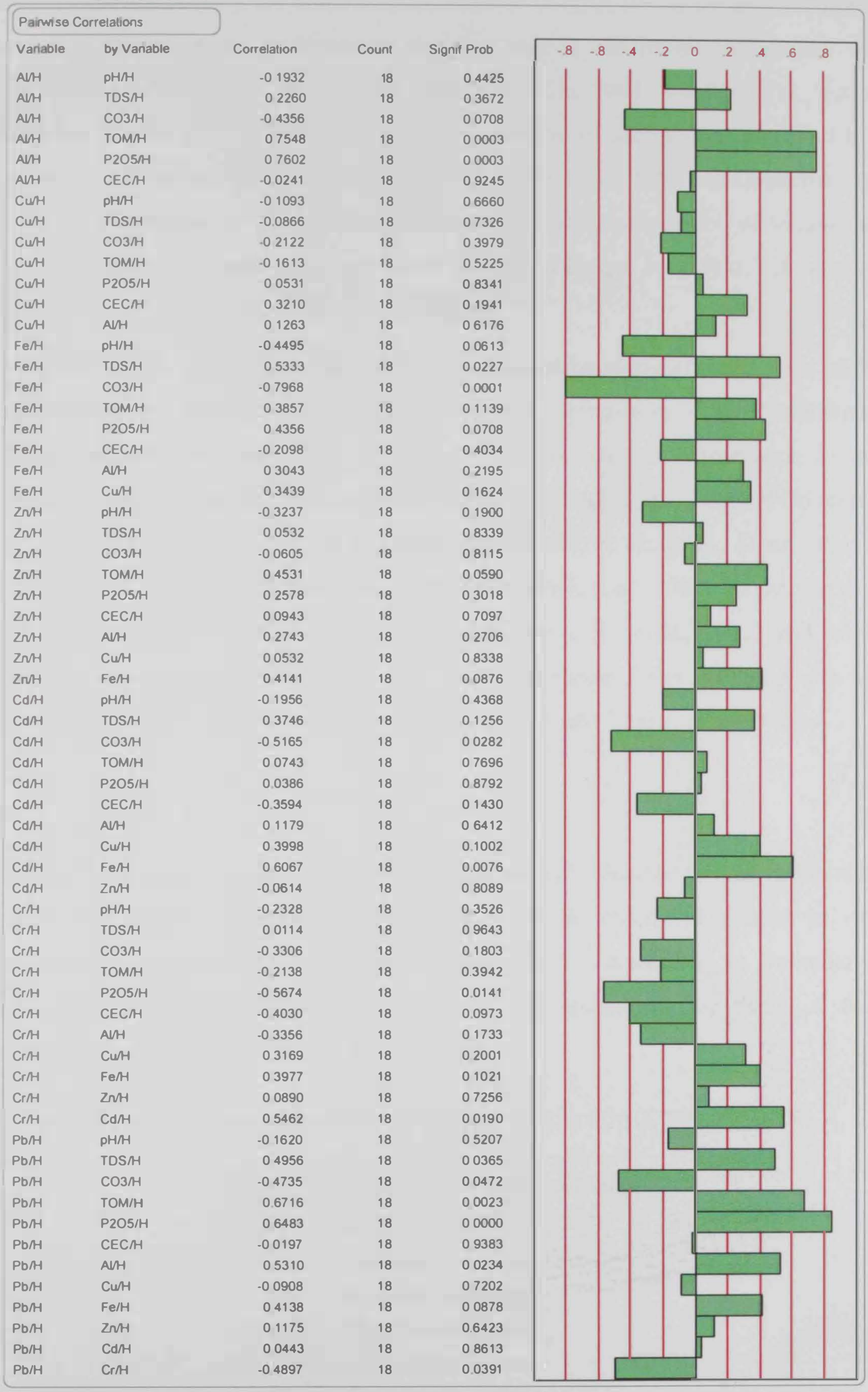
Variable	by Variable	Correlation	Count	Signif Prob
CEC/B	P2O5/B	0.9118	23	0.0000
Al/B	pH/B	-0.3046	23	0.1575
Al/B	TDS/S	0.2032	23	0.3525
Al/B	CO3/B	-0.8229	23	0.0000
Al/B	TOM/B	0.8104	23	0.0000
Al/B	P2O5/B	0.8907	23	0.0000
Al/B	CEC/B	0.8424	23	0.0000
Cu/B	pH/B	-0.3838	23	0.0706
Cu/B	TDS/S	0.0181	23	0.9346
Cu/B	CO3/B	-0.7509	23	0.0000
Cu/B	TOM/B	0.8361	23	0.0000
Cu/B	P2O5/B	0.9455	23	0.0000
Cu/B	CEC/B	0.8978	23	0.0000
Cu/B	Al/B	0.8214	23	0.0000
Fe/B	pH/B	-0.3236	23	0.1320
Fe/B	TDS/S	0.1053	23	0.6325
Fe/B	CO3/B	-0.7891	23	0.0000
Fe/B	TOM/B	0.8837	23	0.0000
Fe/B	P2O5/B	0.9581	23	0.0000
Fe/B	CEC/B	0.8967	23	0.0000
Fe/B	Al/B	0.9469	23	0.0000
Fe/B	Cu/B	0.8775	23	0.0000
Zn/B	pH/B	-0.1585	23	0.4701
Zn/B	TDS/S	0.1609	23	0.4634
Zn/B	CO3/B	-0.5999	23	0.0025
Zn/B	TOM/B	0.5668	23	0.0048
Zn/B	P2O5/B	0.6111	23	0.0019
Zn/B	CEC/B	0.6932	23	0.0002
Zn/B	Al/B	0.6732	23	0.0004
Zn/B	Cu/B	0.5961	23	0.0027
Zn/B	Fe/B	0.6438	23	0.0009
Cd/B	pH/B	1.0000	23	0.0000
Cd/B	TDS/S	1.0000	23	0.0000
Cd/B	CO3/B	1.0000	23	0.0000
Cd/B	TOM/B	1.0000	23	0.0000
Cd/B	P2O5/B	1.0000	23	0.0000
Cd/B	CEC/B	1.0000	23	0.0000
Cd/B	Al/B	1.0000	23	0.0000
Cd/B	Cu/B	1.0000	23	0.0000
Cd/B	Fe/B	1.0000	23	0.0000
Cd/B	Zn/B	1.0000	23	0.0000
Cr/B	pH/B	-0.3496	23	0.1021
Cr/B	TDS/S	0.1064	23	0.6290
Cr/B	CO3/B	-0.8648	23	0.0000
Cr/B	TOM/B	0.8532	23	0.0000
Cr/B	P2O5/B	0.9554	23	0.0000
Cr/B	CEC/B	0.8950	23	0.0000
Cr/B	Al/B	0.9434	23	0.0000
Cr/B	Cu/B	0.8874	23	0.0000
Cr/B	Fe/B	0.9767	23	0.0000
Cr/B	Zn/B	0.6127	23	0.0019
Cr/B	Cd/B	1.0000	23	0.0000
Pb/B	pH/B	-0.4736	23	0.0225
Pb/B	TDS/S	0.7065	23	0.0002
Pb/B	CO3/B	-0.3097	23	0.1504
Pb/B	TOM/B	0.3596	23	0.0919
Pb/B	P2O5/B	0.3070	23	0.1542
Pb/B	CEC/B	0.3155	23	0.1426
Pb/B	Al/B	0.3717	23	0.0808
Pb/B	Cu/B	0.2159	23	0.3225
Pb/B	Fe/B	0.3121	23	0.1471
Pb/B	Zn/B	0.3540	23	0.0975
Pb/B	Cd/B	1.0000	23	0.0000
Pb/B	Cr/B	0.2750	23	0.2042

Table 6.4. Pair wise correlation between the heavy metals (Cu, Zn, Cd, Cr and Pb) with the pollution controlling parameters (pH, TDS, Ca CO_3, TOM, P_2O_5 and CEC) for Al-Tawiyeen dam T: Tawiyeen



Variable	by Variable	Correlation	Count	Signif Prob
Al/T	pH/T	0.5318	11	0.0923
Al/T	TDS/T	-0.4285	11	0.1885
Al/T	CO3/T	-0.2584	11	0.4429
Al/T	TOM/T	-0.2220	11	0.5118
Al/T	P2O5/T	-0.5477	11	0.0811
Al/T	CEC/T	-0.4227	11	0.1952
Cu/T	pH/T	0.3317	11	0.3191
Cu/T	TDS/T	-0.0786	11	0.8183
Cu/T	CO3/T	-0.2877	11	0.3909
Cu/T	TOM/T	-0.3947	11	0.2296
Cu/T	P2O5/T	-0.7417	11	0.0090
Cu/T	CEC/T	-0.6820	11	0.0208
Cu/T	Al/T	0.7907	11	0.0038
Fe/T	pH/T	0.2373	11	0.4824
Fe/T	TDS/T	-0.3914	11	0.2340
Fe/T	CO3/T	-0.3102	11	0.3532
Fe/T	TOM/T	-0.0470	11	0.8909
Fe/T	P2O5/T	-0.4137	11	0.2060
Fe/T	CEC/T	-0.3532	11	0.2866
Fe/T	Al/T	0.8835	11	0.0003
Fe/T	Cu/T	0.7757	11	0.0050
Zn/T	pH/T	-0.4998	11	0.1175
Zn/T	TDS/T	0.1013	11	0.7669
Zn/T	CO3/T	-0.2700	11	0.4220
Zn/T	TOM/T	0.7215	11	0.0122
Zn/T	P2O5/T	0.4142	11	0.2054
Zn/T	CEC/T	0.3859	11	0.2412
Zn/T	Al/T	0.0621	11	0.8560
Zn/T	Cu/T	0.1614	11	0.6354
Zn/T	Fe/T	0.3199	11	0.3376
Cd/T	pH/T	0.5896	11	0.0562
Cd/T	TDS/T	-0.4743	11	0.1405
Cd/T	CO3/T	-0.2885	11	0.3897
Cd/T	TOM/T	-0.5469	11	0.0817
Cd/T	P2O5/T	-0.8337	11	0.0014
Cd/T	CEC/T	-0.7624	11	0.0064
Cd/T	Al/T	0.8574	11	0.0007
Cd/T	Cu/T	0.8857	11	0.0003
Cd/T	Fe/T	0.8263	11	0.0017
Cd/T	Zn/T	-0.0207	11	0.9519
Cr/T	pH/T	0.2602	11	0.4397
Cr/T	TDS/T	-0.3633	11	0.2720
Cr/T	CO3/T	-0.3543	11	0.2850
Cr/T	TOM/T	-0.3895	11	0.2363
Cr/T	P2O5/T	-0.6059	11	0.0482
Cr/T	CEC/T	-0.7317	11	0.0105
Cr/T	Al/T	0.4431	11	0.1723
Cr/T	Cu/T	0.5651	11	0.0701
Cr/T	Fe/T	0.5162	11	0.1041
Cr/T	Zn/T	-0.0572	11	0.8672
Cr/T	Cd/T	0.6380	11	0.0347
Pb/T	pH/T	-0.5988	11	0.0516
Pb/T	TDS/T	0.3388	11	0.3082
Pb/T	CO3/T	-0.1708	11	0.6157
Pb/T	TOM/T	0.7513	11	0.0077
Pb/T	P2O5/T	0.8373	11	0.0013
Pb/T	CEC/T	0.7131	11	0.0138
Pb/T	Al/T	-0.5365	11	0.0889
Pb/T	Cu/T	-0.6051	11	0.0486
Pb/T	Fe/T	-0.4255	11	0.1920
Pb/T	Zn/T	0.3441	11	0.3001
Pb/T	Cd/T	-0.7673	11	0.0058
Pb/T	Cr/T	-0.2881	11	0.3902

Table 6.5. Pair wise correlation between the heavy metals (Cu, Zn, Cd, Cr and Pb) with the pollution controlling parameters (pH, TDS, Ca CO_3, TOM, P_2O_5 and CEC) for Ham dam H: Ham



Pairwise Correlations

Variable	by Variable	Correlation	Count	Signif Prob
Al/H	pH/H	-0.1932	18	0.4425
Al/H	TDS/H	0.2260	18	0.3672
Al/H	CO3/H	-0.4356	18	0.0708
Al/H	TOM/H	0.7548	18	0.0003
Al/H	P2O5/H	0.7602	18	0.0003
Al/H	CEC/H	-0.0241	18	0.9245
Cu/H	pH/H	-0.1093	18	0.6660
Cu/H	TDS/H	-0.0866	18	0.7326
Cu/H	CO3/H	-0.2122	18	0.3979
Cu/H	TOM/H	-0.1613	18	0.5225
Cu/H	P2O5/H	0.0531	18	0.8341
Cu/H	CEC/H	0.3210	18	0.1941
Cu/H	Al/H	0.1263	18	0.6176
Fe/H	pH/H	-0.4495	18	0.0613
Fe/H	TDS/H	0.5333	18	0.0227
Fe/H	CO3/H	-0.7968	18	0.0001
Fe/H	TOM/H	0.3857	18	0.1139
Fe/H	P2O5/H	0.4356	18	0.0708
Fe/H	CEC/H	-0.2098	18	0.4034
Fe/H	Al/H	0.3043	18	0.2195
Fe/H	Cu/H	0.3439	18	0.1624
Zn/H	pH/H	-0.3237	18	0.1900
Zn/H	TDS/H	0.0532	18	0.8339
Zn/H	CO3/H	-0.0605	18	0.8115
Zn/H	TOM/H	0.4531	18	0.0590
Zn/H	P2O5/H	0.2578	18	0.3018
Zn/H	CEC/H	0.0943	18	0.7097
Zn/H	Al/H	0.2743	18	0.2706
Zn/H	Cu/H	0.0532	18	0.8338
Zn/H	Fe/H	0.4141	18	0.0876
Cd/H	pH/H	-0.1956	18	0.4368
Cd/H	TDS/H	0.3746	18	0.1256
Cd/H	CO3/H	-0.5165	18	0.0282
Cd/H	TOM/H	0.0743	18	0.7696
Cd/H	P2O5/H	0.0386	18	0.8792
Cd/H	CEC/H	-0.3594	18	0.1430
Cd/H	Al/H	0.1179	18	0.6412
Cd/H	Cu/H	0.3998	18	0.1002
Cd/H	Fe/H	0.6067	18	0.0076
Cd/H	Zn/H	-0.0614	18	0.8089
Cr/H	pH/H	-0.2328	18	0.3526
Cr/H	TDS/H	0.0114	18	0.9643
Cr/H	CO3/H	-0.3306	18	0.1803
Cr/H	TOM/H	-0.2138	18	0.3942
Cr/H	P2O5/H	-0.5674	18	0.0141
Cr/H	CEC/H	-0.4030	18	0.0973
Cr/H	Al/H	-0.3356	18	0.1733
Cr/H	Cu/H	0.3169	18	0.2001
Cr/H	Fe/H	0.3977	18	0.1021
Cr/H	Zn/H	0.0890	18	0.7256
Cr/H	Cd/H	0.5462	18	0.0190
Pb/H	pH/H	-0.1620	18	0.5207
Pb/H	TDS/H	0.4956	18	0.0365
Pb/H	CO3/H	-0.4735	18	0.0472
Pb/H	TOM/H	0.6716	18	0.0023
Pb/H	P2O5/H	0.6483	18	0.0000
Pb/H	CEC/H	-0.0197	18	0.9383
Pb/H	Al/H	0.5310	18	0.0234
Pb/H	Cu/H	-0.0908	18	0.7202
Pb/H	Fe/H	0.4138	18	0.0878
Pb/H	Zn/H	0.1175	18	0.6423
Pb/H	Cd/H	0.0443	18	0.8613
Pb/H	Cr/H	-0.4897	18	0.0391

6.4. Enrichment Factor (EF) Value for the Tested Metals

Enrichment Factors (EF), are commonly determined to characterize the magnitude of metal contamination in environment samples and to determine the degree of sedimentation as well (Lee, et al., 1998; Huang and Lin, 2003; Woitke, et al., 2003 and Şenol Kartal, et al., 2006). However, composition of sediment is modified by contributions from various man-made sources (Nolting, et al., 1999 and Chatterjee, et al., 2007). The degree of the modification in the chemical composition of sediments may be different at each sampling point due to different magnitude of source contributions at each station (Atgın, et al., 2000).

Generally, EF values less than 10.0 are not considered significant, since such small enrichments may arise from differences in the composition of local sediments material and reference sediments used in EF calculations. An enrichment factor technique is used in the area of atmospheric aerosols (Güllü, et al., 1998 and Odabaşı, et al., 2002), sediments (Ergin, et al., 1991 and Teksöz, et al., 1991; Sanin, et al., 1992; Atgın, et al., 2000. ; Rubio, et al., 2000; Obiajunwa, et al., 2002; Selvaraj, et al., 2004; Conrad and Chisholm-Brause, 2004; and Bergamaschi, et al., 2002), and solid wastes (Obiajunwa, et al., 2002; Wen-hua, 2005 and Hakan Pekey, 2006). Value of the enrichment factor (EF) was calculated using the formula (Banat, et al., 2005):

$$\mathrm{EF} = \frac{Cn}{Bn} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (6.1)}$$

Where Cn (sample) is the content of the examined element in the examined environment and Bn (background) is the content of the examined element in the environment (Banat, et al., 2005 and Wen-hua, 2005). According to Sutherland (2000), contamination categories are generally recognized on the basis of the enrichment factor listed in Table (6.6).

Table 6.6. Contamination categories for enrichment factor (EF) (Sutherland, 2000).

Enrichment Factor (EF)	Designation of sediment quality
<1	No enrichment
< 2	Deficiency to mineral enrichment
= 2–5	Moderate enrichment
= 5–20	Significant enrichment
= 20–40	Very high enrichment
> 40	Extremely high enrichment

The EF and average concentrations of analyzed metals in sediment samples were listed in Table (6.7) for Al-Shuweib dam; Table (6.8) for Al-Bih dam; Table (6.9) for Al-Tawiyeen dam; and Table (6.10) for Ham dam. The concentrations of analyzed metals in the sediment samples for the investigated dams almost low and are similar to those of the average earth crust. The EF of these analyzed metals is less then one, which generally reflects their natural background values in shale.

Table 6 7 Background, average concentration and enrichment factor of Al-Shuweib dam.

Heavy Metal	Average[a] Shale value	Average[b] Clay fractions	Enrichment Factor (EF)	Pollution Intensity
Cd	0.3	0	< 1	No enrichment
Cr	90.0	0.3	< 1	No enrichment
Cu	45.0	0.03	< 1	No enrichment
Zn	95.0	0.09	< 1	No enrichment
Pb	20.0	0.02	< 1	No enrichment
Fe	47200	41.0	< 1	No enrichment
Al	80000	23.6	< 1	No enrichment

[a][b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

Table 6.8. Background, average concentration and enrichment factor of Al-Bih dam.

Heavy Metal	Average[a] Shale value	Average[b] Clay fractions	Enrichment Factor (EF)	Pollution Intensity
Cd	0.3	0	< 1	No enrichment
Cr	90.0	0.16	< 1	No enrichment
Cu	45.0	0.03	< 1	No enrichment
Zn	95.0	0.1	< 1	No enrichment
Pb	20.0	0.04	< 1	No enrichment
Fe	47200	44.1	< 1	No enrichment
Al	80000	26.8	< 1	No enrichment

[a][b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

Table 6.9. Background, average concentration and enrichment factor of Al-Tawiyeen dam.

Heavy Metal	Average[a] Shale value	Average[b] Clay fractions	Enrichment Factor (EF)	Pollution Intensity
Cd	0.3	0.0003	< 1	No enrichment
Cr	90.0	0.3	< 1	No enrichment
Cu	45.0	0.09	< 1	No enrichment
Zn	95.0	0.23	< 1	No enrichment
Pb	20.0	0.04	< 1	No enrichment
Fe	47200	64.7	< 1	No enrichment
Al	80000	28.8	< 1	No enrichment

[a][b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

Table 6.10. Background, average concentration and enrichment factor of Ham dam.

Heavy Metal	Average[a] Shale value	Average[b] Clay fractions	Enrichment Factor (EF)	Pollution Intensity
Cd	0.3	0.0004	< 1	No enrichment
Cr	90.0	0.89	< 1	No enrichment
Cu	45.0	0.13	< 1	No enrichment
Zn	95.0	0.17	< 1	No enrichment
Pb	20.0	0.03	< 1	No enrichment
Fe	47200	73.3	< 1	No enrichment
Al	80000	28.1	< 1	No enrichment

[a][b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

6.5. I-geo accumulation for the tested metals

To assess the extent of pollution, many attempts were made to idealize formulas relating the content of trace metals in sediment samples. Many of these formulas have multivariable related to variations of trace metal contents in sediments including lithologic units, hydrologic effect, geologic feature, physio-chemical characteristics of sediments and vegetation cover (Hawkes and Webb, 1962; Dahlberg, 1968; Mueller, 1969; Förstner and Wittman, 1983 and Nitekim et. al., 1993). According to Muller (1969), Muller (1979), Förstner (1989) and Ntekim et. al., (1993), index of geoaccumulation (I_{geo}) it would be likely to estimate the extent of pollution in the sediments. The I_{geo} values for the metals studied were calculated by computing the base 2 logarithm using the Muller's (1979) expression:

$$I_{geo} = \log_2\left(\frac{Cn}{1.5Bn}\right) \text{..........................Eq. (6.2)}$$

Where Cn is the measured total concentrations of analyzed metal "n" in the sediment and Bn is the average (crystal) concentration of element "n" in the shale (background), and 1.5 is the factor compensating the background data (correction factor) due to lithogenic effects. The analyzed metal pollution levels are measured using this index (I_{geo}), which consists of seven grades: 0–6. The highest grade, 6, reflects a 100-fold metal concentration relative to background values (Table. 6.11). The geoaccumulation index (I_{geo}) values of Al, Fe, Cu, Cd, Cr, Pb, and Zn in the analysed sediments were listed in Table (6.12) for Al-Shuweib dam; Table (6.13) for Al-Bih dam; Table (6.14) for Al-Tawiyeen dam and Table (6.15) for Ham dam. The selected trace metals show (I_{geo}) class zero in the sediment samples which may be described as uncontaminated with respect to these metals.

Table 6.11. Measurements of Index of geoaccumulatin for metal pollution in soils and sediments (Muller, 1969; Ntekim, et al., 1993).

Index of geoaccumulation	I-geo class	Designation of sediment quality
5–10	6	Extremely contaminated
4–5	5	Strongly/extremely contaminated
3–4	4	Strongly contaminated
2–3	3	Moderately/Strongly contaminated
2–1	2	Moderately contaminated
0-1	1	Uncontaminated/Moderately contaminated
0	0	Uncontaminated

Table 6.12 Measure of the metals pollution intensity in sediments of Al-Shuweib dam

Heavy Metal	Average Shale value	Average Clay fractions	I-geo value	I-geo grade	Pollution Intensity
Cd	0.3	0	< 0	0	Uncontaminated
Cr	90.0	0.3	< 0	0	Uncontaminated
Cu	45.0	0.03	< 0	0	Uncontaminated
Zn	95.0	0.09	< 0	0	Uncontaminated
Pb	20.0	0.02	< 0	0	Uncontaminated
Fe	47200	41.0	< 0	0	Uncontaminated
Al	80000	23.6	< 0	0	Uncontaminated

[a,b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

Table 6.13. Measure of the metals pollution intensity in sediments of Al-Bih dam.

Heavy Metal	Average Shale value	Average Clay fractions	I-geo value	I-geo grade	Pollution Intensity
Cd	0.3	0	< 0	0	Uncontaminated
Cr	90.0	0.16	< 0	0	Uncontaminated
Cu	45.0	0.03	< 0	0	Uncontaminated
Zn	95.0	0.1	< 0	0	Uncontaminated
Pb	20.0	0.036	< 0	0	Uncontaminated
Fe	47200	44.1	< 0	0	Uncontaminated
Al	80000	26.8	< 0	0	Uncontaminated

[a,b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

Table 6.14. Measure of the metals pollution intensity in sediments of Al-Tawiyeen dam.

Heavy Metal	Average Shale value	Average Clay fractions	I-geo value	I-geo grade	Pollution Intensity
Cd	0.3	0.0003	< 0	0	Uncontaminated
Cr	90.0	0.31	< 0	0	Uncontaminated
Cu	45.0	0.09	< 0	0	Uncontaminated
Zn	95.0	0.23	< 0	0	Uncontaminated
Pb	20.0	0.037	< 0	0	Uncontaminated
Fe	47200	64.7	< 0	0	Uncontaminated
Al	80000	28.8	< 0	0	Uncontaminated

[a,b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

Table 6.15. Measure of the metals pollution intensity in sediments of Ham dam.

Heavy Metal	Average Shale value	Average Clay fractions	I-geo value	I-geo grade	Pollution Intensity
Cd	0.3	0.0004	< 0	0	Uncontaminated
Cr	90.0	0.89	< 0	0	Uncontaminated
Cu	45.0	0.13	< 0	0	Uncontaminated
Zn	95.0	0.17	< 0	0	Uncontaminated
Pb	20.0	0.029	< 0	0	Uncontaminated
Fe	47200	73.3	< 0	1	Uncontaminated
Al	80000	28.1	< 0	0	Uncontaminated

[a,b] Shale and average values given in ppm. Background values taken from K.K. Turkian and K.H. Wedepohl (1961).

6.6. Comparison of the metal contents among the different dams

The normality of the data needs to be determined before selecting the proper statical procedures to accomplish the comparison. The test of normality of the concentration of elements in Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams are listed in Appendix (II.13) to (II.19), and illustrated as histograms in Appandices (IV.1-7). The Kolmogorov-Smirnov test was used to check the (p-values = α) which showed that the recorded values for the most metal in each dams are <α, (α=0.05), this means that the measured concentration of each metals in the investigated dams are not normally distributed. In this case, the Kruskal-Wallis test was applied to check the mean differences of measured concentration among the investigated dams (Bass, 2005). The hypothesis used is the concentrations of each metal among the four investigated dams are equal. Appendix (II.20) to (II.26) show p-value =zero, which is <α, (α=0.05), therefore, the hypothesis is wrong and there is enough evidence exists to conclude that there is a significant differences in distribution of concentration elements among investigated dams.

The p-value calculated from Kruskal-Wallis test can not tell us which dams is different from others, in this case multiple comparison tests Tukey's Honestly Significant Difference (Tukey's HSD), used to check the difference between dams for the considered metals. The interpretation of the Confidence Interval values listed in Appendix (II.27), concluded that the mean difference of (Al) concentration in samples collected from Al-Bih dam is less than Ham and Al-Tawiyeen dam, whereas, it is greater than Al-Shuweib dam. While, the values of Ham dam is higher than Al-Shuweib dam and equal with Al-Tawiyeen dam. Moreover, the mean difference of (Al) concentration values in Al-Shuwieb dam is less than Al-Tawiyeen dam.

From Appendix (II.28), we concluded that the mean difference of measured concentration of (Fe) in sediments samples collected from Al-Bih dam is less than Ham and Al-Tawiyeen dams, and equal with Al-Shuweib dam. Whereas, in Ham dam the mean differences is greater than Al-Shuweib dam and equal with Al-Tawiyeen dam. In addtion, the mean difference of Al-Shuweib dam is less than Al-Tawiyeen dam.

The multi-comparisons values listed in Appendix (II.29), between the four investigated dams indicate that the mean difference of (Cd) measured concentration in Al-Bih dam is less than Ham, whereas, it is equal with Al-Shuweib dam and Al-Tawiyeen dam. In Ham dam, the mean difference of (Cd) concentration is greater than Al-Shuweib dam and equal with Al-Tawiyeen dam. Moreover, the mean difference of Cd concentration in Al-Shuweib dam is equal with Al-Tawiyeen dam.

The mean difference of (Cr) measured concentration in investigated dams listed in Appendix (II.30), concludes that the Al-Bih dam has less mean differences values of (Cr) than Ham and Al-Tawiyeen, and Al-Shuweib dams, whereas, the mean difference of Ham dam is greater than Al-Shuweib and Al-Tawiyeen dams. Moreover, the mean difference of Al-Shuweib dam is equal with Al-Tawiyeen dam.

The interpretation of Confidence Interval of the mean difference of (Cu) measured concentration listed in Appendix (II.31), which concluded that the values of measured concentration of (Cu) in Al-Bih dam is less than Ham and Al-Tawiyeen dams, and equal with Al-Shuweib dam. Whereas, in Ham dam the mean difference is greater than Al-Shuweib dam and equal with Al-Tawiyeen dam. In addition, the mean difference of Al-Shuweib dam is less than Al-Tawiyeen dam.

Moreover, From Appendix (II.32), it is concluded that the mean difference of measured concentration of (Pb) in samples collected from Al-Bih dam is greater than Ham and Al-Shuweib dams, and equal with Al-Tawiyeen dam. In Ham dam, the mean difference is greater than Al-Shuweib dam and less than Al-Tawiyeen dam, whereas, the mean difference of Pb in Al-Shuweib dam is less than Al-Tawiyeen dam. As well as, from Appendix (II.33), the interpretation of Confidence Interval values of (Zn) measured concentration in investigated dams showed that the mean difference of (Zn) concentration in samples collected from Al-Bih dam is less than Ham and Al-Tawiyeen dams, and greater than Al-Shuweib dam. Whereas, in Ham dam the mean difference is greater than Al-Shuweib dam and equal with Al-Tawiyeen dam. Moreover, the mean difference of Al-Shuweib dam is less than Al-Tawiyeen dam.

It can be conclude that there is a significant difference in distribution of measured concentrations among investigated dams for the selected metals. From the statical comparison, it can be revealed that the highest measured concentrations for the most metals presented in Ham dam. These metals are closely associated with ophiolitic rocks and therefore they are mainly derived from Ophiolite of Oman Mountains. On the other hand, the lowest measured concentrations for the metals found in Al-Shuweib dam. Moreover, several parameters can effect the distribution of the analyzed metals such as the physico-chemical parameters, size range in the source rocks, weathering process, distance of transportation.

6.7. Sequential Extraction / Geochemical Fraction

A quantitative estimate of relative mobility of trace metals under surficial conditions is difficult, but an empirical estimate can be obtained by comparing coexisting mobile and immobile phases (Rose, et al., 1979; Alloway, 1990; Szefer, et al., 1995; Zhixun, et al., 1997 and Howari, et al., 2004). Sequential extraction procedures are commonly applied to assess sediment associated metals in environmental studies. Valuable information was obtained about the mobility and bioavailability of metals to living organisms, using these procedures. This information is not available from a total perspective on metal contamination in the environment. On of the most widely applied procedures was proposed more than 29 years ago by Tessier, et al. (1979). Kirk, et al., (2003) modified this procedure and it partitions elements into five operationally defined geochemical fractions including: exchangeable (F1); carbonates (F2, acid-soluble); Fe/Mn oxides (F3, reducible); organic matter (F4, oxidazable); and residual (F5).

The chemical associations of Cu, Cd, Cr, Pb and Zn in selected sediments samples were listed in Tables (6.16, 6.17, 6.18, and 6.19), and illustrated in Figure (6.18) for Al-Shuweib dam, Figure (6.19) for Al-Bih dam, Figure (6.20) for Al-Tawiyeen dam and Figure (6.21) for Ham dam. The percentages measured values of Cu, Cd, Cr, Pb, and Zn in selected sediments for Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams were presented according to different geochemical phase. Varying contents of gravel, sand, and silt, organic matter and carbonates as well as variation of CEC values cause variation in the concentrations of the measured selected trace metals in the different geochemical phase.

(F1): Exchangeable fraction: The exchangeable fraction is considered to be the most mobile and bioavailable phase present in the soils and sediments (Tessier, et al., 1979; Ahnstrom and Parker, 1999; Howari and Banate, 2001). The exchangeable fraction in the analyzed sediments samples of Al-Shuweib, Al-Bih and Al-Tawiyeen dams are is able to retain heavy metals in the order: Cu > Pb > Zn > Cr > Cd. Whereas, in Ham dam is able to retain heavy metals in the order: Pb > Cu ≥ Zn > Cr > Cd. These metals are considered as loosely bound to this fraction and readily available for transport into the environment (Tessier and Campbell, 1979; Förstner and Wittman, 1983 and Lee and Patrick, 1997).

Table 6.16 Metal percentages of Cu, Cd, Cr, Pb and Zn in the different geochemical phases in the sediments of Al-Shuweib dam.

Metal	Exchangeable (F1)	Bond of Carbonate (F2)	Bound of Fe/Mn oxide (F3)	Bond of Organic matter (F4)	Residual (F5)
Cu	39.2	31.1	43.6	69.5	8.5
Cd	0	0	0.2	0	0.7
Cr	4.8	0.3	2.9	9.5	20.7
Pb	31.7	0	5.6	0	2.8
Zn	24.3	68.6	47.6	21	67.3

Table 6.17 Metal percentages of Cu, Cd, Cr, Pb and Zn in the different geochemical phases in the sediments of Al-Bih dam.

Metal	Exchangeable (F1)	Bond of Carbonate (F2)	Bound of Fe/Mn oxide (F3)	Bond of Organic matter (F4)	Residual (F5)
Cu	57.2	23.5	55.4	71	10.2
Cd	0	0	0	0	1
Cr	2.7	14	2	7.9	8.8
Pb	27.7	4.2	4.6	0	2.6
Zn	12.4	58.2	38	21.1	77.3

Table 6.18. Metal percentages of Cu, Cd, Cr, Pb and Zn in the different geochemical phases in the sediments of Al-Tawiyeen dam.

Metal	Exchangeable (F1)	Bond of Carbonate (F2)	Bound of Fe/Mn oxide (F3)	Bond of Organic matter (F4)	Residual (F5)
Cu	45.7	23.2	57.6	73.1	12
Cd	0	0	0	0	0.8
Cr	0.2	6.9	3.9	13.1	26.9
Pb	33.7	11.3	0.3	0	2.8
Zn	20.4	58.6	38.2	13.8	57.5

Table 6.19. Metal percentages of Cu, Cd, Cr, Pb and Zn in the different geochemical phases in the sediments of Ham dam.

Metal	Exchangeable (F1)	Bond of Carbonate (F2)	Bound of Fe/Mn oxide (F3)	Bond of Organic matter (F4)	Residual (F5)
Cu	22.7	40.3	55.2	72.7	20.4
Cd	0	0	0	0	1.5
Cr	0.2	7.2	8.5	11	36.5
Pb	58.3	0.7	0	0	1.8
Zn	18.8	51.8	36.3	16.3	39.7

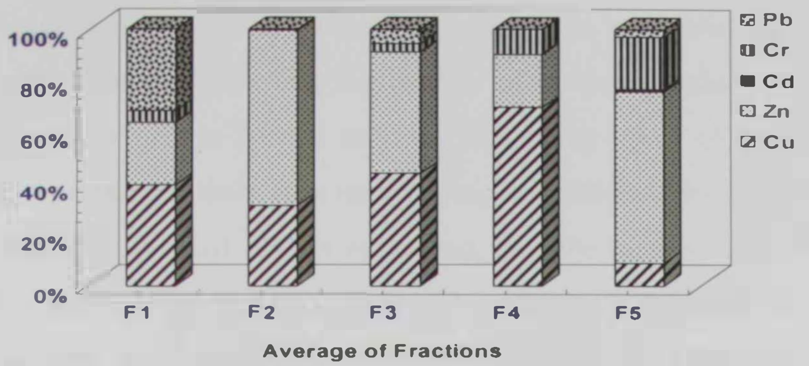


Figure 6.18 Histogram showing heavy metal average percentages in different geochemical phases (fractions: F1: Exchangeable; F2: Carbonate; F3: Fe/Mn oxide; F4: Organic matter; F5: Residual), of the sediment samples collected from Al-Shuweib dam.

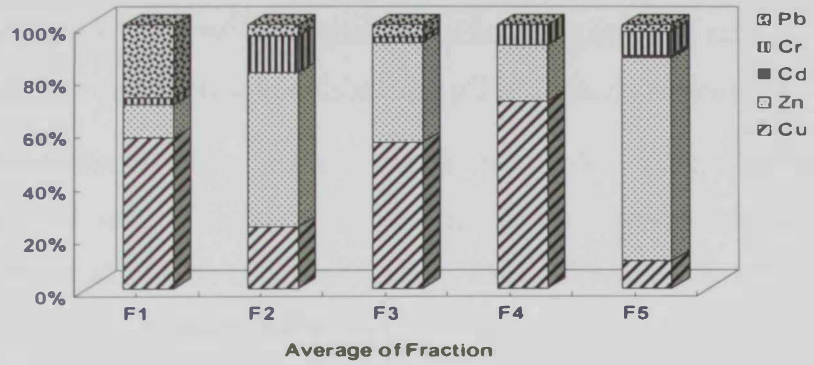


Figure 6.19. Histogram showing heavy metal average percentages in different geochemical phases (fractions: F1: Exchangeable; F2: Carbonate; F3: Fe/Mn oxide; F4: Organic matter; F5: Residual), of the sediment samples collected from Al-Bih dam.

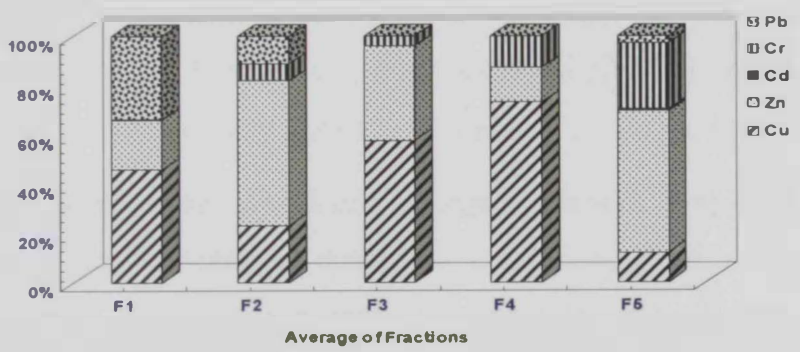


Figure 6.20. Histogram showing heavy metal average percentages in different geochemical phases (fractions: F1: Exchangeable; F2: Carbonate; F3: Fe/Mn oxide; F4: Organic matter; F5: Residual), of the sediment samples collected from Al-Tawiyeen dam.

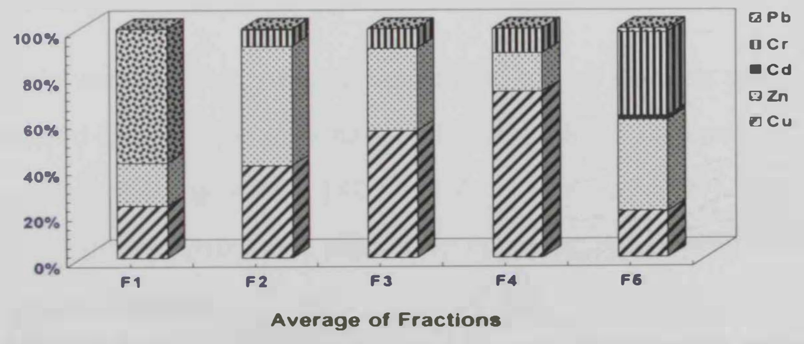


Figure 6.21. Histogram showing heavy metal average percentages in different geochemical phases (fractions: F1: Exchangeable; F2: Carbonate; F3: Fe/Mn oxide; F4: Organic matter; F5: Residual) of the sediment samples collected from Ham dam.

(F2): Carbonate-bound fraction: Heavy metals can be associated significantly with carbonate sediments fraction. The mechanism of co-precipitation with carbonates, whereby the heavy metals sorbed onto surface being apart of the crystal lattice through incorporation in their structure or may be adsorbed by oxides and organic matter that were precipitated, mainly as coating, onto the carbonates or other sediment particles (Förstner and Wittman, 1983). The carbonate fraction in the analyzed sediments samples collected from Al-Shuweib, Al-Bih and Ham dams are able to retain heavy metals in the order: Zn > Cu > Cr > Pb > Cd, whereas, in Al-Tawiyeen dam, sediments are able to retain heavy metals in the order: Zn > Cu > Pb > Cr > Cd. These heavy metals have a higher specific affinity for carbonate and may coprecipitate with carbonate minerals at high pH (Förstner and Wittman, 1983).

(F3): Fe/Mn oxides fraction: Iron and manganese oxides are excellent scavengers for trace metals and can be mobilized under acidic conditions (Tessier, et al., 1979; Szefer Glasby, et al., 1995; Chlopecka, et al., 1996; Karczewska, 1996; Ahumada, et al., 1999; Howari and Banat, 2001; Dang, et al., 2002 and Banat, et al., 2005). The Fe/Mn oxides fraction in the analyzed sediments samples of Al-Shuweib dam is able to retain heavy metals in the order: Zn ≥ Cu > Pb ≥ Cr > Cd, whereas the Fe/Mn oxides fraction in Al-Bih dam sediments are able to retain heavy metals in the order: Cu > Zn > Pb > Cr > Cd. Moreover, this fraction in Al-Tawiyeen and Ham dams sediment are able to retain heavy metals in the order: Cu > Zn > Cr > Pb > Cd.

(F4): Organic matter-bound fraction: The organic phase is a relatively stable phase in nature, but it can be mobilized under strong oxidizing conditions due to organic matter degradation, leading to a release of the soluble metal (Tessier, et al., 1979; Förstner and Wittman, 1983; Panda, et al., 1995 and Banat, et al., 2005). The organic matter fraction in the analyzed sediments samples of four investigated dams are able to retain heavy metals in the order: Cu > Zn > Cr > Pb > Cd.

(F5): Residual fraction: Heavy metals associated to this fraction are not soluble and may be considered as bound or stationary metals, which are assumed to be held within the minerals matrix (Modak, et al., 1992 and Prustry, et al., 1994). The residual solid should contain mainly primary and secondary minerals, which may hold trace metals within their crystal structure.

Metals present in this fraction are a measure of the degree of environmental pollution: the higher the metals present in this fraction indicate the lower degree of pollution (Förstner and Wittman, 1983 and Zhixun, et al., 1997; Howari and Banat, 2001; Dang, et al., 2002 and Banat, et al., 2005). The heavy metals bounded to the residual fraction in the analyzed sediments samples of Al-Shuweib, Al-Taywiyeen and Ham dams are able to retain heavy metals in the order: Zn > Cr > Cu > Pb > Cd, whereas, this fraction in Al-Bih dam sediments is able to retain heavy metals in the order: Zn > Cu $\geq$ Cr > Pb > Cd.

The sequential extraction results reveal that Cu, Cd, Cr, Pb, and Zn are mainly associated with the residual fraction. This can be interpreted that the sediments in the analyzed samples in the investigated dams are unpolluted with the selected heavy metals.

CHAPTER SEVEN

CONCLUSION

7. CONCLUSION

The purpose of this study is to assess the heavy metal concentrations in the different geochemical phases, their enrichment and speciation in the sediments of selected dams in UAE. Another objective of this study is to study the impact of the physico-chemical parameters (pH, TDS, P_2O_5, TOM, $CaCO_3$ and CEC) on the distribution of heavy metals. Dams of concern include Al-Shuweib, Al-Bih, Al-Tawiyeen and Ham dams.

The main conclusions for the present study could be listed as following:

1. The texture analyses of sediments samples collected from Al-Shuweib dam classified as gravely sand, siltey sand and sandy gravel, whereas, Al-Bih dam sediments samples were sandy silt, sandy gravel and silty sand characteristic. Meanwhile, the sediment of Al-Tawiyeen and Ham dams are classified as silty sand and gravelly sand.
2. Microscopic study of sand size fraction revealed that the mineral observed in Al-Shuweib dam are carbonate minerals (calcite), quartz, and plagioclase. Whereas in samples collected from Al-Bih dam consist of quartz, calcite, plagioclase and, gypsum. Moreover, in Al-Tawiyeen dam calcite and plagioclase were observed, and in Ham dam, calcite, plagioclase and iron grain were observed.
3. X-ray diffraction pattern for non-clay size fraction of selected samples from Al-Shuweib dam showed quartz, calcite, dolomite, plagioclase, serpentine and clay minerals were present, whereas, in Al-Bih dam, diffraction pattern presents quartz, calcite, dolomite, clay minerals, serpentine and plagioclase. The average X-ray diffraction pattern for the selected samples collected from Al-Tawiyeen dam showed quartz, calcite, dolomite, serpentine, clay minerals and plagioclase. Moreover, Ham dam diffraction pattern showed quartz, calcite, dolomite, serpentine, plagioclase, amphibole, clay minerals and pyroxene.
4. The X-ray diffraction pattern for clay size fraction of selected samples in the Al-Shuweib dam, showed similar distribution with the same clay minerals of Al-Bih dam and Al-Tawiyeen dam. Assemblage of quartz found as major mineral, Illite as subordinate mineral and chlorite as minor mineral. Whereas in Ham dam, Illite showed as major mineral, quartz as subordinate and chlorite remains as minor mineral.

5. The identified minerals in the collected sediment samples can not be considered as a significant natural source of heavy metals.
6. The pH values for investigated area showed range of 7–8.6 which means that the sediments in the studied area are with alkaline nature.
7. The TDS values are higher in Al-Bih, Al-Tawiyeen and Ham dam than Al-Shuweib dam. This can be explained due to the grain size of collected samples and location of each dam.
8. The calcium carbonate content can be derived as clastics of pre-existing limestone, such as in Al-Shuweib dam, reprecipitated as surface sediments due to evaporation of bicarbonate-rich groundwater, and broken calcareous shells, especially in soils along the coastal land-stretch of Oman Mountains such as in Al-Bih, Al-Tawiyeen and Ham dams.
9. The percentage of organic substance in sediments samples collected from investigated dams is very low due to hot climate and quick decomposition of organic substance.
10. The deficient content of P_2O_5 in the sediments would be related to inorganic phosphate which occurs mainly as apatite (calcium phosphate) that dissolves under acidic medium, hence plant can not uptake phosphates when sediment water is alkaline.
11. The cation exchange capacity values along the tested stations in the four major dam`s sediments showed decreasing, which may be related to the less of organic matter content in the sediments.
12. The concentration of aluminum, iron, copper, cadmium, chromium, lead and zinc contents are nearly reflected of background natural values as evident from calculating the enrichment factor.
13. According to the calculated values of the index of geoaccumulation (I-geo), the sediments of Al-Shuwaib, Al-Bih, Al-Tawiyeen and Ham dams may be described as uncontaminated with respect to Al, Fe, Cu, Cd, Cr, Pb, and Zn.
14. The pair-wais coefficient correlation analyses show that the pollution controlling parameters affected positively with the distribution of measured elements in the sediments samples collected from the dams. Whereas, some parameter show negative correlation which means that it has no effect on the elements distribution.

15. The variance analysis test showed that there is a significant difference in distribution of measured concentrations among investigated dams for the selected metals. It can be revealed that the highest measured concentrations for the most metals presented in Ham dam. These metals are closely associated with ophiolitic rocks and therefore they are mainly derived from Ophiolite of Oman Mountains. On the other hand, the lowest measured concentrations for the metals found in Al-Shuweib dam. Moreover, several parameters can effect the distribution of the analyzed metals such as the physico-chemical parameters, size range in the source rocks, weathering process, distance of transportation.
16. The sequential extraction results reveal that Cu, Cd, Cr, Pb, and Zn are mainly associated with the residual fraction. This can be interpreted that the sediments in the analyzed samples in the investigated dams are unpolluted with the selected heavy metals.

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APPENDIXES

Appendix I.1. List of samples location collected from the four dams (UTM)

S.No.	Al-Shuweib		Al-Bih		Al-Tawiyeen		Ham	
	East	North	East	North	East	North	East	North
1	380226	2741197	404256	2850982	404600	2827890	427473	2779955
2	380291	2741210	404214	2850956	404584	2827957	427544	2779931
3	380362	2741235	404188	2850941	404566	2828025	427634	2779860
4	380423	2741260	404160	2850888	404545	2828117	427723	2780042
5	380500	2741277	404173	2850870	404653	2828129	427839	2780106
6	380568	2741295	404214	2850907	404801	2828044	427963	2780184
7	380642	2741288	404238	2850940	404753	2827934	427943	2780271
8	380713	2741279	407246	2850933	404704	2827829	427890	2783470
9	380780	2741263	404253	2850917	405011	2827832	427792	2780456
10	380843	2741249	404274	2850881	404931	2827646	427682	2780496
11	380903	2741249	404131	2850957	405069	2827348	427434	2780618
12	380960	2741244	404134	2850899	–	–	427340	2780718
13	381036	2741241	404169	2850841	–	–	427324	2780592
14	381093	2741229	404190	2850790	–	–	427341	2780410
15	381126	2741223	404195	2850715	–	–	427356	2780279
16	381149	2741262	404198	2850627	–	–	427396	2780158
17	381154	2741299	404234	2850794	–	–	427439	2780020
18	381158	2741366	404283	2850882	–	–	427331	2779846
19	381062	2741377	404331	2850938	–	–	–	–
20	380976	2741361	404306	2851011	–	–	–	–
21	380906	2741348	404223	2850952	–	–	–	–
22	380878	2741412	404204	2850847	–	–	–	–
23	380866	2741456	404251	2850913	–	–	–	–
24	380850	2741521	–	–	–	–	–	–
25	380760	2741495	–	–	–	–	–	–
26	380686	2741487	–	–	–	–	–	–
27	380563	2741457	–	–	–	–	–	–
28	380483	2741454	–	–	–	–	–	–
29	380410	2741436	–	–	–	–	–	–
30	380346	2741417	–	–	–	–	–	–
31	380272	2741395	–	–	–	–	–	–
32	380260	2741313	–	–	–	–	–	–
33	380258	2741238	–	–	–	–	–	–
34	380259	2474200	–	–	–	–	–	–
35	380514	2741288	–	–	–	–	–	–
36	380512	2741362	–	–	–	–	–	–
37	380505	2741396	–	–	–	–	–	–
38	380482	2741493	–	–	–	–	–	–
39	380903	2741317	–	–	–	–	–	–
40	380911	2741263	–	–	–	–	–	–
41	380909	2741234	–	–	–	–	–	–

Appendix II 1 List of pH values for the four dams in the study area

S. No.	Al-Shuwieb	Al-Bih	Al-Tawiyeen	Ham
1	8.60	7.20	7.38	7.23
2	7.49	7.32	7.47	7.33
3	7.70	7.35	7.50	7.38
4	7.45	7.27	7.30	7.73
5	7.26	7.44	7.35	7.60
6	7.20	7.37	7.38	7.42
7	7.80	6.98	7.60	7.35
8	7.37	7.03	7.38	7.30
9	7.84	7.32	7.42	7.42
10	7.64	7.01	7.43	7.64
11	7.78	7.45	7.78	7.31
12	7.21	7.18	–	7.41
13	7.20	7.61	–	7.30
14	7.43	7.30	–	7.40
15	7.74	7.46	–	7.44
16	7.33	7.69	–	7.82
17	7.62	7.74	–	7.40
18	7.60	8.11	–	7.68
19	7.68	7.46	–	–
20	7.79	7.40	–	–
21	7.80	7.49	–	–
22	8.19	7.32	–	–
23	8.47	7.87	–	–
24	8.28	–	–	–
25	8.13	–	–	–
26	8.15	–	–	–
27	8.29	–	–	–
28	8.42	–	–	–
29	8.31	–	–	–
30	8.20	–	–	–
31	8.03	–	–	–
32	8.42	–	–	–
33	7.72	–	–	–
34	7.97	–	–	–
35	7.83	–	–	–
36	8.27	–	–	–
37	8.10	–	–	–
38	8.24	–	–	–
39	7.66	–	–	–
40	7.68	–	–	–
41	7.96	–	–	–
Average	**7.85**	**7.41**	**7.47**	**7.46**
Minimum	**7.2**	**6.98**	**7.30**	**7.23**
Maximum	**8.6**	**8.11**	**7.78**	**7.82**
STD	**0.4**	**0.30**	**0.13**	**0.17**

Appendix II 2 List of Total dissolved solids content (TDS) for the four dams

S. No.	TDS (ppm)			
	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
1	133.1	775.0	487.0	275.8
2	179.2	1274.9	426.2	338.2
3	134.4	382.1	667.2	394.9
4	234.2	696.3	727.0	190.1
5	257.9	842.9	932.2	231.2
6	336.1	488.3	504.3	439.0
7	352.2	1538.6	437.1	338.6
8	322.6	1064.3	463.4	315.8
9	231.0	347.5	463.4	426.1
10	217.2	1813.8	935.0	359.0
11	208.6	567.7	183.0	424.8
12	438.7	1778.6	–	447.2
13	402.0	540.8	–	381.7
14	266.9	848.0	–	374.2
15	134.4	490.9	–	260.8
16	373.8	427.5	–	251.3
17	610.6	423.7	–	374.3
18	285.4	260.2	–	295.0
19	291.2	458.9	–	–
20	206.1	270.7	–	–
21	204.8	696.3	–	–
22	137.0	890.2	–	–
23	120.3	246.8	–	–
24	122.2	–	–	–
25	140.2	–	–	–
26	155.5	–	–	–
27	105.0	–	–	–
28	133.8	–	–	–
29	178.6	–	–	–
30	200.3	–	–	–
31	158.7	–	–	–
32	104.3	–	–	–
33	163.2	–	–	–
34	177.9	–	–	–
35	222.1	–	–	–
36	129.3	–	–	–
37	130.6	–	–	–
38	144.6	–	–	–
39	307.8	–	–	–
40	288.0	–	–	–
41	108.8	–	–	–
Average	**227.1**	**744.5**	**564.9**	**337.8**
Minimum	**104.3**	**246.8**	**183.0**	**190.1**
Maximum	**610.6**	**1813.8**	**935.0**	**447.2**
STD	**107.8**	**495.4**	**228.1**	**76.14**

Appendix II 3 List of Total Carbonate Content (CO_3 %) for the four dams.

S. No.	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
1	20.06	49.27	27.87	14.27
2	23.38	29.28	31.34	19.04
3	18.70	29.40	26.10	12.35
4	16.86	27.30	24.21	16.95
5	19.72	26.90	26.05	20.71
6	18.29	23.45	37.31	14.52
7	16.90	25.57	26.78	16.84
8	19.13	26.64	24.80	15.84
9	14.56	31.84	26.89	14.28
10	20.14	33.03	28.14	16.21
11	21.66	27.52	24.31	15.43
12	21.33	28.57	–	15.34
13	21.25	37.47	–	12.07
14	20.56	30.25	–	17.11
15	17.41	28.56	–	21.99
16	27.40	34.68	–	19.74
17	23.05	40.78	–	21.50
18	17.35	45.45	–	17.93
19	17.96	29.62	–	–
20	17.72	41.79	–	–
21	21.46	29.74	–	–
22	22.33	31.63	–	–
23	20.02	33.13	–	–
24	24.07	–	–	–
25	18.19	–	–	–
26	18.43	–	–	–
27	19.87	–	–	–
28	22.07	–	–	–
29	22.28	–	–	–
30	23.08	–	–	–
31	12.92	–	–	–
32	16.10	–	–	–
33	15.02	–	–	–
34	15.77	–	–	–
35	16.57	–	–	–
36	13.47	–	–	–
37	12.47	–	–	–
38	12.06	–	–	–
39	20.31	–	–	–
40	20.74	–	–	–
41	25.57	–	–	–
Average	**19.20**	**32.58**	**28.10**	**16.81**
Minimum	**12.06**	**23.45**	**24.21**	**12.07**
Maximum	**27.40**	**49.27**	**37.31**	**21.99**
STD	**3.52**	**6.58**	**3.80**	**2.92**

Appendix (II.4)–List of Total Organic Matter Content (TOM %) for the four dams

S. No.	**Al-Shuweib**	**Al-Bih**	**Al-Tawiyeen**	**Ham**
1	1.08	2.61	4.88	6.22
2	1.84	4.91	4.84	5.53
3	2.03	5.12	5.48	7.04
4	0.22	6.34	7.33	4.01
5	2.64	5.29	5.87	5.43
6	3.96	5.56	5.64	6.96
7	3.21	6.23	5.62	5.03
8	6.35	6.09	5.77	5.20
9	3.58	7.02	4.77	5.78
10	2.67	4.54	4.52	6.81
11	4.30	6.13	3.81	3.26
12	4.13	7.41	–	3.97
13	2.22	5.49	–	2.66
14	1.02	5.39	–	3.71
15	0.85	6.17	–	2.32
16	3.21	5.61	–	3.20
17	4.35	3.63	–	2.65
18	4.03	2.52	–	2.52
19	1.93	4.71	–	–
20	2.56	2.49	–	–
21	1.95	5.19	–	–
22	0.43	2.98	–	–
23	1.83	3.78	–	–
24	1.77	–	–	–
25	1.23	–	–	–
26	4.07	–	–	–
27	1.87	–	–	–
28	1.67	–	–	–
29	1.60	–	–	–
30	0.51	–	–	–
31	0.95	–	–	–
32	0.39	–	–	–
33	0.58	–	–	–
34	1.47	–	–	–
35	1.37	–	–	–
36	0.62	–	–	–
37	0.90	–	–	–
38	1.16	–	–	–
39	3.78	–	–	–
40	3.67	–	–	–
41	0.93	–	–	–
Average	**2.22**	**5.00**	**5.36**	**4.58**
Minimum	**0.22**	**2.49**	**3.81**	**2.32**
Maximum	**6.35**	**7.41**	**7.33**	**7.04**
STD	**1.43**	**1.42**	**0.92**	**1.63**

Appendix (II.5) – List of Total Phosphate Content (%P_2O_5) for the four dams

S. No.	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
1	1.15	2.60	9.58	7.58
2	1.53	5.20	8.98	4.55
3	1.53	4.83	9.58	7.58
4	2.12	5.58	11.38	3.79
5	1.95	4.83	9.58	3.03
6	3.40	4.83	10.18	8.33
7	3.40	4.83	9.58	6.06
8	3.82	5.58	10.18	6.06
9	2.97	5.58	8.38	8.33
10	3.40	3.35	7.78	7.58
11	2.55	5.20	4.79	4.55
12	4.25	5.20	–	5.30
13	3.40	4.83	–	2.27
14	1.70	4.83	–	6.06
15	1.70	4.83	–	3.79
16	3.40	3.72	–	5.30
17	3.40	3.72	–	4.55
18	5.52	2.60	–	5.30
19	5.10	3.72	–	–
20	2.12	2.23	–	–
21	2.97	4.83	–	–
22	1.27	3.35	–	–
23	1.27	3.72	–	–
24	1.27	–	–	–
25	1.27	–	–	–
26	1.27	–	–	–
27	1.27	–	–	–
28	1.27	–	–	–
29	1.70	–	–	–
30	1.70	–	–	–
31	2.12	–	–	–
32	1.27	–	–	–
33	1.70	–	–	–
34	1.70	–	–	–
35	2.55	–	–	–
36	1.70	–	–	–
37	1.70	–	–	–
38	1.27	–	–	–
39	5.10	–	–	–
40	5.95	–	–	–
41	1.27	–	–	–
Average	**2.49**	**4.35**	8.94	5.53
Minimum	**1.15**	**2.23**	4.79	2.27
Maximum	**5.95**	**5.58**	11.38	8.33
STD	**1.31**	**1.07**	1.71	1.80

Appendix II.6 List of Cation Exchange Capacity (CEC) for the four dams

S. No.	Al-Shuweib	Al-Bih	Al-Tawiyeen	Ham
1	9.1	28.7	63.2	85.4
2	19.2	55.3	60.3	37.1
3	18.7	55.0	71.8	27.6
4	19.9	62.8	82.3	33.0
5	14.1	53.8	63.9	21.5
6	30.0	59.0	76.1	24.1
7	28.4	53.6	68.0	37.4
8	38.5	72.5	65.7	51.8
9	33.6	63.1	40.6	39.5
10	19.0	38.4	45.7	52.8
11	28.4	61.3	16.6	40.0
12	43.2	45.6	–	51.1
13	36.5	50.3	–	20.0
14	22.6	51.3	–	23.6
15	16.8	56.6	–	50.3
16	38.4	55.3	–	78.7
17	42.3	36.8	–	53.0
18	48.1	23.2	–	68.1
19	38.8	45.6	–	–
20	23.6	20.9	–	–
21	43.2	62.4	–	–
22	21.1	38.4	–	–
23	17.5	41.2	–	–
24	16.4	–	–	–
25	26.3	–	–	–
26	23.8	–	–	–
27	25.4	–	–	–
28	28.6	–	–	–
29	33.8	–	–	–
30	26.5	–	–	–
31	23.4	–	–	–
32	21.4	–	–	–
33	22.2	–	–	–
34	24.7	–	–	–
35	27.8	–	–	–
36	22.0	–	–	–
37	23.3	–	–	–
38	24.5	–	–	–
39	61.7	–	–	–
40	71.2	–	–	–
41	15.9	–	–	–
Average	**29.1**	**49.0**	**57.9**	**45.0**
Minimum	**9.1**	**20.9**	**16.6**	**20.0**
Maximum	**71.2**	**72.5**	**82.3**	**85.4**
STD	**12.5**	**13.3**	**18.7**	**19.1**

Appendix (II.7) – List of Bulk Trace Metals analysis for Al-Shuweib dam.

S. No.	Al (ppm)	Fe (ppm)	Cu (ppm)	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
1	18.1	35	0.02	0	0.3	0.01	0.05
2	20	35.7	0.02	0	0.2	0.01	0.06
3	19.7	45.1	0.05	0	0.3	0.02	0.07
4	20.9	37.9	0.02	0	0.3	0.01	0.08
5	20.9	25.7	0.03	0	0.3	0.02	0.1
6	23.1	44.7	0.04	0	0.3	0.02	0.2
7	23.1	39.6	0.04	0	0.3	0.02	0.4
8	23.9	48.7	0.04	0	0.3	0.02	0.1
9	24.2	49.3	0.04	0	0.3	0.02	0.1
10	23.8	44.3	0.04	0	0.2	0.02	0.09
11	24.1	36.2	0.03	0	0.2	0.02	0.07
12	25.2	54.1	0.04	0	0.3	0.03	0.1
13	25.4	39.6	0.03	0	0.2	0.02	0.1
14	23.7	26.7	0.02	0	0.2	0.01	0.05
15	22.8	27.8	0.02	0	0.2	0.01	0.05
16	25	42.4	0.04	0	0.3	0.02	0.1
17	24.9	44.6	0.03	0	0.3	0.03	0.09
18	26.9	69.5	0.07	0	0.4	0.03	0.1
19	27.3	65.5	0.06	0	0.4	0.03	0.1
20	24.1	26.2	0.02	0	0.2	0.01	0.07
21	24.9	48.4	0.04	0	0.4	0.02	0.09
22	22.2	24.4	0.01	0	0.2	0.01	0.04
23	22.5	20.8	0.01	0	0.1	0.01	0.03
24	23.7	23.5	0.01	0	0.2	0.02	0.04
25	22.3	42.5	0.02	0	0.4	0.01	0.06
26	22.2	39.6	0.02	0	0.4	0.01	0.06
27	23.1	39.7	0.02	0	0.4	0.01	0.06
28	23.8	38.9	0.02	0	0.4	0.02	0.08
29	24.5	45.7	0.03	0	0.5	0.01	0.07
30	23.5	37.7	0.02	0	0.4	0.02	0.06
31	24.4	32.1	0.03	0	0.3	0.01	0.06
32	22.8	32.4	0.03	0	0.3	0.01	0.05
33	23.2	39.9	0.02	0	0.4	0.01	0.06
34	23.4	33.4	0.02	0	0.3	0.01	0.05
35	25.5	44.8	0.03	0	0.3	0.01	0.07
36	23.9	41.3	0.02	0	0.4	0.01	0.06
37	22.9	40.3	0.02	0	0.4	0.01	0.06
38	22.4	44.4	0.05	0	0.5	0.02	0.07
39	27.9	63.8	0.06	0	0.3	0.03	0.1
40	28.5	72.8	0.07	0	0.4	0.03	0.2
41	22.7	25.6	0.01	0	0.2	0.01	0.04
Average	**23.6**	**41**	**0.03**	**0**	**0.3**	**0.02**	**0.09**
Minimum	**18.1**	**20.8**	**0.01**	**0**	**0**	**0.01**	**0.03**
Maximum	**28.5**	**72.8**	**0.07**	**0**	**0.5**	**0.03**	**0.4**
STD	**2.06**	**12**	**0.02**	**0**	**0.1**	**0.01**	**0.06**

Appendix (II.8) – List of Bulk Trace Metals analysis for Al-Bih dam

S. No.	Al (ppm)	Fe (ppm)	Cu (ppm)	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
1	23.6	28.8	0.02	0	0.1	0.03	0.06
2	27.9	48.5	0.04	0	0.18	0.038	0.1
3	27.8	48.2	0.04	0	0.19	0.033	0.1
4	27.2	50.4	0.05	0	0.19	0.039	0.1
5	28.1	48.9	0.04	0	0.18	0.034	0.1
6	28.1	47.6	0.04	0	0.18	0.04	0.1
7	27.4	46.7	0.04	0	0.18	0.034	0.1
8	28	51.4	0.05	0	0.19	0.04	0.1
9	28.2	58.7	0.04	0	0.2	0.038	0.1
10	26.6	39.2	0.02	0	0.14	0.06	0.1
11	27.5	50.7	0.04	0	0.19	0.038	0.1
12	27.9	49.7	0.04	0	0.18	0.035	0.1
13	28.3	48.6	0.04	0	0.17	0.04	0.1
14	27.9	46.8	0.04	0	0.17	0.04	0.1
15	27.7	49.2	0.04	0	0.18	0.033	0.1
16	26.4	40.2	0.03	0	0.14	0.033	0.1
17	26.2	41.1	0.03	0	0.14	0.03	0.09
18	23.3	27.3	0.01	0	0.1	0.03	0.06
19	26.8	43.8	0.03	0	0.16	0.03	0.1
20	22.6	24.4	0.02	0	0.09	0.03	0.06
21	27.5	47.7	0.04	0	0.17	0.038	0.17
22	26.4	39.3	0.02	0	0.15	0.029	0.08
23	26.9	41.5	0.03	0	0.16	0.03	0.09
Average	**26.8**	**44.1**	**0.03**	**0**	**0.16**	**0.036**	**0.1**
Minimum	**22.6**	**24.4**	**0.01**	**0**	**0.09**	**0.029**	**0.06**
Maximum	**28.3**	**58.7**	**0.05**	**0**	**0.2**	**0.06**	**0.17**
STD	**1.61**	**8.28**	**0.01**	**0**	**0.03**	**0.007**	**0.02**

Appendix II.9. List of Bulk Trace Metals analysis for Al-Tawiyeen dam

S. No.	Al (ppm)	Fe (ppm)	Cu (ppm)	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
1	28.1	62.2	0.07	0	0.28	0.038	0.17
2	28.5	57.4	0.07	0	0.28	0.033	0.15
3	28.6	60.5	0.07	0	0.28	0.037	0.16
4	28.7	68.2	0.09	0	0.3	0.043	0.6
5	28.8	66.5	0.08	0	0.3	0.037	0.18
6	28.8	65.6	0.08	0	0.3	0.036	0.2
7	29	62	0.07	0	0.3	0.04	0.16
8	29.1	65.4	0.08	0	0.34	0.044	0.17
9	27.7	58.2	0.07	0	0.37	0.038	0.16
10	28.3	56.9	0.1	0	0.3	0.037	0.14
11	30.8	80.9	0.14	0.002	0.38	0.026	0.2
Average	**28.8**	**64.7**	**0.09**	**0.0003**	**0.31**	**0.037**	**0.23**
Minimum	**27.7**	**56.9**	**0.07**	**0**	**0.28**	**0.026**	**0.14**
Maximum	**30.8**	**80.9**	**0.14**	**0.002**	**0.38**	**0.044**	**0.6**
STD	**0.79**	**6.79**	**0.02**	**0**	**0.03**	**0.005**	**0.13**

Appendix II.10. List of Bulk Trace Metals analysis for Ham dam

S. No.	Al (ppm)	Fe (ppm)	Cu (ppm)	Cd (ppm)	Cr (ppm)	Pb (ppm)	Zn (ppm)
1	29.4	77.4	0.2	0	0.86	0.029	0.3
2	27.9	79	0.1	0	1.02	0.024	0.5
3	28.6	78.6	0.1	0	0.82	0.038	0.17
4	27.7	72.2	0.1	0	0.94	0.021	0.1
5	28.4	56.9	0.1	0	0.93	0.022	0.08
6	29	84.2	0.16	0.001	0.84	0.04	0.19
7	28.3	73	0.1	0.001	0.73	0.035	0.16
8	28.3	73.5	0.1	0	0.76	0.03	0.1
9	29.5	80.9	0.15	0.002	0.74	0.033	0.17
10	28.8	75.9	0.1	0.001	0.74	0.033	0.16
11	27.1	75.6	0.1	0	0.98	0.03	0.1
12	28.1	69.7	0.1	0	0.71	0.03	0.1
13	27.1	85.2	0.19	0.003	1.54	0.019	0.1
14	28.5	71.9	0.1	0	0.77	0.028	0.13
15	27	66.9	0.17	0	0.75	0.025	0.1
16	26.7	67.6	0.13	0	0.76	0.029	0.13
17	27.3	64.9	0.1	0	0.78	0.02	0.1
18	28.5	70.2	0.18	0	0.8	0.025	0.1
Average	**28.1**	**73.3**	**0.13**	**0.0004**	**0.89**	**0.029**	**0.17**
Minimum	**26.7**	**56.9**	**0.1**	**0.0**	**0.71**	**0.019**	**0.08**
Maximum	**29.5**	**85.2**	**0.2**	**0.003**	**1.54**	**0.04**	**0.5**
STD	**0.83**	**7.05**	**0.04**	**0.0009**	**0.19**	**0.006**	**0.1**

Appendix II.11. Grain size values for Al Bih and Al Shuweib dams

	sample no.	Blh1	Blh3	Blh5	Blh7	Blh10	Shuweib 1	Shuweib 9	Shuweib 18	Shuweib 27	Shuweib 34	Shuweib 41
Phi (Ø)	mm						wt %					
-2.0	4	59.98	0.00	0.00	0.00	0.00	13.00	13.15	0.00	21.66	15.12	12.18
-1.0	2	10.64	0.00	0.00	0.00	0.00	24.01	6.77	0.00	14.86	15.02	4.04
0.0	1	6.64	0.64	0.00	0.00	3.89	18.01	9.87	7.60	11.79	13.82	4.64
1.0	0.5	6.57	3.32	4.00	0.34	6.02	11.75	12.78	7.98	8.70	10.01	4.17
2.0	0.25	6.22	3.88	1.70	0.96	5.22	10.90	19.37	20.89	13.89	14.50	10.18
3.0	0.125	3.27	16.53	7.28	3.28	21.27	16.93	15.91	24.61	19.62	19.53	41.69
4.0	0.062	2.41	47.82	32.41	13.01	32.10	4.77	12.31	19.71	7.04	8.69	20.71
>4	<0.062	4.29	27.81	54.61	82.41	31.50	0.63	9.84	19.21	2.44	3.31	2.38
	Wt %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Appendix II.12 Grain size values for Al Bih and Al Shuweib dams

sample no		Tawiyeen 7	Tawiyeen 9	Tawiyeen 11	Ham2	Ham6	Ham11	Ham13
mm	Phi (Ø)				wt. %			
4	-2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	-1.0	0.00	0.00	11.95	0.00	0.00	0.00	45.58
1	0.0	0.00	0.68	14.67	0.00	0.00	0.00	15.49
0.5	1.0	0.00	0.50	26.42	1.29	0.00	3.80	14.71
0.25	2.0	0.00	2.01	28.73	10.62	0.70	4.87	9.59
0.125	3.0	31.82	28.58	11.31	32.36	47.04	41.46	5.10
0.062	4.0	46.36	50.65	5.63	35.50	38.54	35.91	5.31
<0.062	>4	21.81	17.57	1.29	20.23	13.72	13.97	4.22
Wt %		100.0	100.0	100.0	100.0	100.0	100.0	100.0

Appendix II.13. Normality of (Al) concentration in samples collected from the four dams

	Dam	Kolmogrov-Smirnov[a] Statistic	df	Sig.
Al	Al-Bih	.208	23	.011
	Ham	.140	18	.200*
	Al-Shuweib	.127	41	.095
	Al-Tawiyeen	.244	11	.067

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Appendix II.14. Normality of (Fe) concentration in samples collected from the four dams

	Dam	Kolmogrov-Smirnov[a] Statistic	df	Sig.
Fe	Al-Bih	.223	23	.004
	Ham	.075	18	.200*
	Al-Shuweib	.145	41	.030
	Al-Tawiyeen	.176	11	.200*

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Appendix II.15. Normality of (Cd) concentration in samples collected from Ham and Al-Tawiyeen dams

	Dam	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
Cd	Ham	.528	11	.000
	Al-Tawiyeen	.421	18	.000

a. Lilliefors Significance Correction
b. Cd is constant when Dam = Bih. It has been omitted.
c. Cd is constant when Dam = Shwaib. It has been omitted.

Appendix II.16. Normality of (Cr) concentration in samples collected from the four dams

	Dam	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
Cr	Al-Bih	.208	23	.011
	Ham	.221	18	.020
	Al-Shuweib	.121	41	.137
	Al-Tawiyeen	.358	11	.000

a. Lilliefors Significance Correction

Appendix II.17. Normality of (Cu) concentration in samples collected from the four dams

	Dam	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
Cu	Al-Bih	.316	23	.000
	Ham	.374	18	.000
	Al-Shuweib	.218	41	.000
	Al-Tawiyeen	.296	11	.008

a. Lilliefors Significance Correction

Appendix II.18. Normality of (Pb) concentration in samples collected from the four dams

	Dam	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
Pb	Al-Bih	.216	23	.007
	Ham	.117	18	.200*
	Al-Shuweib	.172	41	.004
	Al-Tawiyeen	.222	11	.137

Appendix II.19. Normality of (Zn) concentration in samples collected from the four dams

	Dam	Kolmogorov-Smirnov[a]		
		Statistic	df	Sig.
Zn	Al-Bih	.384	23	.000
	Ham	.274	18	.001
	Al-Shuweib	.331	41	.000
	Al-Tawiyeen	.434	11	.000

a. Lilliefors Significance Correction

Appendix II.20. Kruskal-Wallis test for (Al) concentration in the four investigated dams

	Ranks			Test Statistics^{a,b}	
	Dams	N	Mean Rank		Al
Al	1.00	41	24.65	Chi-Squar	60.078
	2.00	23	52.26	df	3
	3.00	11	81.14	Asymp. Sig.	.000
	4.00	18	70.33		
	Total	93			

a. Kruskal Wallis Test
b. Grouping Variable: Dams
1: Al Shuweib dam, 2: Al-Bih dam, 3: Al-Tawiyeen dam, and 4: Ham dam

Appendix II.21. Kruskal-Wallis test for (Fe) concentration in the four investigated dams

	Ranks			Test Statistics^{a,b}	
	Dams	N	Mean Rank		Fe
Fe	1.00	41	29.79	Chi-Squar	56.153
	2.00	23	39.59	df	3
	3.00	11	69.55	Asymp. Sig.	.000
	4.00	18	81.89		
	Total	93			

a. Kruskal Wallis Test
b. Grouping Variable: Dams
1: Al Shuweib dam, 2: Al-Bih dam, 3: Al-Tawiyeen dam; and 4: Ham dam

Appendix II.22. Kruskal-Wallis test for (Cd) concentration in the four investigated dams

	Ranks			Test Statistics^{a,b}	
	Dams	N	Mean Rank		Cd
Cd	1.00	41	44.00	Chi-Squar	17.758
	2.00	23	44.00	df	3
	3.00	11	48.32	Asymp. Sig.	.000
	4.00	18	56.86		
	Total	93			

a. Kruskal Wallis Test
b. Grouping Variable: Dams:
1: Al Shuweib dam; 2: Al-Bih dam; 3: Al-Tawiyeen dam; and 4: Ham dam

Appendix II.23. Kruskal-Wallis test for (Cr) concentration in the four investigated dams

	Ranks			Test Statistics^{a,b}	
	Dams	N	Mean Rank		Cr
Cr	1.00	41	47.11	Chi-Squar	66.461
	2.00	23	15.57	df	3
	3.00	11	50.95	Asymp. Sig.	.000
	4.00	18	84.50		
	Total	93			

a. Kruskal Wallis Test
b. Grouping Variable: Dams:
1: Al Shuweib dam; 2: Al-Bih dam; 3: Al-Tawiyeen dam; and 4: Ham dam

Appendix II.24. Kruskal-Wallis test for (Cu) concentration in the four investigated dams

	Ranks			Test Statistics^{a,b}	
	Dams	N	Mean Rank		Cu
Cu	1.00	41	29.88	Chi-Squar	62.642
	2.00	23	37.39	df	3
	3.00	11	71.14	Asymp. Sig.	.000
	4.00	18	83.53		
	Total	93			

a. Kruskal Wallis Test
b. Grouping Variable: Dams
1: Al Shuweib dam, 2: Al-Bih dam, 3. Al-Tawiyeen dam, and 4. Ham dam

Appendix II.25. Kruskal-Wallis test for (Pb) concentration in the four investigated dams

	Ranks			Test Statistics^{a,b}	
	Dams	N	Mean Rank		Pb
Pb	1.00	41	23.67	Chi-Squar	62.083
	2.00	23	70.80	df	3
	3.00	11	76.09	Asymp. Sig.	.000
	4.00	18	51.94		
	Total	93			

a. Kruskal Wallis Test
b. Grouping Variable: Dams:
1: Al Shuweib dam, 2: Al-Bih dam; 3: Al-Tawiyeen dam; and 4: Ham dam

Appendix II.26. Kruskal-Wallis test for (Zn) concentration in the four investigated dams

	Ranks			Test Statistics^{a,b}	
	Dams	N	Mean Rank		Zn
Zn	1.00	41	30.13	Chi-Squar	43.454
	2.00	23	46.65	df	3
	3.00	11	80.64	Asymp. Sig.	.000
	4.00	18	65.31		
	Total	93			

a. Kruskal Wallis Test
b. Grouping Variable: Dams:
1: Al Shuweib dam; 2: Al-Bih dam; 3: Al-Tawiyeen dam; and 4: Ham dam

Appendix II.27. Multiple Comparisons (Tukey's HSD), for Rank of (Al) concentration in the investigated four dams

(I) Dam	(J) Dam	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bih	Ham	-18.07246*	5.085455	.003	-31.38741	-4.75752
	Shuweib	27.61453*	4.209904	.000	16.59198	38.63707
	Tawiyeen	-28.87549*	5.924030	.000	-44.38603	-13.36495
Ham	Bih	18.07246*	5.085455	.003	4.75752	31.38741
	Shuweib	45.68699*	4.569155	.000	33.72384	57.65014
	Tawiyeen	-10.80303	6.184498	.306	-26.99554	5.38948
Shuweib	Bih	-27.61453*	4.209904	.000	-38.63707	-16.59198
	Ham	-45.68699*	4.569155	.000	-57.65014	-33.72384
	Tawiyeen	-56.49002*	5.487208	.000	-70.85686	-42.12319
Tawiyeen	Bih	28.87549*	5.924030	.000	13.36495	44.38603
	Ham	10.80303	6.184498	.306	-5.38948	26.99554
	Shuweib	56.49002*	5.487208	.000	42.12319	70.85686

Based on observed means * The mean difference is significant at the .05 level

Appendix II.28 Multiple Comparisons (Tukey's HSD), for Rank of (Fe) concentration in the investigated four dams

(I) Dam	(J) Dam	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bih	Ham	-42.30193*	5.390484	.000	-56.41552	-28.18834
	Shuweib	9.79427	4.462417	.133	-1.88941	21.47796
	Tawiyeen	-29.95850*	6.279358	.000	-46.39937	-13.51762
Ham	Bih	42.30193*	5.390484	.000	28.18834	56.41552
	Shuweib	52.09621*	4.843216	.000	39.41550	64.77692
	Tawiyeen	12.34343	6.555449	.243	-4.82031	29.50718
Shuweib	Bih	-9.79427	4.462417	.133	-21.47796	1.88941
	Ham	-52.09621*	4.843216	.000	-64.77692	-39.41550
	Tawiyeen	-39.75277*	5.816335	.000	-54.98134	-24.52420
Tawiyeen	Bih	29.95850*	6.279358	.000	13.51762	46.39937
	Ham	-12.34343	6.555449	.243	-29.50718	4.82031
	Shuweib	39.75277*	5.816335	.000	24.52420	54.98134

Based on observed means * The mean difference is significant at the .05 level

Appendix II.29. Multiple Comparisons (Tukey's HSD), for Rank of (Cd) concentration in the investigated four dams

(I) Dam	(J) Dam	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bih	Ham	-12.86111*	3.303266	.001	-21.50986	-4.21236
	Shuweib	.00000	2.734551	1.000	-7.15971	7.15971
	Tawiyeen	-4.31818	3.847964	.677	-14.39308	5.75672
Ham	Bih	12.86111*	3.303266	.001	4.21236	21.50986
	Shuweib	12.86111*	2.967903	.000	5.09043	20.63180
	Tawiyeen	8.54293	4.017152	.153	-1.97494	19.06080
Shuweib	Bih	.00000	2.734551	1.000	-7.15971	7.15971
	Ham	-12.86111*	2.967903	.000	-20.63180	-5.09043
	Tawiyeen	-4.31818	3.564226	.621	-13.65019	5.01382
Tawiyeen	Bih	4.31818	3.847964	.677	-5.75672	14.39308
	Ham	-8.54293	4.017152	.153	-19.06080	1.97494
	Shuweib	4.31818	3.564226	.621	-5.01382	13.65019

* The mean difference is significant at the .05 level

Appendix II 30. Multiple Comparisons (Tukey's HSD), for Rank of (Cr) concentration in the investigated four dams

(I) Dam	(J) Dam	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bih	Ham	-68.93478*	4.540348	.000	-80.82251	-57.04705
	Shuweib	-31.54454*	3.758647	.000	-41.38558	-21.70349
	Tawiyeen	-35.38933*	5.289037	.000	-49.23730	-21.54135
Ham	Bih	68.93478*	4.540348	.000	57.04705	80.82251
	Shuweib	37.39024*	4.079390	.000	26.70942	48.07107
	Tawiyeen	33.54545*	5.521586	.000	19.08861	48.00230
Shuweib	Bih	31.54454*	3.758647	.000	21.70349	41.38558
	Ham	-37.39024*	4.079390	.000	-48.07107	-26.70942
	Tawiyeen	-3.84479	4.899038	.861	-16.67165	8.98207
Tawiyeen	Bih	35.38933*	5.289037	.000	21.54135	49.23730
	Ham	-33.54545*	5.521586	.000	-48.00230	-19.08861
	Shuweib	3.84479	4.899038	.861	-8.98207	16.67165

* The mean difference is significant at the .05 level

Appendix II.31. Multiple Comparisons (Tukey's HSD), for Rank of (Cu) concentration in the investigated four dams

(I) Dam	(J) Dam	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bih	Ham	-46.13647*	4.820991	.000	-58.75899	-33.51.395
	Shuweib	7.51326	3.990972	.243	-2.93607	17.96258
	Tawiyeen	-33.74506*	5.615957	.000	-48.44899	-19.04113
Ham	Bih	46.13647*	4.820991	.000	33.51395	58.75899
	Shuweib	53.64973*	4.331541	.000	42.30871	64.99075
	Tawiyeen	12.39141	5.862880	.157	-2.95902	27.74185
Shuweib	Bih	-7.51326	3.990972	.243	-17.96258	2.93607
	Ham	-53.64973*	4.331541	.000	-64.99075	-42.30871
	Tawiyeen	-41.25831*	5.201852	.000	-54.87802	-27.63861
Tawiyeen	Bih	33.74506*	5.615957	.000	19.04113	48.44899
	Ham	-12.39141	5.862880	.157	-27.74185	2.95902
	Shuweib	41.25831*	5.201852	.000	27.63861	54.87802

Based on observed means *: The mean difference is significant at the .05 level

Appendix II 32. Multiple Comparisons (Tukey's HSD), for Rank of (Pb) concentration in the investigated four dams

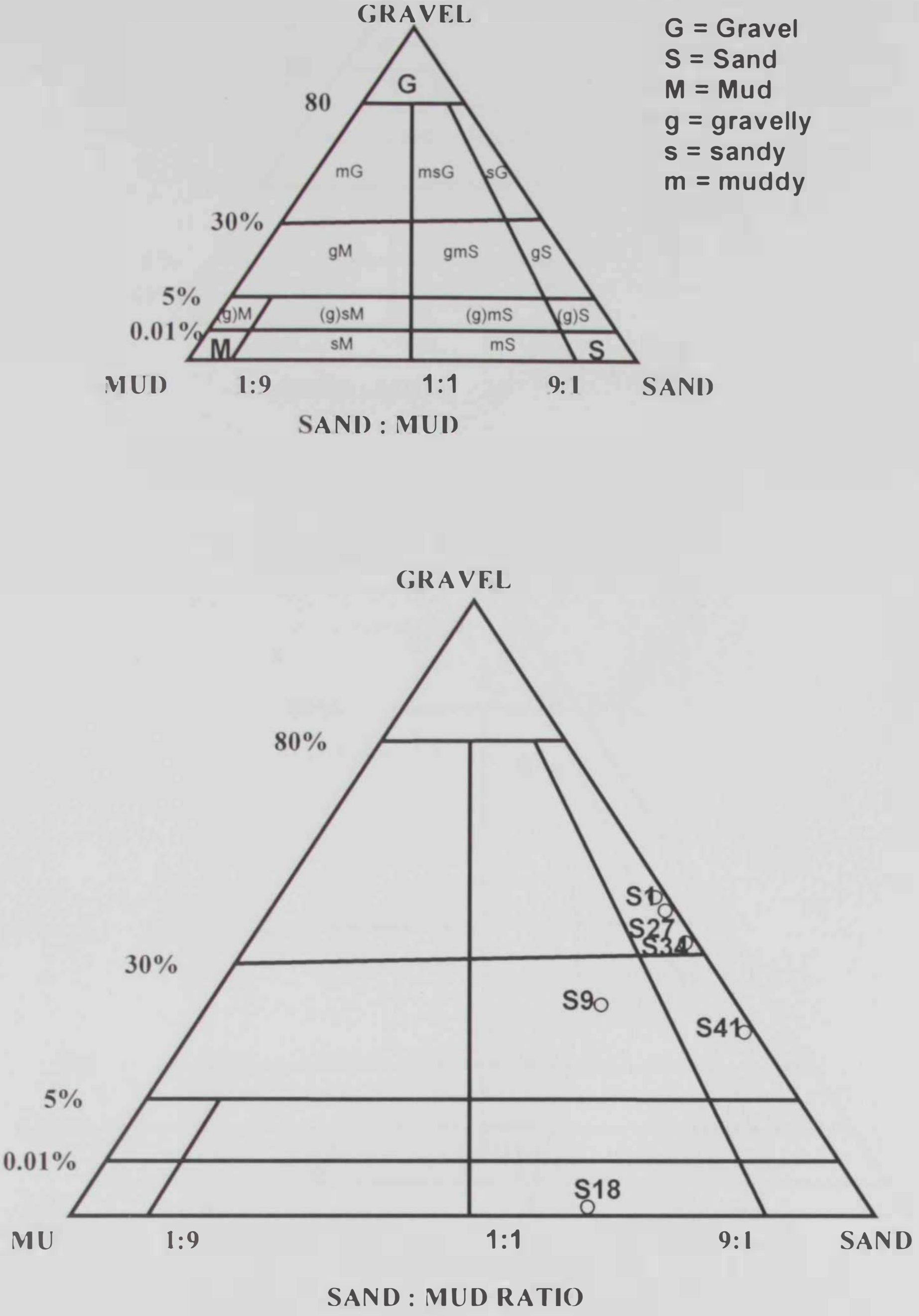
(I) Dam	(J) Dam	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bih	Ham	18.85990*	4.917472	.001	5.98478	31.73503
	Shuweib	47.13362*	4.070842	.000	36.47517	57.79206
	Tawiyeen	-5.28656	5.728347	.793	-20.28476	9.71163
Ham	Bih	-18.85990*	4.917472	.001	-31.73503	-5.98478
	Shuweib	28.27371*	4.418226	.000	16.70573	39.84170
	Tawiyeen	-24.14646*	5.980211	.001	-39.80410	-8.48883
Shuweib	Bih	-47.13362*	4.070842	.000	-57.79206	-36.47517
	Ham	-28.27371*	4.418226	.000	-39.84170	-16.70573
	Tawiyeen	-52.42018*	5.305955	.000	-66.31245	-38.52791
Tawiyeen	Bih	5.28656	5.728347	.793	-9.71163	20.28476
	Ham	24.14646*	5.980211	.001	8.48883	39.80410
	Shuweib	52.42018*	5.305955	.000	38.52791	66.31245

Based on observed means * The mean difference is significant at the .05 level

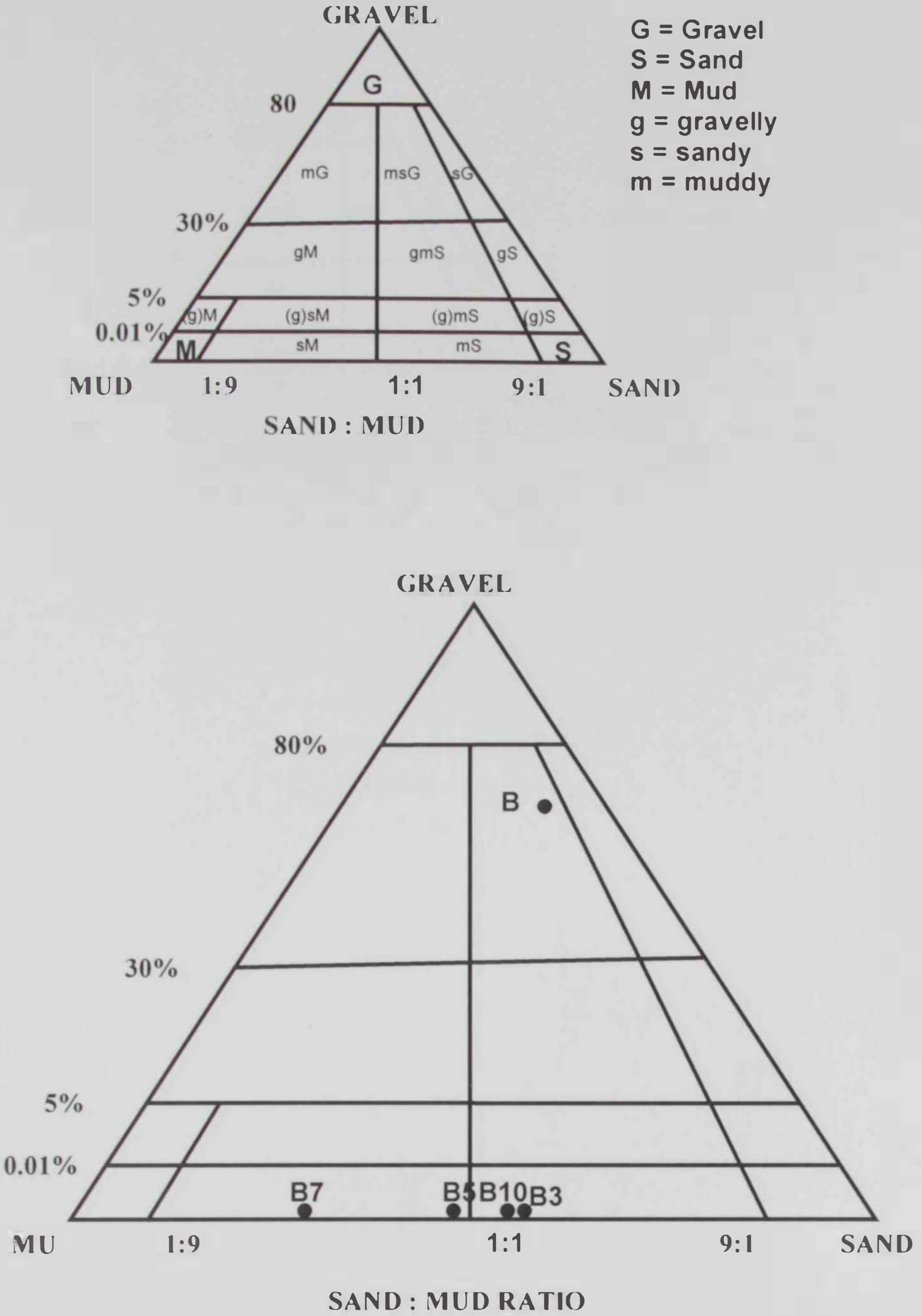
Appendix II 33. Multiple Comparisons (Tukey's HSD), for Rank of (Zn) concentration in the investigated four dams

(I) Dam	(J) Dam	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bih	Ham	-18.65338*	6.121338	.016	-34.68052	-2.62624
	Shuweib	16.51803*	5.067441	.008	3.25024	29.78581
	Tawiyeen	-33.98419*	7.130726	.000	-52.65415	-15.31423
Ham	Bih	18.65338*	6.121338	.016	2.62624	34.68052
	Shuweib	35.17141*	5.499870	.000	20.77142	49.57140
	Tawiyeen	-15.33081	7.444250	.175	-34.82165	4.16004
Shuweib	Bih	-16.51803*	5.067441	.008	-29.78581	-3.25024
	Ham	-35.17141*	5.499870	.000	-49.57140	-20.77142
	Tawiyeen	-50.50222*	6.604926	.000	-67.79551	-33.20893
Tawiyeen	Bih	33.98419*	7.130726	.000	15.31423	52.65415
	Ham	15.33081	7.444250	.175	-4.16004	34.82165
	Shuweib	50.50222*	6.604926	.000	33.20893	67.79551

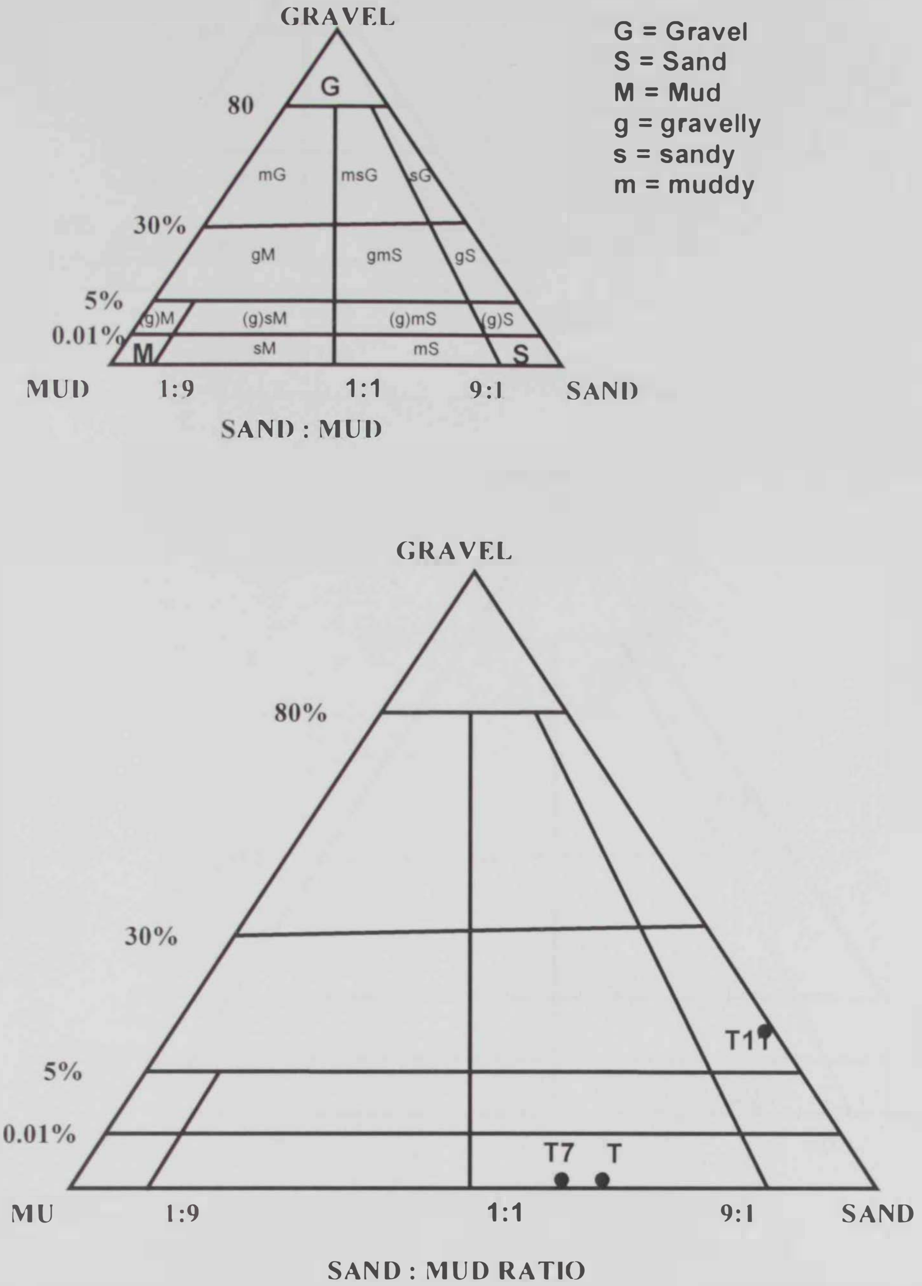
Based on observed means * The mean difference is significant at the .05 level



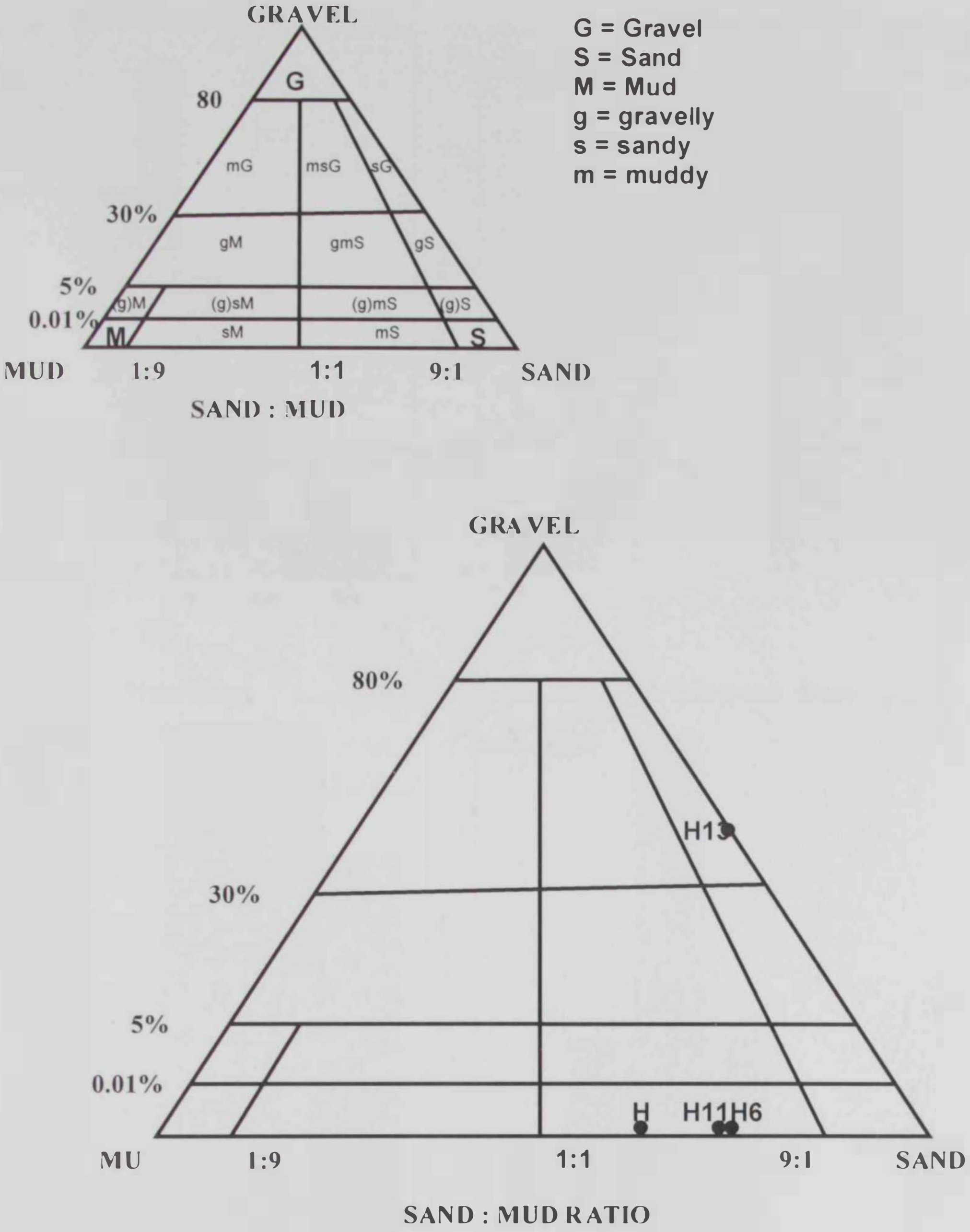
Appendix III.1 Plotted histogram showing the textural classification of the sediment samples of Al-Shuweib dam according to textural Classification Triangle (Folk, 1974).



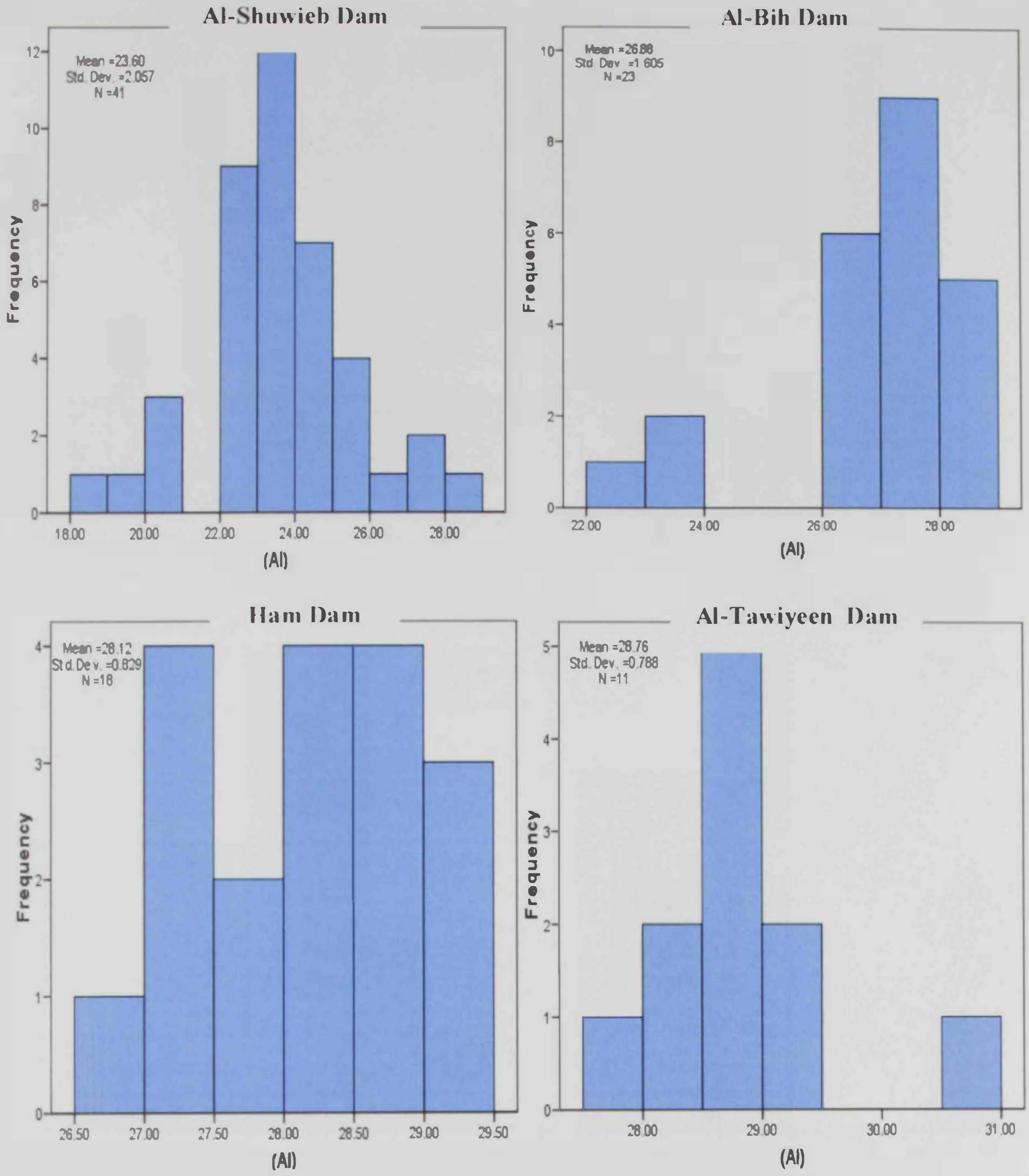
Appendix III.2 Plotted histogram showing the textural classification of the sediment samples of Al-Bih dam according to textural Classification Triangle (Folk, 1974).



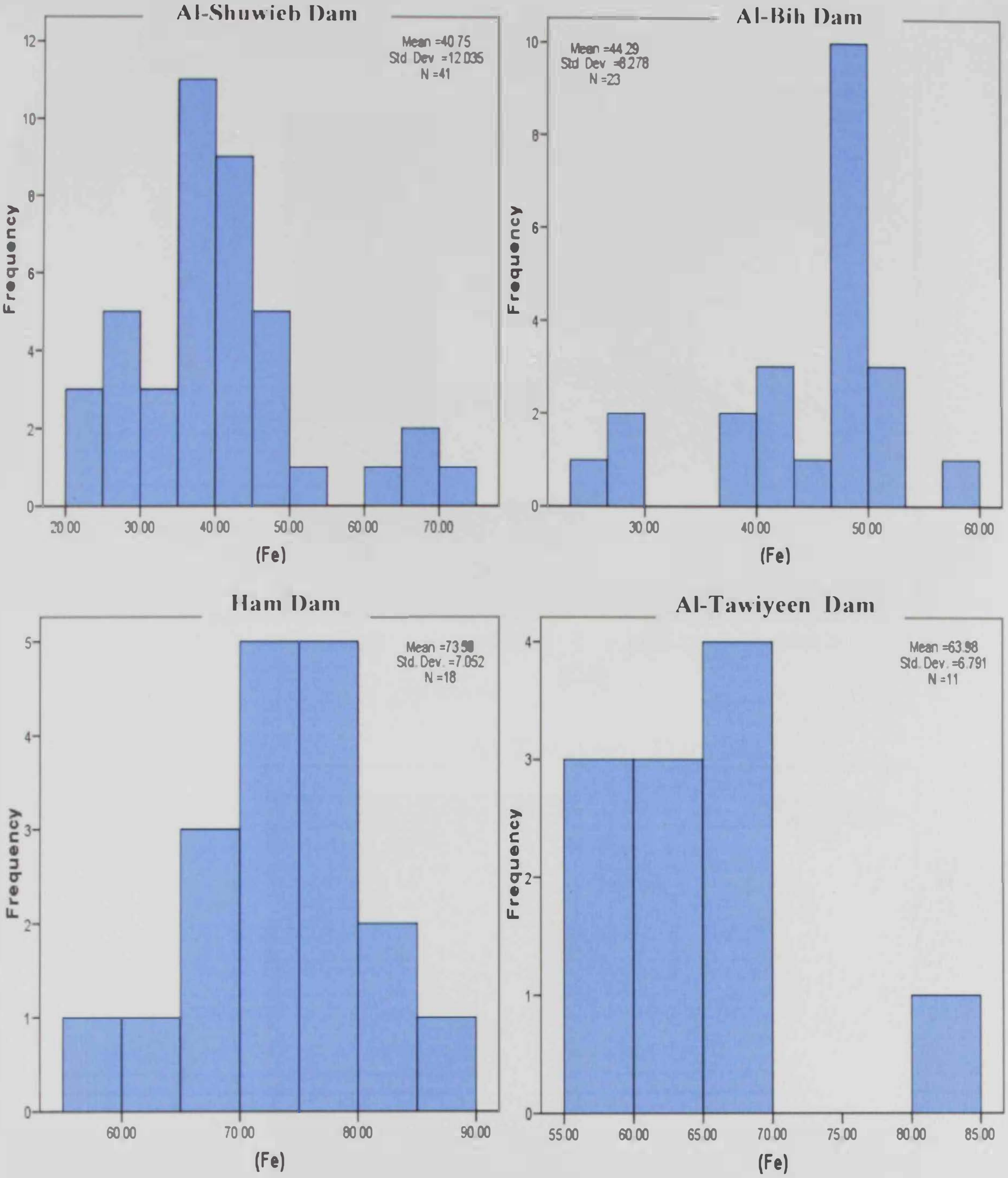
Appendix III 3. Plotted histogram showing the textural classification of the sediment samples of Al-Tawiyeen dam according to textural Classification Triangle (Folk, 1974)



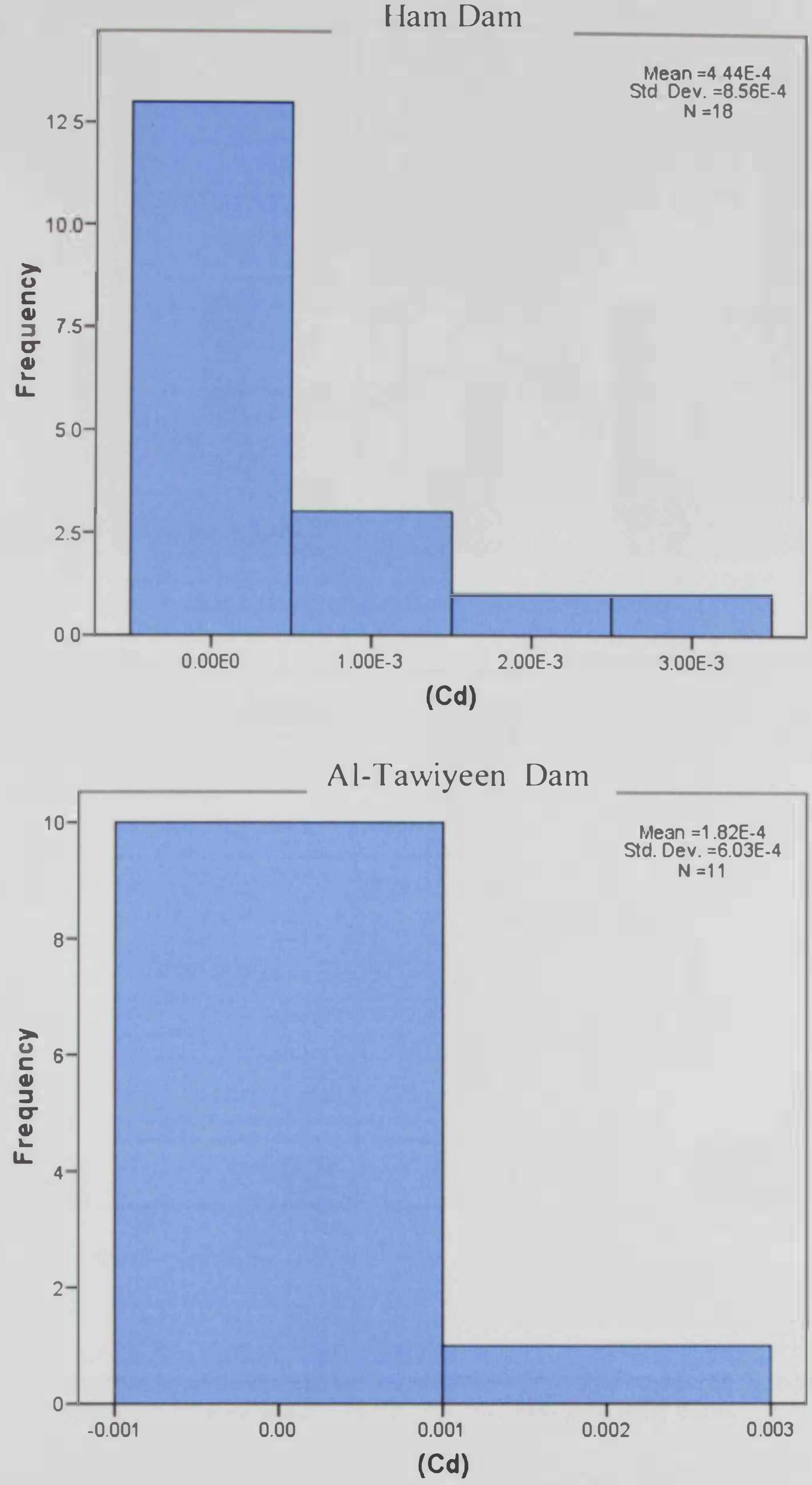
Appendix III.4. Plotted histogram showing the textural classification of the sediment samples of Ham dam according to textural Classification Triangle (Folk, 1974)



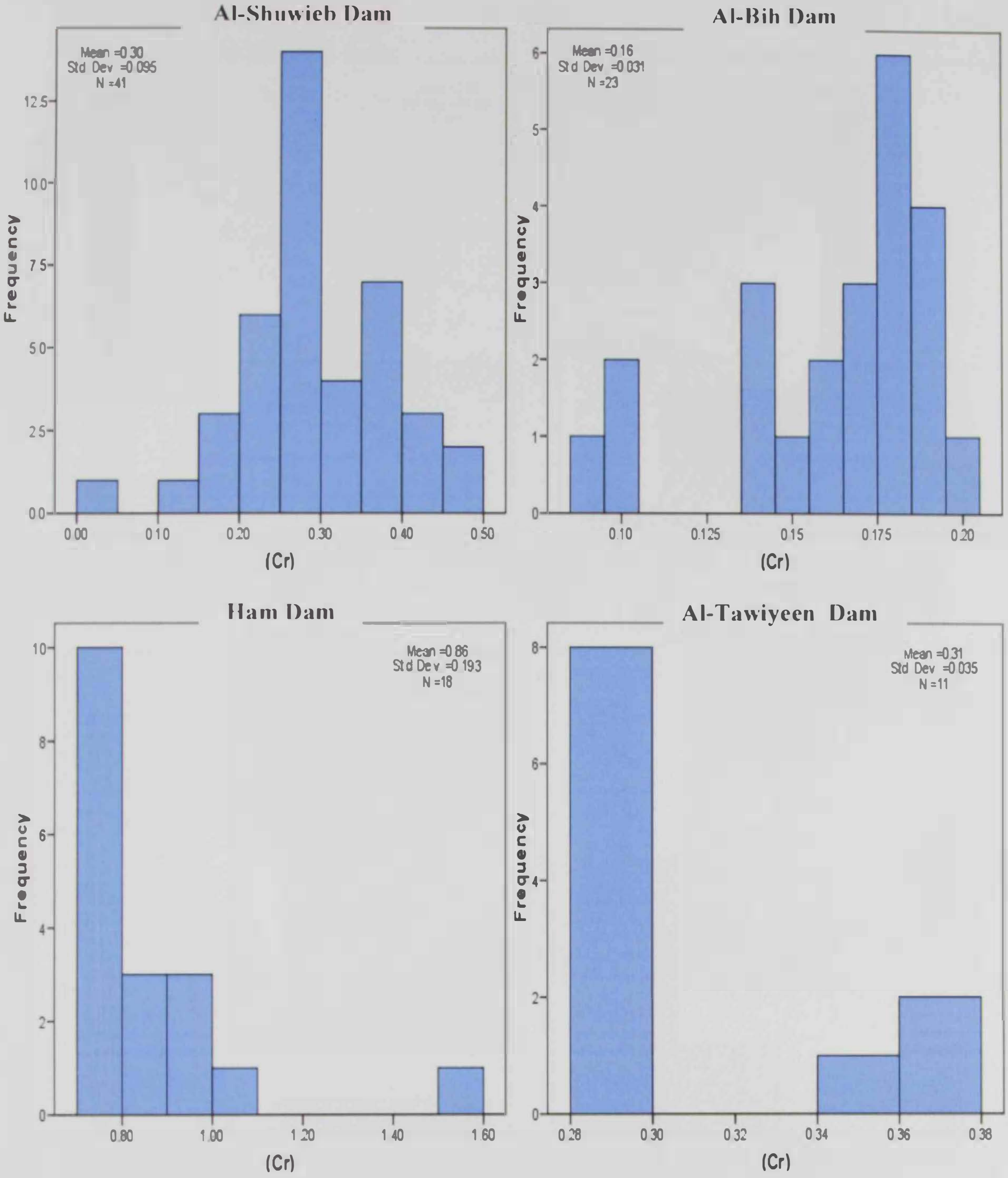
Appendix IV.1. Histogram shows the distribution of (Al) concentration measured in sediments collected from Al-Shwaibb, Al-Bih, Al-Tawiyeen, and Ham dams.



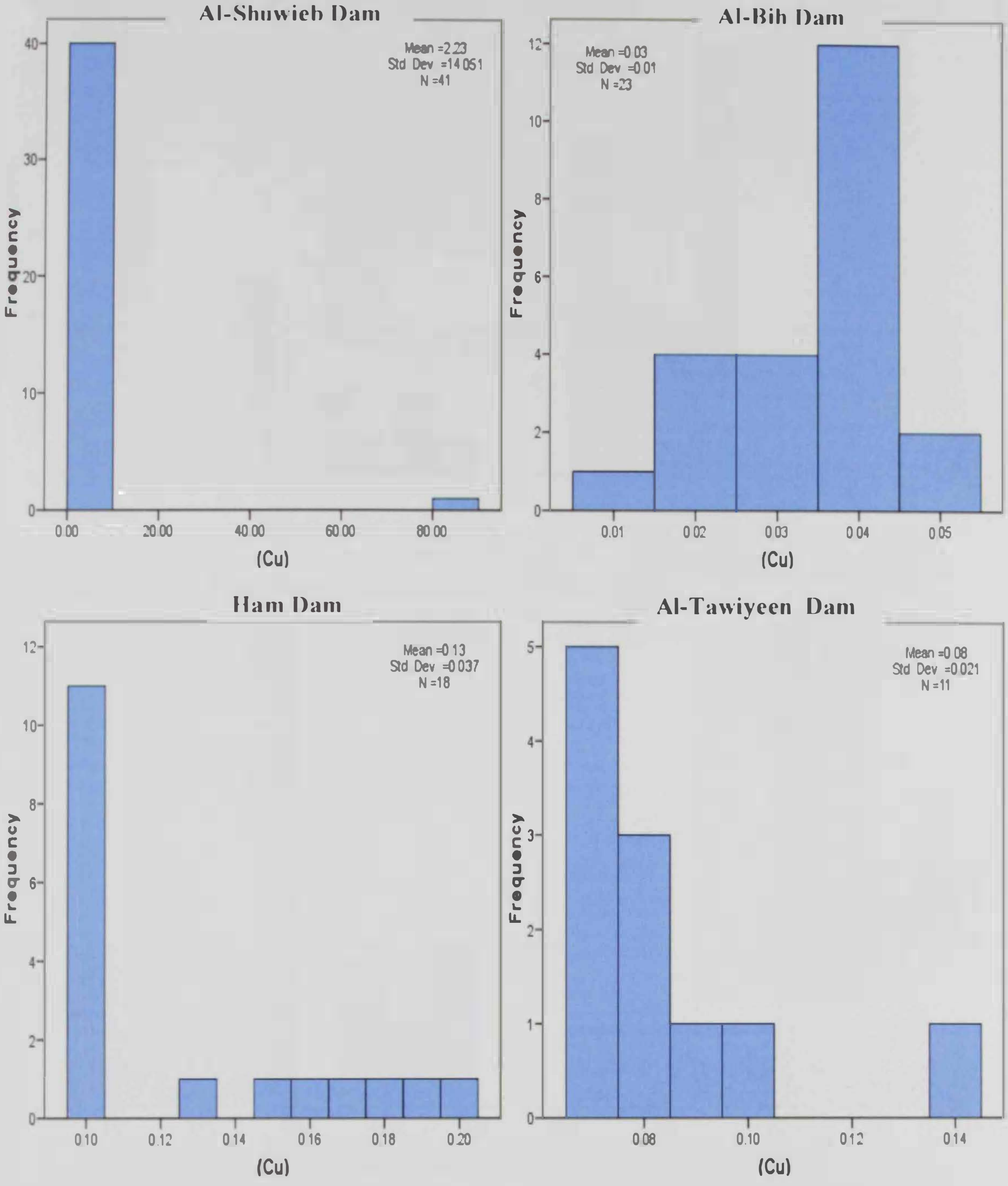
Appendix IV.2. Histogram shows the distribution of (Fe) concentration measured in sediments collected from Al-Shwaibb, Al-Bih, Al-Tawiyeen, and Ham dams



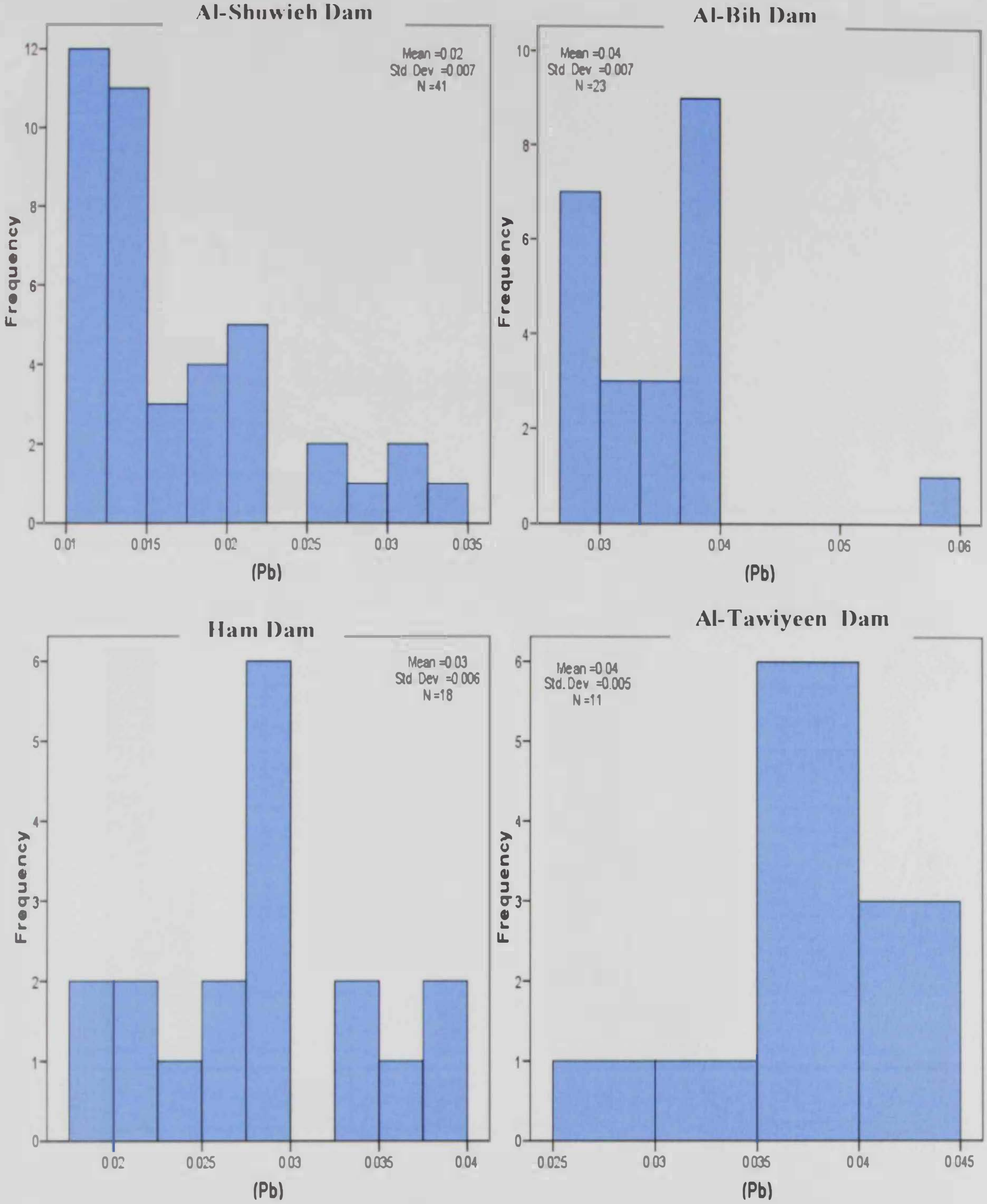
Appendix IV.3. Histogram shows the distribution of (Cd) concentration measured in sediments collected from Al-Tawiyeen, and Ham dams



Appendix IV.4. Histogram shows the distribution of (Cr) concentration measured in sediments collected from Al-Shwaibb, Al-Bih, Al-Tawiyeen, and Ham dams



Appendix IV.5. Histogram shows the distribution of (Cu) concentration measured in sediments collected from Al-Shwaibb, Al-Bih, Al-Tawiyeen, and Ham dams



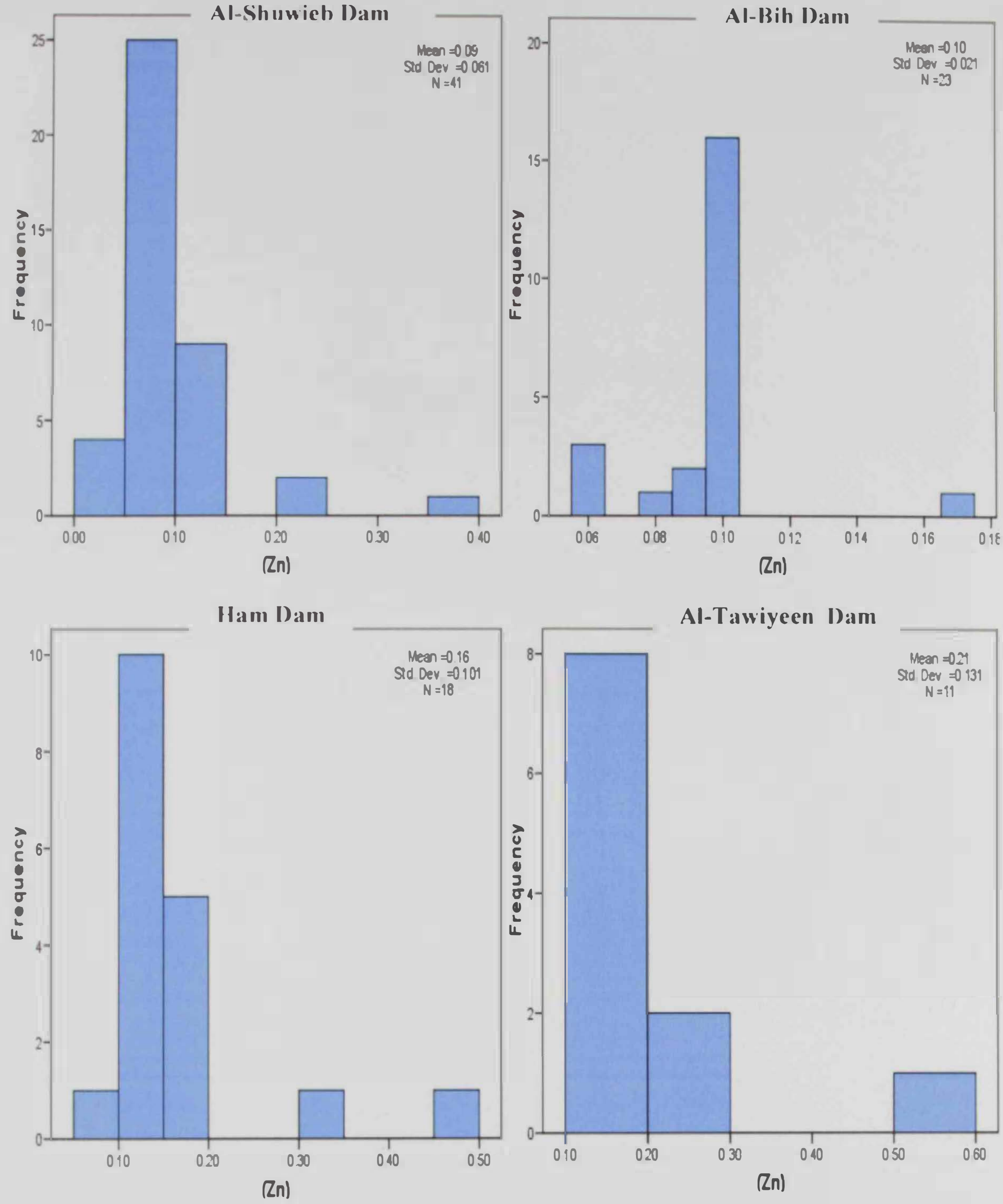
Al-Shuwieh Dam

Al-Bih Dam

Ham Dam

Al-Tawiyeen Dam

Appendix IV.6. Histogram shows the distribution of (Pb) concentration measured in sediments collected from Al-Shwaibb, Al-Bih, Al-Tawiyeen, and Ham dams



Appendix IV.7. Histogram shows the distribution of (Zn) concentration measured in sediments collected from Al-Shwaibb, Al-Bih, Al-Tawiyeen, and Ham dams.

ملخص الدراسة

تقييم الوفرة وقابلية حركة المعادن الثقيلة يتطلب دراسة لسلوك المعادن الثقيلة في رواسب السدود، الذي يُعيقان مياه الأمطار واستعمالاته. لذا تم اختيار ثلاثة وتسعون عينة منْ الرواسب جمعت من سدود وادي الشويّب و وادي البيح و وادي الطويين و وادي حام ، وخضوعها لتحاليل التربة الرسوبية والجيوكيميائية للرصاص والكادميوم والزنك والكروم والنحاس والألمنيوم والحديد.

وقد استخدمت تقنيات متكاملة تشمل الأشعة السينية الحيودية والأشعة السينية الوميضية وامتصاص الطيف الذري لقياس تركيز المعادن الثقيلة. وتم معالجة نتائج الدراسة إحصائياً باستخدام برامج الإحصاء المختلفة وعرضها على الخرائط الخاصة لكل سدّ.

تم استخدام تجربة الفصل المتتالي أو التجزيئي للعناصر الكيميائية لتجزئة تراكيز العناصر التالية: الرصاص والكادميوم والزنك والكروم والنحاس للمراحل الخمس المختلفة. واتضح من الناحية المعدنية أن المعادن الغير طينية المنتشرة في حجم المساوي لحجم حبيبات الرمل يتكون بشكل رئيسي منْ الكوارتز والكالسيت والدولوميت و السربنتين والبلاجيوكليز والأمفيبول و البيروكسين. ووجد إنَ التجمّع المعدني الطينيَ صادفَ في العيناتِ المُحَلّلةِ أنها تتكوّن من الكوارتز كمعدن رئيسي والّيت كمعدن ملحق والكلوركمعدن بسيط. فلا تعتبر هذه المعادن مصدراً للمعادن الثقيلة الضارة. الدراسة على التربة الرسوبية التي جمعت من السدود لم تظهر أي قيمة لعامل البناء للمعادن الثقيلة للرصاص والكادميوم والزنك والكروم والنحاس، ماعدا زيادةِ طفيفة في الحديد. وطبقاً لدليل التراكم الجيولوجي ، لرواسب تربة المناطق الخاضعة للدراسة تعتبر غير ملوّثة فيما يتعلق بالمعادن الثقيلة للرصاص والكادميوم والزنك والكروم والنحاس، وغير ملوّثة إلى ملوث باعتدال فيما يتعلق بمعدن الألمنيوم والحديد.

وربطتْ المعادنُ المدروسةُ إيجابياً ببعض الصفات الكيميائية والفيزيائية مثل قلوية التربة و كمية الأملاح المذابة وكمية كربونات الكالسيوم وكمية المادة العضوية والفوسفور وقيمة سعة التبادل الأيوني لهذه التربة اعتماداً على طبيعة وحجم حبيبات التربة الرسوبية لكل سد مؤكدة أن هذه العوامل قد يكون لها تأثير على السلوك الجيوكيميائي للمعادن الثقيلة.

وتبين أن تركيز كل من رصاص والكادميوم والزنك والكروم والنحاس والألمنيوم والحديد تعكس قيم الخلفية لكل عنصر. وقد دلت النتائج تحاليل الفصل التجزيئ ومراحل التكسير الجيوكيميائي على أن معظم العناصر هي منتشرة وبكميات وفيرة في الجزء المتبقي بعد التحليل التجزيئ مما يدل على أن الجزء الأكبر من هذه التراكيز هو غير ثابت وغير متحرك ضمن البناء البلوري للمعادن.

جامعة الإمارات العربية المتحدة
عمادة الدراسات العليا
برنامج ماجستير علوم موارد المياه

عنوان الأطروحة :

دراسة توزيع والتجزئة الجيوكيميائية للرصاص والكادميوم والزنك والكروم والنحاس في رسوبيات السدود الرئيسية في دولة الإمارات العربية المتحدة

الاسم :

منى راشد مصبح العليلي

المشرفون :

الاسم	الوظيفة
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د. فارس هواري	أستاذ مساعد خارجي كلية جاكسون للعلوم الجيولوجية جامعة تاكسس- الولايات المتحدة الأمريكية

﴿أنزَلَ مِنَ السَّمَاء مَاء فَسَالَتْ أَوْدِيَةٌ بِقَدَرِهَا فَاحْتَمَلَ السَّيْلُ زَبَدًا رَّابِيًا
وَمِمَّا يُوقِدُونَ عَلَيْهِ فِي النَّارِ ابْتِغَاء حِلْيَةٍ أَوْ مَتَاعٍ زَبَدٌ مِّثْلُهُ
كَذَلِكَ يَضْرِبُ اللّهُ الْحَقَّ وَالْبَاطِلَ فَأَمَّا الزَّبَدُ فَيَذْهَبُ جُفَاء
وَأَمَّا مَا يَنفَعُ النَّاسَ فَيَمْكُثُ فِي الأَرْضِ
كَذَلِكَ يَضْرِبُ اللّهُ الأَمْثَالَ﴾

(١٧– الرعد)

جامعة الإمارات العربية المتحدة
عمادة الدراسات العليا
برنامج ماجستير علوم موارد المياه

دراسة توزيع والتجزئة الجيوكيميائية للرصاص والكادميوم والزنك والكروم والنحاس في رسوبيات السدود الرئيسية في دولة الإمارات العربية المتحدة

رسالة مقدمة لاستكمال متطلبات الحصول على
درجة الماجستير في برنامج علوم موارد المياه

منى راشد مصبح العليلي

بكالوريوس العلوم (٢٠٠٠) جامعة الإمارات العربية المتحدة

ديسمبر ٢٠٠٨