UTILIZING OF GIS TO MAP TRACE METALS DISTRIBUTION IN SABKHA AL-FASL, JUBAIL, SAUDI ARABIA BY YOUSEF AL-MUTAWAH A Thesis Presented to the DEANSHIP OF GRADUATE STUDIES KING FAHD UNIVERSITY OF PETROLEUM & MINERALS DHAHRAN, SAUDI ARABIA In Partial Fulfillment of the Requirements for the Degree of MASTER OF SCIENCE In ENVIRONMENTAL SCIENCE DECEMBER, 2015

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2015

This thesis is dedicated

To my wife, daughters Fatimah & Maria, and Sons Mohammed & Husaain

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LIST OF ABBREVIATIONS

ANZECC : Australian and New Zealand Environment and Conservation Council.

CCME : Canadian Council of Ministers of the Environment.

COD : Chemical Oxygen Demand.

Cm : Centimeter.

DO : Dissolved Oxygen.

DI : Distilled Water.

EC : Electrical Conductivity.

FWS United States Fish and Wildlife Service.

ha Hectare.

GPS : Global Positioning System.

GIS : Geological Information System.

IDW : Inverse Distance Weighted.

KACST : King Abdul Aziz City for Science and Technology.

Kg : Kilogram.

Km : Kilometer.

m³ : Cubic Meter.

Mg Milligram.

NWI National Wetlands Inventory.

NOAA : National Oceanic and Atmospheric Administration-USA.

OWOW : Office of Wetlands, Oceans and Watersheds.

Ppm: part per million.

pH : Power of Hydrogen.

PME : Presidency of Meteorology and Environment- Saudi Arabia.

RC : Royal Commission for Jubail and Yanbu.

TP : Total Phosphorous.

USEPA : United States Environmental Protection Agency.

USGS : United States Geological Survey.

VROM : Ministry of Housing, Spatial Planning and the Environment –

Netherlands

WFD : Water Framework Directive.

XRF : X-Ray Fluorescence Spectrometer.

ABSTRACT

Full Name : Yousef Jawad Al-Mutawah

Thesis Title : Utilizing GIS to Map Trace Metals Distribution in Sabkha Al-Fasl,

Jubail, Saudi Arabia

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Wetlands occur in every country, but some areas account for more numbers of wetlands than others depending on the climate where humid climate highly supports wetlands more than hot arid climate. Due to their biodiversity richness and ecological functions, wetlands are considered as one of the most important ecosystems on the Earth because they provide many important services to human society sand vital functions to the other living organisms. In Saudi Arabia, Sabkha Al-Fasl Lagoon is one of the man-made wetland located on the southwest of Jubail Industrial City. It is an evaporation lagoon, using the excess treated waste water effluents supplied from Jubail Industrial City. The treated wastewater has high concentration of nutrients which lead to produce a reasonable quantity biomass of micro-flora and micro-fauna, which results in supplying the essential food for many types of feeding birds. Sediment is one of the main components of the Sabkha and it is an essential to the functioning of aquatic ecosystems. Trace metals are one of the most common pollutants which have severely deteriorated the ecosystems due to their toxicity, abundance, persistence, and subsequent bio-accumulation. Therefore, total 25 sediment samples were collected across Sabkha Al-Fasl to determine concentrations level of trace metals (V, Cr, Co, Ni, Cu, Zn, Mo, Ba, and Pb) as well as their distribution. The concentration levels were measured by ICP-AES according to USEPA Method 200.7. The average concentrations of the metals are: V(1.46ppm), Cr (1.59ppm), Co(0.37ppm), Ni(2.48ppm), Cu(0.81ppm), Zn(2.56ppm), Mo(0.28ppm), Ba(2.67ppm) and Pb (0.21ppm). All the concentration levels of those metals are within the permissible limits of local and international sediment guidelines. By utilizing ArcGIS 10.1, trace metals concentrations levels and their distribution in sediment as well as their spatial variation maps were developed in GIS

ملخص الرسالة

الاسم الكامل: يوسف جواد المطاوعة

عنوان الرسالة: استخدام نظم المعلومات الجغرافية لرسم خريطة توزيع المعادن النزرة في سبخة الفصل ، الجبيل، المملكة العربية السعودية

التخصص: علوم البيئة

تاريخ الدرجة العلمية: ديسمبر 2015

توجد الأراضي الرطبة في كل بلد، ولكن بعض المناطق تحتوي على اعداد كبيره من الأراضي الرطبة مقارنه مع المناطق الأخرى اعتمادا على المناخ حيث المناخات الرطبة تدعم الأراضي الرطبة اكثر من المناخات الجافة الساخنة. نظرا لخصوبه البينية والتنوع البيولوجي، تعتبر الأراضي الرطبة واحدة من أهم النظم الإيكولوجية على الأرض لأنها توفر العديد من الخدمات الهامة للا نسان والكاننات الحية الأخرى. في المملكة العربية السعودية، سبخة آلفصل هي واحدة من تلك الأراضي الرطبة التي من صنع الإنسان والتي تقع على الحافة الجنوبية الغربية المعينة الجبيل الصناعية. فسبخة الفصل هي بحيرة للتبخير، وذلك باستخدام فاتض مياه الصرف الصحي المعالجة القادمة من مدينة الجبيل الصناعية. تعتبرمياه الصرف الصحي المعالجة غنية بالمواد الغذائية التي توفر بدورها أساس السلسلة الغذائية لأنواع عديدة من الطيور والكاننات الحيه الاخرى. تعتبر الرواسب بالمواد الغذائية التي توفر بدورها أساس السلسلة الغذائية لأنواع عديدة من الرواسب الرملية من جميع انحاء السبخة لتحديد شيوعا التي تدمر النظم البيئية نظرا لسميتها الشديدة. لذلك، تم جمع 25 عينة من الرواسب الرملية من جميع أنحاء السبخة لتحديد توزيعها. تم قياس مستويات تركيز من قبل ICP-AES وفقا لوكالة حماية البيئة الأمريكية باستخدام الطريقة رقم 200.7 متوسط توزيعها. تم قياس الفواد هي: الفنيديوم (1.46ppm)، الكوبات (1.49ppm)، النواس (1.40ppm) والربط (1.40ppm) والزنك (1.40ppm) والزنك (1.40ppm)، الموبليديوم (1.40ppm)، النواد هي: الفنيديوم (1.40ppm)، الموبليديوم (1.40ppm)، المارية السبخة الفصل المستويات تركيز هذه المعادن هي ضمن المدود المسموح بها من الحدود محليا ودوليا. باستخدام نظم المعلومات الجغرافية مستويات تركيز هذه المعادن هي ضمن المدود المسموح بها من الحدود محليا ودوليا. باستخدام نظم المعلومات الجغرافية مستويات تركيز هذه المعادن المربطة المبخرة المعلومات الجغرافية المبخرة الفصل المربطة المبخرة الفصل المتوضح المتراء وتراكيز المعادن النزرة في الرواسب الرملية المبخرة الفصل المتوضعة المعلومات الجغرافية المبخرة المعلومات الجغرافية المبخرة المعلومات الجغرافية المبخرة المعادن المنزرة المعادن المنزرة المعادن النزرة المعادن النزرة المعادن المنزرة المعادن المنزرة المعادن المنزرة المعادن الميز المعادن المنزرة المعادن المنزرة المعادن المنزرة المعادن المنز

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Natural habitats have unique values in terms of their biodiversity richness and ecological functions (M. Lindegarth and M. G. Chapman, 2001). Wetlands are one of those habitats in which they are considered as one of the most important ecosystems on the Earth because they provide many important services to human society and vital functions to other living organisms (www.water.epa.gov/type/wetland). They occur at the transition between terrestrial and aquatic systems (Freshwater wetlands). These transition zones are combination of the water flow, nutrients, and the sun's energy that produce a unique ecosystem characterized by hydrology, soils, and vegetation in which communities depend plants, animals and human variety of (www.water.epa.gov/type/wetland). On the other hand, wetlands are the most richest and distinctive ecosystem when compared with rainforests and coral reefs (Freshwater wetlands).

Throughout the history, wetlands are considered as unproductive and unhealthy lands that human can utilize (M. Getachew et al, 2012), and disease-ridden waste lands fit only to be drained. This explains why more than 50% of the initial wetlands in the world have been lost and deteriorated (Freshwater Wetlands). This deterioration is caused by either anthropogenic or natural causes (M. Getachew et al, 2012). For example, drainage of agriculture, dredging, filling, construction, discharging of pollutants, tillage and hunting are considered the main threats for wetlands which resulted from human activities (Yaxin Wang et al, 2011). USA for example, lost 50

million ha of 90 millions ha of wetlands in the last 500 years (Freshwater wetlands). Other than those two causes, the hidden problem is that decision-makers at different levels are unaware of the strong relationship between wetland ecological importance, wetland services and the benefits that wetlands provide to people (M. Getachew et al, 2012).

Consequently, in recent years, the perception of wetland (i.e. as unhealthy land) has changed especially after realization of goods, services and functions provided by wetlands. This change started in 1960s when the concept of "environment movement" appeared aiming to protect the environment. As a result of that, wetlands have been recognized internationally as the most threatened ecosystem environment and became as a critical issue that needs to be managed (Andras and Dionysius, 2012). For example, Ramsar Convention was created in 1971 as the "Convention on Wetlands of International Importance". It is "an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources" (www.ramsar.org).

On the other hand, different countries have included wetlands as important natural resources in their directives and regulations. For example, in Europe the Water Framework Directive (WFD) which is established in 2000 provides "a framework for the protection of inland surface waters (rivers and lakes), transitional waters (estuaries), coastal waters and ground water". While in US, Environment Protection Agency (USEPA) has created what is called Office of Wetlands, Oceans, and Watersheds (OWOW) which "promotes the protection and restoration of the nation's wetlands

through both regulatory and cooperative programs", and linked to the Clean Water Act Section 404 (www.water. epa.gov/type/wetland).

So, to protect wetland from destruction, maintain them, and resolve related environmental problems, and help decision makers, it is required to develop proper management programs. These programs should be able: to record historical data and present data, analyze and evaluate data, estimate trends of changes that have occurred at different times, and prediction of different management scenarios and the changes of the future (Chris et al, 1998 and R. Janssen et al, 2005). Accordingly, Geographical Information Systems (GIS) which was introduced in 1980s with its variety environmental applications has made out of it a powerful tool to: describe ecosystems, identify a species distribution and habitat use, and to organize conservation strategies (Chris et al, 1998).

1.2 DESCRIPTION OF THE PROBLEM

Wetlands are considered as one of the most productive ecosystems on the Earth. They provide numerous beneficial services for people and other living organisms (e.g. fish and wildlife). Destruction or degradation of wetlands can lead to negative environmental impacts. Human activities as the main reason that cause wetlands degradation and loss by altering water quality, quantity, and flow rates which leads to increase pollutants releases and variation in species composition.

As a matter of fact, the climate in the Arabian Peninsula particularly Saudi Arabia is extremely an arid climate where it is very hot in summer and cold in winter with low precipitation, but Saudi Arabia contains different types of natural wetlands as well as some man-made wetlands. Some of these wetlands are a way from the coastal zones and at the same time they are very significant features in the landscape. Sabkha Al-Fasl wetland is one of these man-made wetlands which is located on the southwest of Jubail Industrial City. It is an evaporation lagoon, using the excess treated wastewater effluents discharged from Jubail Industrial City. The treated wastewater contains high concentrations levels of nutrients which lead to produce a massive quantity of biomass of micro-flora and micro-fauna that provides the essential and required food for many types of feeding birds. Moreover, Sabkha Al-fasl has the largest density and diversity of migratory waterfowl known along Saudi Arabian Gulf coast. Also, at the national eco-tourism conference which was held in 2002, Jubail City was considered as the second in the Kingdom for potential as a birding venue due to the existence of Sabkha Al-Fasl.

However, it is expected to decrease the treated wastewater to the Sabkha as Jubail Industrial City continues to expand particularly the urban development. The Sabkha is located within the area that is close to this urban expansion. This expansion will lead to Sabkha Al-Fasl destruction and elimination all of types of living organisms. Losing such important ecosystem, means losing all the benefits that wetland provide. Therefore, this highlights the importance of assessing and studying Sabkha Al-Fasl in order to protect it as well as list it under the international wetland conservation.

1.3 STUDY SITE

Sabkha Al-Fasl (figure 1) is a man-made wetland. Originally, it was created to receive the excess of treated wastewater effluents from Jubail Industrial City. It is located on southwest of Jubail Industrial City of the Eastern Province with coordinates of 27°00'N,

49°40'E with an area of 1300ha. Those effluents are normally used as irrigation water for landscape within the city, where the excess water is sent to evaporate on the Sabkha. The water is shallow with depth ranging between 1-30 cm, and it is vulnerable to wind's motion with subsequent effect of tidal, when there are changes in wind direction. The first source of water to the Sabkha is the treated wastewater that is discharged to the area from October to May each year where during summer season this can lead to drying the Sabkha. The second source of water to the area is the rainwater where this can rise the water level. In addition to the main area, the Sabkha has 3 large 100 ha of concrete reservoirs.

As the treated water is the main source of water supply to the site, this water is rich of nutrients that produce sufficient biomass of micro-flora and micro-fauna that provide the necessary and required food for large number of feeding birds. Furthermore, the site was a key foraging and roosting site for waterbirds, mainly shorebirds which come from the north Gulf coastline that is affected by oil pollution that resulted from Gulf War. After 4 years of Gulf War, a wide variety of species still utilize the area for feeding and nesting. The concrete reservoirs and some areas of the lagoon edges are fringed with reeds *Phragmites* and *Tamarix* scrub. Finally, the site has been identified as an "Important Bird Area" by BirdLife International as well as "an internationally important site for passage and wintering wildfowl and shorebirds".



Figure 1 Study Site of Sabkhat AL Fasl Wetland

1.4 OBJECTIVES

Although Sabkha Al Fasl is considered one of the important Wetland habitats, there is a lack of information on this important ecosystem. Royal Commission, in 2003 carried out a study count and categorization of birds visiting this area. This study showed that the Sabkha Al Fasl contains a large number and different types of birds, where it is considered as the number 2 potential area in the Kingdom as a bird venue. Based on its ecological importance, the main objectives of this study are to environmentally assess Sabkha Al Fasl through the following objectives:

 Determination of trace metals levels in sediment at various locations distributed within the study area to be used as a guide for future monitoring, or mitigation program.

- 2. Studying the impact of weather on the Sabkha such as summer season and winter season; and
- 3. Develop GIS database/maps for trace metals, and water level fluctuations through various seasons.

The gathered information through those objectives will help decision makers to develop a proper management program for this important ecosystem.

CHAPTER 2 LITERATUR REVIEW

2.1 WETLAND DEDINITION

In general term, wetlands are the connection between the water and the land (www.water, epa. gov/type/wetland). Defining wetlands is a complicated task as there are many definitions (more than 50 definitions) for wetlands because they are available in variety of forms (William, James, Christopher and Li, 2009, and Frazier, 1999). Most of the definitions include two components biotic (vegetation) and abiotic (soil and hydrology) (William, James, Christopher and Li, 2009). On the other hand, some researchers use a definition called "working definition" which is based on three components ecosystem. These components include hydrology which includes water level, flow, frequency, etc. Secondly, physiochemical environment component including soil, chemistry, etc. The final one is the biota component which includes vegetation, animals, and microbes. Based on this definition, those components are directly linked to each other where any change in one of these three components will change the other two. For example, changes in hydrology will influence physiochemical environment which in turn will determine biota communities that are available in the wetland (William, James, Christopher and Li, 2009).

According to Clean Water Act of EPA, wetlands can be defined as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas" (www.wetland.epa. gov/type/wetland).

However, the most common and well known definition (internationally) is the Ramsar Convention, according to this convention wetland can be defined as "Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which a low tide does not exceed six meters" (www.ramsar.org).

2.2 WETLAND TYPES

2.2.1 RAMSAR CLASSIFICATION

Wetland systems are characterized as dynamic and complex habitats which make it very difficult to identify the type or classify a wetland (Frazier, 1999). That is due each wetland differs in soil, landscape, climate, water regime and chemistry, vegetation, and humans disturbance (www.wetland.epa. gov/type/wetland). However, there is a wide range of methods to classify wetlands depending on the needs of the researchers, government agency, or nonprofit organization (R. W. Tiner, 2009). Consequently, it is difficult to assign a wetland to a single system where a single system can contain different types of wetlands. For example, 85% of 957 Ramsar sites around the world contain more than one type of wetland within one site (Frazier, 1999). Ramsar Convention classifies wetlands into five basic systems: Lakes, Rivers, Swamps, Estuaries, and Marine. In addition to these five systems, Ramsar Convention added artificial wetlands (created by human) as the sixth system. Figure 2 shows the percentage of each system worldwide. This figure shows: out of 24,465 wetland systems, 31% is swamps and marshes, 25% lakes, 16% rivers, 10% marine, 10% artificial and low percentage (8%) of estuary (Frazier, 1999).

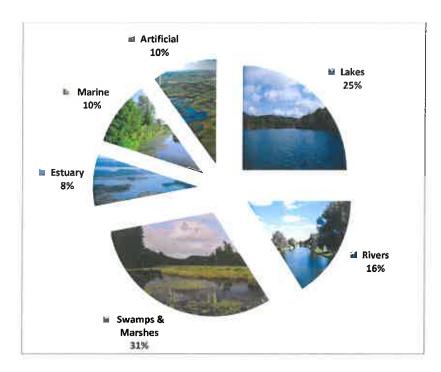


Figure 2 Ramsar Convention Wetland Systems Worldwide

For more effective and simple way to identify wetlands types, Ramsar has adapted a new scheme to classify the wetlands known as "Classification System for Wetland Type". Based on this scheme, there are 40 types of wetlands recorded from 957 Ramsar sites in the seven regions of the world as shown in Table 1 (Frazier, 1999).

Table 1 Ramsar Convention Wetland Types and their description

Code Ramsar wetland type

347-411	Code Ramsar wetland type
Wetland Type	Code-Description
Marine/Coastal	A — Permanent shallow marine waters in most cases less than six meters deep at low tide; includes sea
Wetlands	bays and straits.
	B — Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows.
	C — Coral reefs.
	D — Rocky marine shores; includes rocky offshore islands, sea cliffs.
	E — Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems
	and humid dune slacks.
	F — Estuarine waters; permanent water of estuaries and estuarine systems of deltas.
	G — Intertidal mud, sand or salt flats.
	H — Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal
	brackish and freshwater marshes.
	I — Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp
	forests.
	J — Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow
	connection to the sea.
	K — Coastal freshwater lagoons; includes freshwater delta lagoons.
	Zk(a) - Karst and other subterranean hydrological systems, marine/coastal
Inland Wetlands	L — Permanent inland deltas.
illialiu vvetialius	M — Permanent rivers/streams/creeks; includes waterfalls.
	N — Seasonal/intermittent/irregular rivers/streams/creeks.
	O — Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.
	P — Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.
	Q — Permanent saline/brackish/alkaline lakes.
	R — Seasonal/intermittent saline/brackish/alkaline lakes and flats.
	Sp - Permanent saline/brackish/alkaline marshes/pools.
	Ss - Seasonal/intermittent saline/brackish/alkaline marshes/pools.
	Tp - Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils;
	with emergent vegetation water-logged for at least most of the growing season.
	Ts - Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes,
	seasonally flooded meadows, sedge marshes.
	U — Non-forested peatlands; includes shrub or open bogs, swamps, fens.
	Va - Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.
	Vt - Tundra wetlands; includes tundra pools, temporary waters from snowmelt.
	W — Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder
	thicket on inorganic soils.
	Xf - Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded
	forests, wooded swamps on inorganic soils.
	Xp - Forested peatlands; peatswamp forests.
	Y — Freshwater springs; oases.
	Zg - Geothermal wetlands
	Zk(b)- Karst and other subterranean hydrological systems, inland
Human-made	1 — Aquaculture (e.g., fish/shrimp) ponds
wetlands	2 — Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
	3 — Irrigated land; includes irrigation channels and rice fields.
	4 — Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or
	pasture).
	5 — Salt exploitation sites; salt pans, salines, etc.
	6 — Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha).
	7 — Excavations; gravel/brick/clay pits; borrow pits, mining pools.
	8 — Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.
	9 — Canals and drainage channels, ditches.
	Zk(c) - Karst and other subterranean hydrological systems, human-made
	Entry - reasonable subtermined in the reason of the state

2.2.2 USEPA WETLAND CLASSIFICATIONS

US EPA categorizes wetlands to 4 categories: marshes, swamps, bogs, and fens as shown in table 2 (www.wetland. epa. gov/type/wetland)

Table 2 EPA Wetlands Categories

Type	Definition	Sub Category	Description
		Tidal (coastal) marshes	occur along coastlines and are influenced by tides and often by freshwater from runoff, rivers, or ground water.
	are periodically saturated, flooded, or ponded with water and characterized by herbaceous (non-woody) vegetation adapted to wet soil conditions.	Nontidal (inland) marshes	are dominated by herbaceous plants and frequently occur in poorly drained depressions, floodplains, and shallow water areas along the edges of lakes and rivers.
		Freshwater marshes	are characterized by periodic or permanent shallow water, little or no peat deposition, and mineral soils
Marshes		Wet meadows	commonly occur in poorly drained areas such as shallow lake basins, low-lying depressions, and the land between shallow marshes and upland areas
		Wet prairies	are similar to wet meadows but remain saturated longer
		Prairie potholes	develops when snowmelt and rain fill the pockmarks left on the landscape by glaciers.
		Playas	small basins that collect rainfall and runoff from the surrounding land.
		Vernal pools	have either bedrock or a hard clay layer in the soil that helps keep water in the pool.
	are fed primarily by surface water inputs and are dominated by trees and shrubs. Swamps occur in either freshwater or saltwater floodplains.	Forested swamps	Common deciduous trees found in these areas include bald cypress, water tupelo, swamp white oak, and red maple
Swamps		Shrub swamps	are similar to forested swamps except that shrubby species like buttonbush and swamp rose dominate.
		Mangrove swamps	are coastal wetlands characterized by salt-tolerant trees, shrubs, and other plants growing in brackish to saline tidal waters
Bogs	are freshwater wetlands characterized by spongy peat deposits, a growth of evergreen trees and shrubs, and a floor covered by a thick carpet of sphagnum moss. These systems, whose only water source is rainwater	Pocosin	found only in the Southeastern Coastal Plain
Fens	are ground water-fed peatforming wetlands covered by grasses, sedges, reeds, and wildflowers.		

2.2.3 EUROPE CLASSIFICATION

Europe region contains variety of wetlands types with different classifications, but Habitats Directive (92/43/EC) in Annex I provides a list of wetlands cover types and their ecological features. The directive lists 40 wetland habitats types (Table 3). On the other hand, to make an easy categorization, this directive classifies wetlands to seven major types (Joáo P. S et al, 2007), those are:

- Marine and coastal wetlands
- Estuaries and deltas;
- Rivers and floodplains
- Lakes
- Freshwater marshes
- Peatlands
- Man-made wetlands, such as canals and reservoirs

Table 3 LIFE-Europe Directive Wetland Habitats Classification

Code	Habitat		
1. Coastal and halop	hytic habitats		
1130	Estuaries		
1140	Mudflats and sandflats not covered by seawater at low tide		
1150*	Coastal lagoons		
1160	Large shallow inlets and bays		
1630*	Boreal Baltic coastal meadows		
1650	Boreal Baltic narrow inlets		
3. Freshwater habita	nts		
31 etc, 32 etc	All the habitats		
7. Raised bogs and n	nires and fens		
71 etc, 72 etc, 73 etc	All the habitats		
9. Forests			
9030*	Natural forests of primary succession stages of land upheaval coast		
91Do*	Bog woodland		
91Eo*	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)		
91Fo*	Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulme-nion minoris)		
92Ao	Salix alba and Populus alba galleries		
92Bo	Riparian formations on intermittent Mediterranean water courses with Rho- dodendron ponticum, Salix and others		
92Co	Platanus orientalis and Liquidambar orientalis woods (Platanion orientalis)		
92Do	Southren riparian galleries and thickets (Nerio-Tamaricetea and Securine-gion tinctoriae)		

2.3 IMPORTANCE OF WETLAND

In recent years, wetlands are receiving considerable attention in environmental science and policy. That is because wetlands provide vital functions and services to human and other living organisms. Thus, they need to be looked after and used wisely. The functions and services that are performed by wetlands may include the following:

They provide numerous resources for human uses such as providing food,
 irrigation for agriculture, and industrial purposes. Many people directly depend

on natural ecosystems such as wetland for their survival (fishing industry), for example, 75% of commercially harvested fish are wetland-dependent (Ministry of Environment & Forests Government of Inida, 2007, I. Zacharia et al, 2005, and www.wetland.epa.gov/type/wetland).

- They support fisheries and a number of rare and endangered species of flora and fauna (Ministry of Environment & Forests Government of India, 2007).
- Maintain natural biodiversity. Biodiversity is the variation of life forms within a given ecosystem. Wetlands are characterized as the most biologically productive natural ecosystem in the world in which they are richness of plants, animals including wildlife habitat, and macro-organisms and micro-organisms (Ministry of Environment & Forests Government, 2007, K. Y. Rybaczuk, 2005, and J. Kashaigili et al. 2006).
- Regulating hydrological regimes in terms of flood control, recharging of
 aquifers, wastewater treatment, reducing sediment load, nutrient removal,
 pollution filtering, etc. For example, in terms of flood control, wetlands absorb
 excess of water during rainy seasons or snow melts (Ministry of Environment
 & Forests Government of Inida, 2007, K. Y. Rybaczuk, 2005).
- Control of soil erosion. Extensive agriculture, industrialization, and urbanization are the major factor causing soil erosion. So, wetlands act as wetting agent to minimize erosion (K. Y. Rybaczuk, 2005).
- Recreational opportunities where they can be utilized for swimming, diving,
 and tourism (Ministry of Environment & Forests Government of Inida, 2007).

Valuable for educational and scientific researches due to high biodiversity (Ministry of Environment & Forests Government of Inida, 2007).

2.4 GLOBAL WETLANDS DISTRIBUTION

Wetlands occur in every country, but some areas account for more numbers of wetlands than the others. That is due to the climate, where humid climate highly supports wetlands more than hot arid climate. This is related to the higher participation rates and higher evapotranspiration rates in humid climate (R. W. Tiner, 2009). The distribution of global Ramsar sites is shown in figure 1. This figure shows high numbers of wetland in Europe (L. M. Rebelo et al, 2008). On the other hand, the estimated area of wetland around the world is ranging form 1.3 to 3.5 billion hectares as shown in table 4. Wetlands cover from 1% to 9% of the Earth's surface and from 3% to 30% of its land surface (R. W. Tiner, 2009).

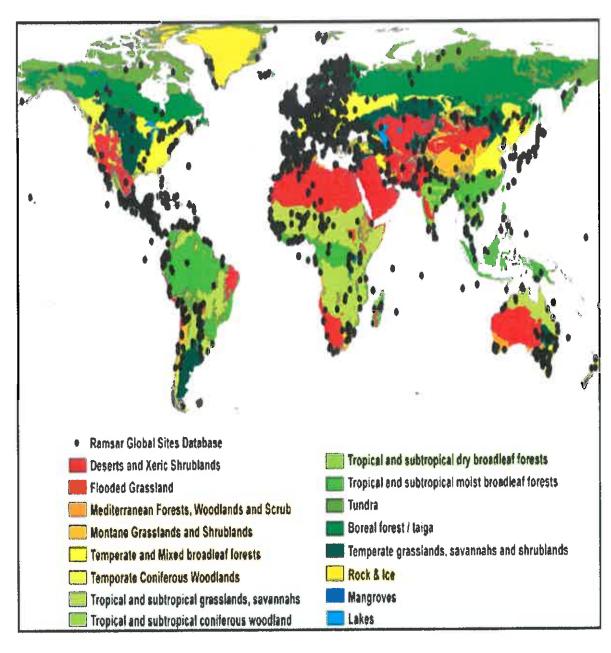


Figure 3 World Wide Distribution of Ramsar Site, Source: Ramsar website

Table 4 Wetlands Area Estimation Around the World

Region	Area (ha)	Source
Africa	121 321 683-124 686 189	Stevenson and Frazier (1999a)
Asia	211 501 790-224 117 790	Watkins and Parish
Oceania	4 792 700-35 750 000	Watkins (1999), Finlayson and Davidson (1999)
Europe Eastem	225 821 930-229217 000	Stevenson and Frazier (1999, errata), Finlayson and Davidson (1999)
Western	28821979	Stevenson and Frazier (1999c)
Middle East	7 434 790	Frazier and Stevenson (1999)
North	244 903 000-	Finlayson and
America	2 05 7 3 6 9 0 0 0	Davidson (1999)
Canada	127 199 000- 150 000 000	Davidson et al. (1999b)
United States of America	114 544 800	Tiner (1999)
Neotropics	414 996 613	Davidson et al.
	1782103000	(1999a),
Total	1 256 435 285-	Finlayson and
	4 486 1 0 4 6 7 8	Davidson (1999)

2.5 SEDIMENT and Trace Metals CONTAMINATION

USEP defines sediments as "Sediments are fragmented materials that originate from weathering and erosion of rocks or unconsolidated deposits and are transported by, suspended in, or deposited by water" (www.water.epa.gov/polwaste/sediment). Sediments are playing the major role in functioning of aquatic ecosystems in terms of food chain, and as a source of pollution for bioaccumulation and trophic transfer (G. Allen Burton, Jr, 2002). Many studies have reported that there is a strong link between ecosystem quality and contaminated sediments (G. Allen Burton, Jr, 2002). Sediments can increase pollutants concentration in which those pollutants bind to (Abdel Ghani, S. A, 2015), and normally sediments settle at the bottom of an ecosystem and remain for long time where sediment can accumulate contaminants and act as sources of ecosystems pollution (G. Allen Burton,

Jr, 2002). Among the different types of contaminants that have an adverse negative impact on aquatic ecosystems quality (Abdel Ghani, S. A, 2015), and considered as the most important sediment pollution is the trace metals (Mohammad Z. I et al, 2012). That is due their toxicity, abundance, persistence (Abdel Ghani, S. A, 2015), and non-degradable in the ecosystem they deposited in (B. D. Battacharya et al, 2015). Also, they bind into sediment particles where they become less likely to bio-transformed and desorption is usually very low. So, sorbed contaminants will reside for long periods of time in the sediment (G. Allen Burton, Jr, 2002). Mainly, there are two sources in which trace metals enter an ecosystem either from natural or anthropogenic sources or combination of those two sources (V. Paraskevopoulou et al, 2014). Natural sources include the transport of weathered crust material via rivers, surface runoff, submarine groundwater discharges, diffusion from sediments, atmospheric deposition and upwelling of deep waters (V. Paraskevopoulou et al, 2014). Anthropogenic sources include direct industrial emissions, emissions from roads and marine traffic, surface runoff from urbanized areas, activities in ports (V. Paraskevopoulou et al, 2014), industrial and domestic effluents, leaching of metals from garbage and solid waste dumps (Ahmed S. I et al, 2011).

In terms of pathways to an ecosystem, pollutants behavior including trace metals is not fully understood due to lack of knowledge of the loading, mobility, and pollutant turnover as well as the complexity and heterogeneity of the affected ecosystem (Mohammad Z. I et al, 2012). However, chemical, physical and biological contaminants enter aquatic environment or any ecosystem types through atmosphere, surface water and groundwater, land and biota. That means, these four components are linked to each other where any releases to any one of these environmental components can lead to transfer the

contaminants to the other one. For example, in the United States, about 1.2 billion out of 12 billion cubic yards of contaminated sediments are having high level of contamination that put human and wildlife under risk from eating contaminated fish (G. Allen Burton, Jr, 2002).

If the sediments contain high level concentrations of trace metals, this can cause loss of desirable species (G. Allen Burton, Jr, 2002). On the other hand, due to their bioaccumulation in plants and animals, human health will be affected through food chain (D Purushotham et al, 2012) as well as aqueous ecosystems (B. D. Battacharya et al, 2015). For examples, they can cause deformities, cancer, and death of aquatic animals and their terrestrial predators (B. D. Battacharya et al, 2015).

2.6 GIS APPLICATION IN WETLAND

2.6.1 GIS DEFINTION

There are different definitions of Geographical Information System (GIS) from different aspects. For example, according to Al-Ramadan, 2005, GIS can be defined as "a system of hardware and software that supports the capture, management, manipulation, analysis, and display of geographic information". This definition explains the two main components of the GIS (software and hardware) and the main aspects of the system. However, a more explanatory definition of GIS states that "A Geographical Information System is a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modeling, representation and display of geo-referenced data to solve complex problems regarding planning and management of resources" (S. Ramachandran, 2003). This definition includes modeling as one of the important aspects of GIS as well as the types of data that GIS

can display. Also, it provides the purpose of these data which is planning and management of the resources.

On the other hand, data entry, data display, data management, information retrieval and analysis, all of these are the main functions of GIS (Al-Ramadan, 2005). These functions help to improve the ability to make decisions. So, in this regard, GIS characterized as a chain of operations starting from planning and data collection, storing and data analysis, where all of this helps in gathering required information to decision making process (S. Ramachandran, 2003).

2.6.2 GIS ENVIRONMENTAL APPLICATIONS

As there is a heavily increasing demand on the Earth's natural resources, and at the same time we cannot meet these demands without creating consequences or negative impacts on the environment. So, responsible and successful environmental management is no longer a luxury, but rather a necessity (Chris et al, 1998). Thus, protecting and restoring the environment requires better ways of managing the world using sophisticated techniques. In recent years and as a result of introduction of GIS, GIS has became as a powerful tool for successful environmental management. It has a wide variety of applications related to the environment as shown in figure 4 (Sader et al, 1995). For example, in natural resources management (e.g. water, and minerals), it can provide different scenarios how to protect, monitor, perceive such resources in order to balance between the human demands and environment. While in waste management, GIS can provide for example suitable method and suitable area for disposal. Further, in groundwater, it helps in identifying rocks types, soil types in order

to develop hydrology balance of certain aquifer as well as to manage water uses. In addition, GIS helps to perform environmental impact assessment since it will help to provide information of ecology, ecosystems, land use, land cover and others important parameters in environmental impact assessment (I. Zacharias et al, 2005).



Figure 4 GIS Environmental Applications

As seen from the above, wide environmental applications of GIS, there are several reasons for using GIS in the above mentioned applications to resolve, analyze, monitor and manage the environmental related issues (L. E. Reinelt et al, 1991)

a) It has high capabilities to store large database management. This helps to create one sources of information with one type of format, instead of different agencies holding different types of information. For example, meteorology department holds weather information, while environmental department holds wetland inventory and other related information with different formats. GIS brings these

- spatial data together and it will view it and integrate it in one cohesive system (L. E. Reinelt et al, 1991 and I. Zacharias et al, 2005).
- b) It can generate variety of reports. GIS displays the output in form of tubular, map, images as well as in different resolution (L. E. Reinelt et al, 1991). In environment application, the result layout is very important, because in some cases a tubular format is required in order to present sample analysis. On the other hand, map presentation is required to show land cover (vegetation) for a certain area, for example.
- between different types of geographic features such as land use, soils, and topography. Also, it overlays these features to display interactions (L. E. Reinelt et al, 1991). So, the environmental studies as well as most of the geographic features are interconnected and it is very difficult to separate them, GIS can provides separate and precise analysis for each feature without affecting the final results, and at the same it will provide a scientific management to analyze and modeling the environmental aspects.
- d) A powerful tool in analyzing the trends (changes over time), and it can be easily updated with new information whenever they are available (L. E. Reinelt et al, 1991). In reality, things keep changing over time, for example, in wetland, through the history; the land use has dramatically change due to urban development and other reasons.
- e) Has the ability to test management options (L. E. Reinelt et al, 1991). GIS helps in developing management plans such as daily operational tasks (e.g. sampling,

and monitoring), modeling, and assessment. All these help to provide decision makers a better view of the study area, where they will come up with different scenarios in how to manage the area.

2.6.3 HISTORICAL BACKGROUND OF GIS AND WETLAND

Geographical Information System (GIS) is used since 1980s by the National Wetlands Inventory (NWI) of USA to create maps database for wetlands, and they have the largest polygonal database in the world. However, US Fish & Wildlife Service (FWS) is the leader for mapping wetlands in USA by mapping and transferring wetlands to USGS topographical maps, and by providing digital wetlands data that can be displayed on images of USGS maps, or rectified images like orthophoto quads. Further, since 1990s, the applications of GIS getting wider in range where many organizations are started to utilize this technology and extended its applications to map the natural resources (Leah Stetson, 2008).

2,6.4 ENVIRONMENTAL INPUT DATA TO GIS

The data input is one of the main functions of GIS as mentioned earlier and for each application there are specific data that are required to use GIS. Figure 5 shows three categories of the required data input for environmental applications (www.esri.com/environment):

 Environmental Geodatabase, this includes roads, documents, environmental inventories, remote sensing, etc.

- Data Sources, this relates to the different types of environmental sources such as biology, hydrology, environmental qualities, etc.
- Internet, this includes getting information from or about private and public sectors, and interested organizations

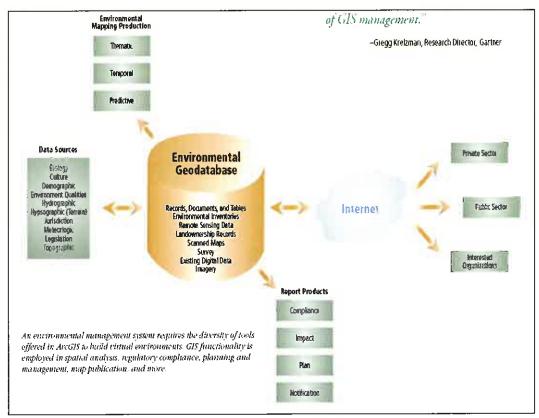


Figure 5 GIS Input Data for Environmental Applications

2.7 PREVIOUS STUDIES

This part explores some of the studies that have been carried for different wetlands which help the decision makers and other regulatory authorities to develop monitoring strategies as well as educate public and other users of the importance and the benefits that wetlands provide.

Cheffa wetland ecological assessment (M. Getachew et al. (2012):

In Ethiopia, wetlands are covering about 2% (i.e. 22,600Km²) of the total country's surface area. Wetlands in Ethiopia lost most of their species and habitat due to lack of knowledge by the decision-makers of the connection between the wetland ecological condition, services and benefits for people they provide as well as adequate management plans to restore those wetlands. In addition to that, wetlands are considered unproductive, unhealthy and their biodiversity are underestimated. For example, it is estimated that 65% of wetland destructions are due to human activities, while 35% because of natural causes. Therefore, an ecological assessment was carried out to assess the link between biological parameters (macro-invertebrate and bird distribution), physiochemical factors in Cheffa wetland, and to find out the benefits and services that this wetland can provide to the people who are living around this area. 300Km northeast of Addis Ababa, Cheffa wetland is located and contains three different type of habitats; hot spring, river/stream and swamp.

For the assessment, 10 sites were selected to collect representative samples for water quality and aquatic macro-invertebrates in the three habitats. The samples were collected based on the level of human impact at considerable distance between the sampling points. Macro-invertebrate samples were collected by using a D-shaped sweep-net, while bird population identified by using total count (direct counts) method. On other hand, physical and chemical parameters were measured by using different devises such as HACH multi-meter hand-held probe for pH and temperature and spectrophotometer for total nitrogen, total phosphorous and COD. The existing habitats

were assessed by using the method developed by Barbour, and the level of public impacts was assessed by the method of the Marine Department of Environmental Protection.

This study showed that the anthropogenic activities strongly affect water quality, macro-invertebrates diversity, birds, and habitat conditions. In terms of water quality, the measured values of the physicochemical parameters showed low DO, and high COD, turbidity and chlorine that is due to releases of organic pollutants from different sources such as fecal matters from animal, and sewer water from surrounded villages and towns. Furthermore, the electrical conductivity (EC) and total phosphorous (TP) values for all the sites were greater than irrigation water quality standards. Temperature and pH values were within permissible limits. On the other hand, the total collected macroinvertebrates were 2789 species classified into 10 orders and 34 families. The assemblages of macroinvertebrates were greatly affected by human impact, total phosphorus, water temperature, total nitrogen, orthophosphate and nitrate as consequence of vegetation clearance, waste dumping, deforestation and cultivation.

In regards to the birds' population, total of 3128 birds belong to 57 species were recorded. In this wetland, the most seen and recorded bird species are; White-faced whistling duck (11.5%), cattle egret (10.1%) and Egyptian goose (4.4%). As result of destroying their habitats by different activities such as overgrazing, and cutting the existing vegetation for making mattresses and houses construction have led to lower their diversity.

However, based on focus group discussion, the wetland is considered as an important financial aid for the surrounding public where it provides services such as tillage, livestock grazing, main source of domestic water, agriculture and income generation. For example, based on United Nations Emergencies unit for Ethiopia in 2002, it was estimated that around 50,000 pastoralists with 200,000 domestic animals utilized Cheffa wetland for watering and grazing.

This ecological assessment of Cheffa wetland proves that the biological parameters and physiochemical factors are greatly affect the health of the wetland in which the low bird count and low microinvertebrate diversity shows an overall water degradation and vegetation disturbance affect the whole wetland. Also, it indicates that there is a need to develop and implement a national wetland policy to assess and monitor such natural resources in terms of developing wetland conservation and restoration.

Sabkha Al-Fasl, Environmental Control Department, Royal Commission for Jubail and Yanbu, 2003:

According to a bird count study that has conducted in Sabkha Al-Fasl by RC in 2003, it has been identify as having the largest density and diversity of migratory Waterfowl known along the Saudi Arabian Gulf coast. During the study it was estimated that the total number during migration and in mid-winter approach 20,000 bird. This number of bird population and based on the Convention on Wetland of International Importance, especially as Waterfowl Habitat (Ramsar, 1971), the wetland is considered as international importance, also is has been identified as an Important Bird Area in the Middle East since it can hold about 1% more of the Middle East population for the

waders/shorebirds. In addition to that, the study showed that Sabkhat Al-Fasl supports around 25% of the total duck population wintering in the Eastern Province of Saudi Arabia and for one species (Shelduck). It is the only regular wintering area on the Arabia Peninsula. The recoded counts of Shelduck during the 2002/2003 winter include 2535 birds on 17 January refer to Appendix A for the checklist of birds seen in Sabkha Al-Fasl, Jubail from 1994-2003.

However, based on the study results, the species in Sabkha Al-Fasl were categorized based on known globally-recognized categories, these are:

- <u>Category 1:</u> Site supporting globally threatened species in which it includes
 Imperial Eagle (1-2 in winter feeding on carrion) and Spotted Eagle (winter and passages)
- <u>Category 2:</u> Site where birds concentrate with high numbers as passage or stay in winter either for:
 - i) Breeding which is including 2 species namely Avocet (up to 100 pairs) and Kentish Plover (60-80 pairs).
 - ii) Non-breeding species. There are 10 species under this type, these are: Avocet, Kentish Plover Lesser Sand Plover, Little Stint, Curlew Sandpiper, Dunlin, Broad-billed Sandpiper, Ruff, Green Sandpiper and Turnstone

- <u>Category 3:</u> Site for threaten species in the Middle East and they are not available in the Sabkhat.
- <u>Category 4:</u> species for which have relatively small total world ranges with important populations in the Middle East. There are 4 species: Blackwinged Pratincole, Basra Reed Warbler, Upcher's Warbler and Dead Sea Sparrow.

Wetland inventory by GIS and Remote Sensing, Sri Lanka (M. Rebelo et al, 2008):

Vegetation cover is a detrimental factor of a wetland in which it indicates the functionality and productivity of the wetland. Further, the amount of vegetation determines biodiversity richness of a wetland. However, in recent years, land cover started to deplete or change on the most of wetlands around the world. That is because human activities and extensive use of water, or short in rainfall, or invasion of new species. So, it is very important to develop mechanisms or management plans to minimize the degradation of the vegetation cover as long as it supports human and many other types of organisms. GIS technology helps in developing such plans by creating a database or vegetation layer that includes types of vegetations, type of plant community, the wildlife it supports, dominant species as well as the changes that occur over time and predict future change Further, with help of GPS, remote sensing, and filed observation or survey, these data can be created for GIS vegetation layer (J. J. Kashaigili et al., 2006, and Discovery Southeast, 2004).

GIS was used to detect wetland land cover change in Sri Lanka for Muthurajawela Marsh and adjoining Negombo Lagoon. These two are considered as one wetland ecosystem, and it was listed as 12 priority wetlands in Sri Lanka. The area is experiencing extensive agriculture, urbanization and industrialization which led to convert the wetland to other uses. GIS was used to analyze the extent of ecological changes and future threats. Changes that occurred in wetland cover between 1992 and 2002 (figure 6) were loss of deep water areas by 33%, mangrove 49%, and marsh 40% caused by sedimentation, infilling and clearing of vegetation and the expansion of human settlements. Also, it showed effects of settlements on each type of vegetation (Figure 7). The study showed that the largest conversions to settlements have occurred in marshland, followed by areas of littoral vegetation (L. M. Rebelo et al, 2008).

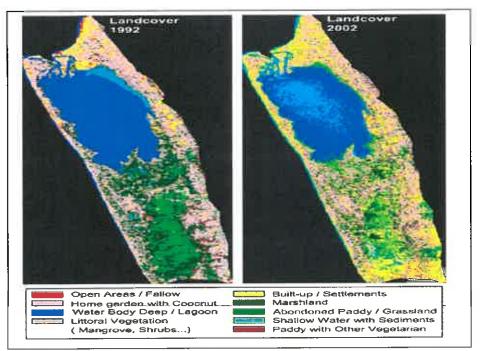


Figure 6 Change in land cover of the Muthurajawela Marsh and the adjacent Negombo Lagoon, Sri Lanka

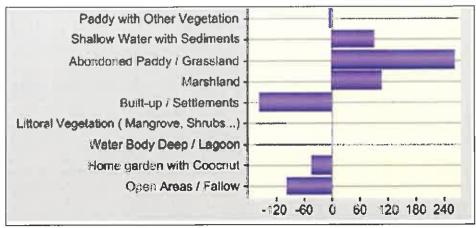


Figure 7 Contribution of changes in land cover to the increased area of settlements (Km²)

Heavy Metals contamination in soil, India (D Purushotham et al. (2012):

Soil is considered as an important and essential to support plant life in which it provides critical services for all the living organisms. Different types of pollutants can contaminate the soil; among these pollutants are heavy metals. Heavy metals have great negative impacts on the soil due to their toxicity, persistence and bioaccumulation. Through food chain, these pollutants can affect the humans due to bioaccumulation in plants and animals. The main source of the heavy metals in soil is the anthropogenic sources. So, soil sampling (analysis) is the best method to monitor those elements as well as to provide the environment overall health.

Due to the expansion of the Hyderabad international airport, and releasing effluents and dumping industrial waste from the manufacturing industries around Masheshwaram watershed, this has led to environmental degradation. Additionally, groundwater resources within this area will be contaminated by the leach of the heavy metals. The Masheshwaram watershed has an area of 25Km² and its topography is flat. The study area is located in semi-arid climate zone. The yearly average precipitation in the area is 884.1mm, whereas the maximum precipitation occurs during June-

September with a range of 22°C to 44°C. So, this assessment was carried to determine the "natural background levels of heavy metals as a guide for future pollution monitoring with suitable recommendations for mitigation of environmental impacts". Also, this assessment will help to provide a sustainable management of groundwater resources in the area.

For the study, 25 samples of soil were collected from 10-25cm depth below the surface. X-Ray Fluorescence spectrometer (XRF) was used to determine the concentration of the heavy metals (Ba, Co, Cr, Mo, Ni, Pb, Rb, Sr, V, Y, Zn and Zr) in the study area. Arc GIS 9.3.1 Spatial variation maps also was used to identify the locations and which zone has the highest concentration of the heavy metals. Additionally, the land use/land cover change map of the area was generated between year 2003 and 2009 as shown in figure 8. Land use/coven adversely effects the soil regime and soil Redox Potential (Eh) which in turns it effects solubility, toxicity, bioavailability, mobility and redistribution of heavy metals in the soil. For example, Barium (Ba) concentration (as shown in figure 9) in the soil of the study area was ranging from 130.3-744.6mg/kg which exceeded the reference value of 550mg/kg, and the spatial variation map showed Ba concentration was more in the northern part of the study area. Similarly, the remaining elements samples concentrations were found to be higher than the desirable limits (reference values) in the study area.

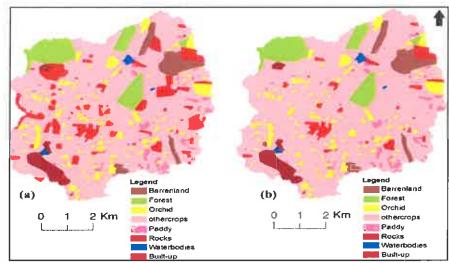


Figure 8 Land use/cover Change of the watershed from (a) 2003 to (b) 2009

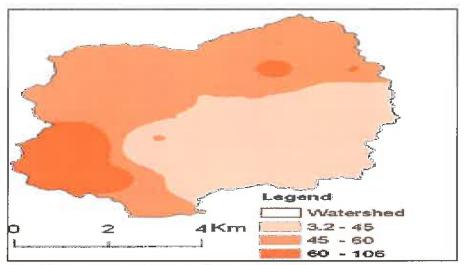


Figure 9 Barium concentration in the soil of Masheshwaram watershed

As a result of this study, the area is experienced degradation of soil and water quality due to increased human population, rapid urbanization and unscientific disposal of waste and improper water management. By utilization of GIS application, the research team was able to determine the contamination zones for heavy metals pollution in the study area. Consequently, the research team proposed the following preventive measures to minimize the soil pollution:

- To develop a proper waste disposal management including industrial and domestic waste, and stopping random dumping of waste;
- To construct a landfill to receive the waste;
- To treat the area as sensitive for further research;
- As remedial measures, excavation and replanting, stabilization of the soil,
 phyto-remediation, bio-remediation can be carried for the area;
- To develop a periodical monitoring of the environment in order to implement the necessary mitigation measures as well as monitoring the soil quality should be taken in consideration.

CHAPTER 3 METHODOLOGY

3.1 Site Description

Sabkha is Al-Fasl is divided into two parts; the first is the main Sabkha which receives the treated water (Influent) by two pump stations. The second one is used to receive the excess water from Sabkha through underground pipe and by overflow in some locations. The two parts are divided by a road that was built (approximately before 3 years) to install Electrical Pylons. The main Sabkha is surrounded by thick layer of Reed Beds plant which makes it very difficult to go inside the wetland. The second part is large in area and it is open water like water pond without any plants (plain area).

During the filed visit prior to sampling, the following observations were noted (Figures 10-17):

- The area around the wetland is covered by different types of small plants.
- In general, the thick layer of Reed Beds (Phragmites) plant makes it difficult to go
 inside the wetland and collect samples, where there is only one narrow access to
 the main wetland.
- Reed Beds plant is dividing wetland into small areas. This can be seen clearly when standing under the electrical pylons. Each Pylon represent a small area surrounded by Reed Beds.
- New bird species called Purple Swamphen (Porphyrio Poliocephalus) was seen during the visit, this species was not available before 5 years. This is according to the RC representative.

• During the visit, there were some people fishing and others were hunting. The kind of fish is Tilapia (Oreochromis niloticus).

Figure 10 Station Pump#01For Water Supply



Figure 11 Reed Beds plant Around the Sabkha

Reed Beds Plant

Figure 12 The small entrance to Sabkha water





Figure 14 Underground Pipe for Acess water





Figure 16 The new Bird Species (Purple Swamphen)



Figure 17 Electrical Pylon



A total of 25 (figure 18) soil samples were collected from depth of 60cm in which 12 samples were collected from the main Sabkha which is called Entrance Area. The second group of the samples were collected around the seven Electrical Pylons (columns). The last 6 samples were collected from the open area. Glass jars were used to keep all the samples as well as samples locations were detected by using GPS tool to identify both altitude and longitude.



Figure 18 Sampling Plan in the Study Site

3.2 SAMPLES ANALYSIS

EPA Method 200.7 for "Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) Revision 4.4" (T. D. Martin et al, 1994) was used for analysis:

- Approximately 20g from each samples were transferred to 250mL to Phillis beakers for acid extraction.
- 4mL of (1:1) HNO3 and 10mL of (1:4) HCl were added to the beakers.
- The beakers were placed on the hot plate for reflux extraction with approximate temperature of 95°C for one hour.
- The samples were allowed to be cooled, and then transferred to 100 mL volumetric flask where 50mL of DI water were added to the samples.
- The final step of samples preparation was allowing the samples extracted solution to stand overnight to separate insoluble material or centrifuge portion to ensure that the samples solutions are clear and no suspended solids.
- Prior to analysis, ICP-MS (XSERIES 2) which is manufactured by Thermo
 Scintific was calibrated. The used standard solution was prepared by 100ug/ml
 multi standard developed by SPtEX Certiprep (Custom Assurance Standard).

3.3 GIS Implementation

To trace metals distribution, ArcGIS 10.1 Software was used where sample point locations (X, Y) of the trace metals were noted at the time of sampling. Attribute data for each trace metal was prepared to upload them in ArcGIS 10.1, where these data linked to GIS to create the required map. Then, data from ESRI, Inc. was used as the background image data. Spatial Variation maps of the metals contamination were prepared into the three zones

(Main Area, 2. Columns, and 3. Open Water Pond Area) buy using IDW (Inverse Distance Weighted) interpolation method in ArcGIS 10.1 (www.esri.com).

For weather impacts on the Sabkha, satellite images were obtained from KACST for the years; 2010, 2011, 2012, 2013 and 2014 (KACST: National Satellites Technology Center, 2014). In order to reflect these impacts on the study area, the following steps were performed (www.esri.com):

- Extract the Images covering the Study Area.
- Add the Images (2010, 2011, 2012, 2013, 2014) in ArcGIS.
- Geo-reference the images using the Geo-referencing tool in ArcGIS.
- Extract the Study Area by using the ArcGIS Tool 'Extract by Mask'.
- Then the images are cropped in photo editor for the report.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Trace Metals Contamination

Contamination of sediment by trace metals is characterized by non-degradable nature in the ecosystem they linked to in which they can be converted from one chemical form to another via chemical and biochemical reactions, and remain in the environment for a long time (D Purushotham et al, 2012, Battacharya et al, 2015, and Ahmed et al, 2011). When trace metal present in high concentrations, they can cause degradation of the environment and pose a high risk to human and health and aqueous ecosystem (V. Paraskevopoulou et al). The trace metals (V, Cr, Co, Ni, Cu, Zn, Mo, Ba and Pb) concentrations of the study area are presented in Table 5.

To assess sediment contamination in Sabkha Al-Fasl, the concentrations of the trace metals and their spatial distribution was compared with trace metals concentration of: PME Sediment Draft Guideline- Saudi Arabia, National Oceanic and Atmospheric Administration (NOAA-USA), Canadian Council of Ministers of the Environment (CCME-Canada), Australian and New Zealand Environment and Conservation Council (ANZECC-Australia), and Ministry of Housing, Spatial Planning and the Environment (VROM-Netherlands) as shown in Table 6 (G. Allen, 2002).

Table 5 Trace metals concentrations in study area sediment from ICP-MS

Area Sample #		GPS Locations		Concentration (ppm)								
		N	E	v	Ce	Co.	NI	Cu	Za	Me	Be	Pb
Main Area	A1	27 02 677	049 29 440	0.60	0.68	0.13	0.93	0.26	0.65	0.06	1,46	0.07
	A2	27 02 685	049 29 436	2.91	3.72	0.71	5.42	1.64	4.98	0.31	6.12	0.27
	A3	27 02 697	049 29 426	0.60	0.83	0.15	1.08	0.29	0.49	0.06	2.26	0.08
	A4	27 02 687	049 29 410	2.48	2.44	0.65	3.59	1.27	5.73	0.31	0.94	0.27
	A5	27 02 666	049 29 419	2.42	2.56	0.69	3.72	1.16	5.39	0.25	4.73	0.29
	A6	27 02 647	049 29 410	0.59	0.60	0.10	0.75	0.30	1.09	0.12	0.59	0.08
	A7	27 02 630	049 29 369	0.44	0.49	0.09	0.70	0.23	0.76	0.06	0.75	0.06
	A 8	27 02 711	049 29 388	2.43	2.98	0.87	4.55	1.38	3.60	0.20	5.15	0.31
	A9	27 02 722	049 29 347	0.52	0.64	0.13	0.92	0.25	0.46	0.04	0.93	0.06
	A10	27 02 806	049 29 410	4.53	5.71	1.18	8.38	2.71	5.14	0.33	4.97	0.48
	A11	27 02 773	049 29 503	0.61	0.69	0.13	0.95	0.29	1.01	0.08	1.18	0.07
	A12	27 02 724	049 29 438	1.67	1.56	0.43	4.04	2.77	4.62	0.26	2.92	0.32
	C2	27 03 962	049 30 354	1.22	1.29	0.36	2.95	0.74	2.61	0.31	2.14	0.19
	C3	27 03 881	049 30 169	0.35	0.33	0.07	0.46	0.14	0.39	0.04	0.53	0.06
\rea	C4	27 03 701	049 29 975	1.12	0.91	0.22	1.67	0.54	2.58	0.30	2.93	0.20
Columns Area	C6	27 03 407	049 29 620	2.21	2.09	0.60	3.15	1.14	3.94	0.45	2.07	0.25
Colu	C7	27 03 273	049 29 458	0.82	0.88	0.16	1.26	0.33	1,41	0.30	2.64	0.13
	C5N	27 03 596	049 29 845	0.31	0.34	0.07	0.46	0.12	0.31	0.06	0.64	0.05
	C5S	27 03 529	049 29 785	0.37	0.46	0.09	0.62	0.16	0.38	0.04	0.84	0.05
Open Water Pond Area	AOC2	27 04 191	049 30 088	0.82	0.91	0.28	2.17	0.55	2.19	0.06	2.37	0.18
	AOC3	27 04 056	049 29 979	2.74	2.83	0.74	3.64	1.07	3.28	1.25	5.46	0.48
	AOC4	27 04 009	049 29 942	1.07	1.08	0.20	1.52	0.50	2.45	0.30	3.30	0.19
	AOC5	27 03 876	049 29 846	3.47	3.64	0.69	4.77	1.45	4.85	0.69	7.39	0.60
	AOC6	27 03 677	049 29 696	1.79	1.86	0.52	3.81	0.90	5.11	1.01	3.75	0.29
	AOC7	27 03 490	049 29 562	0.32	0.34	0.07	0.44	0.13	0.49	0.05	0.63	0.06

Table 6 Sediment Quality Guidelines for metals in ppm

Trace Metal	Present Study	PME Sediment Draft Guideline, Saudi Arabia		NOAA, USA		CCME, Canada		ANZECC, Australia		VROM, Netherlands	
Trace Metai		Action Level 1	Action Level 2	ERL	ER M	ISQG	PEL	ISQG Low	ISQG High	NEC	MPC
17 1!	M=1.42	_	-	-	-	-	-	-	-	-	-
Vanadium	0.436-4.53										
	M=1.53	52	160	81	370	52.3	160	80	370	100	
Chromium	0.488-5.71										380
	128.7-1354										
Cobalt	M=0.36							_	_	_	_
Cobait	0.094-1.184] -	_	_	-	-	-		-		
NT: -11	M=2.38	16	42.8	21	51.6	NR	NR	21	52	35	44
Nickel	0.696-8.375										
Common	M=0.76	18	108	34	270	18.7	108	65	270	36	73
Copper	0.235-2.77										
	M=2.52	124	271	150	410	124	271	200	410	140	
Zinc	0.463-5.73										520
	106.0-1354.0										
	M=0.32	-	-	-	-	-	-	-	-	-	-
Molybdenum	0.039-0.327										
Barium	M=2.72	-	-	-	-	-	-	-	-	_	
	0.592-6.12									-	-
	ND										
	M=0.21	30	112	47	218	30.2	112	50	220	85	530
Lead	0.058-0.477										

Action Level 1: If the 95% Upper Confidence Level of any substance exceeds Action level 1 value. Action Level 2: If the 95% UCL for any substance exceeds Action Level 2 value. ERL= Effects Range Low, ERM= Effects Range Medium, ISQG= Canadian Interim Marine Sediment Quality Guidiline, PEL= Probable Effects Level, M= Mean.

Trace metals including Cr, Ni, Cu, Zi and Pb that were detected in the sediment of the study area are within the permissible limit when they are compared with PME Sediment Draft Guideline, Saudi Arabia and other international guidelines as shown in Table 6. On the other hand, there are no limits or guidelines for V, Co, Mo and Ba as shown in Table 6.

The higher standard deviation observed for all the trace metals in the sediment shows that those metals are not uniformly distributed across the study area. Spatial variation maps (figure 19a-i) of trace metals were prepared into the three zones (Main Area, 2. Columns, and 3. Open Water Pond Area) buy using IDW (Inverse Distance Weighted) interpolation method in ArcGIS 10.1. Based on figure 19a-i, it is indicated that the flow of the trace metals is from the main area toward open pond area, and the concentrations distribution in the study area as follows:

- Cr, V, Zn, and Co are having same pattern of concentration distribution and higher concentration in Main area and open water pond water area (open area).
 Additionally, all these metals are showing a wider distribution in the open area.
- Ni, Pb, and Ba have the same pattern of concentration distribution and are having higher concentrations in the open area.
- Mo has different pattern of concentration distribution than the other metals and has
 a higher concentration level in the open area.
- Cu also has different pattern of concentration distribution and it is high in the main area.

The statistical summary of trace metals concentrations is presented in Table 7 compared with PME sediment draft guidelines. Across the wetland, Barium has the highest concentration (2.67ppm) among all the metals and Lead has the lowest concentration (0.20ppm) as shown in Figure 20.

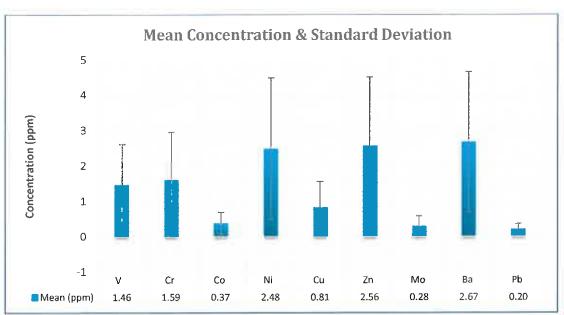
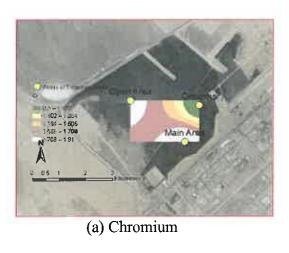
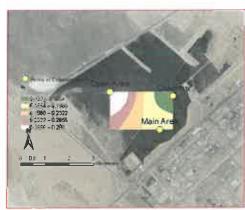


Figure 20 Summary of Trace Metals concentration and Standard Deviation Across the Study Site

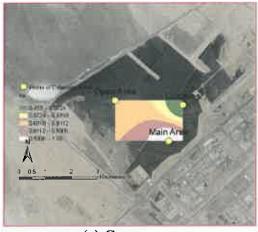
Table 7 Trace metals concentrations statistic results of the Sabkha area and the permissible limit of PME Sediment Draft Guideline, Saudi Arabia

Trace	Min (ppm)	Max (ppm)	Mean (ppm)	Std Deviation (ppm)	Variances	%RSD	PME Sediment Draft Guideline, Saudi Arabia (ppm)		
Metal					v arrances				
							Action Level 1	Action Level 2	
V	0.31	4.53	1.46	1.15	1.33	79.18	-	_	
Cr	0.33	5.71	1.59	1.36	1.84	85.15	52 .	160	
Co	0.07	1.18	0.37	0.31	0.1	83.4	-	-	
Ni	0.44	8.38	2.48	2	4	80.75	16	42.8	
Cu	0.12	2.77	0.81	0.75	0.56	92.01	18	108	
Zn	0.31	5.73	2.56	1.94	3.77	75.96	124	271	
Mo	0.04	1.25	0.28	0.3	0.09	109.41	_	-	
Ba	0.53	7.39	2.67	1.98	3.9	74.26		-	
Pb	0.05	0.6	0.2	0.15	0.02	75.38	30	112	

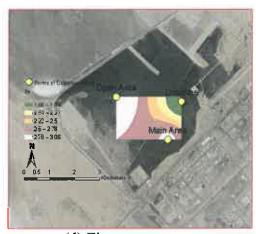




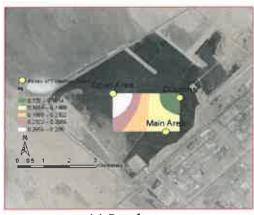
(b) Nickel



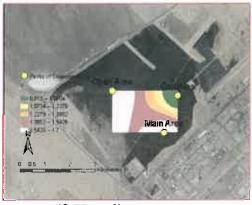
(c) Copper



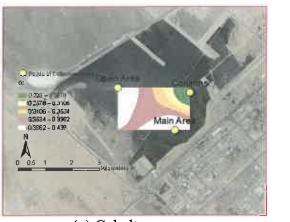
(d) Zinc



(e) Lead



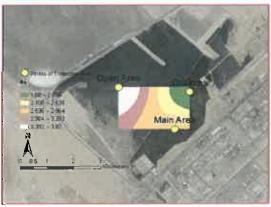
(f) Vanadium



7 774 - 2 (406) 7 774 - 2 (406) 7 736 - 0 (401) 7 1316 - 0 (50)

(g) Cobalt

(h) Molybdenum



(i)Barium

Figures 19 (a-i) Spatial variability maps showing distribution of trace metals in the sediment of the study area.

4.1.1 Chromium

In the main area, the concentration of Chromium varies from 0.49ppm to 5.71ppm with an average of 1.91ppm. Around the columns it varies from 0.327ppm to 2.09ppm with an average of 0.9ppm. On the other hand, in the open water pond area the concentration varies from 0.342ppm to 3.64ppm with an average of 1.78ppm. The spatial variation map shows that Chromium concentration is more in the main area and open area of the study site (figure 19a). Overall, the concentration level of Chromium in the study area is lower than the limit of the five standards in table. The main sources of Chromium are steel industries, chrome-plating, and pigment production.

4.1.2 Nickel

In the main area, the concentration of Nickel varies from 0.70ppm to 8.38ppm with an average of 2.92ppm. Around the columns it varies from 0.459ppm to 3.15ppm with an average of 1.51ppm. In the open water pond area, the concentration varies from 0.442ppm to 4.77ppm with an average of 2.73ppm. The spatial variation map shows that Nickle concentration is more in the open area of the study site (figure 19b). Overall, the concentration level of Nickel in the study area is lower than the limits of the five standards in table. Municipal sewage sludge, wastewater from sewage treatment plant and groundwater near landfill sites are the main sources of Nickel contamination in sediment.

4.1.3 Copper

Copper concentration varies from 0.23ppm to 2.77ppm with an average of 1.05ppm in the main area. Around the columns it varies from 0.123ppm to 1.14ppm with an average of 0.453ppm. In the open water pond area, the concentration varies from 0.126ppm to 1.45ppm with an average of 0.766ppm. The spatial variation map shows that Copper concentration is more in the main area of the study site (figure 19c). The concentration level of Copper in the study area is lower than the limits of the five standards in table. The main source of Cooper is steel industry.

4.1.4 Zinc

The concentration of Zinc in the main area varies from 0.46ppm to 5.73 with an average of 2.83ppm, while around columns, it varies from 0.306ppm to 3.94ppm with an average of 1.66ppm. In the open water pond area, it varies from 0.491ppm to 5.11ppm with an average

of 3.06ppm. The spatial variation map shows that Zinc concentration is more in the main area and open area of the study site (figure 19d). These results shows that the Zinc concentration is below the standard limit of the five standards in table 7.

4.1.5 Lead

The range of Lead concentration is from 0.06ppm to 0.48ppm with an average of 0.196ppm, and from 0.045ppm to 0.249 with an average of 0.132ppm around the columns. Open pond water area has concentration variation from 0.061ppm to 0.599 with an average of 0.299ppm. The spatial variation map shows that Lead concentration is more in the open area of the study site (figure 19e). The concentration level of Lead in the study area is lower than the limits of the five standards in table 7.

4.1.6 Vanadium

In the main area, the concentration of Vanadium varies from 0.44ppm to 4.53ppm with an average of 1.65ppm. Around the columns it varies from 0.307ppm to 2.21pm with an average of 0.913ppm. In the open water pond area, the concentration varies from 0.324ppm to 3.47ppm with an average of 1.7ppm. The spatial variation map shows that Vanadium concentration is more in the main area and open area of the study site (figure 19f). According to the five standards, there is no limit for Vanadium.

4.1.7 Cobalt

The concentration of Cobalt in the main area varies from 0.09ppm to 1.18ppm with an average of 0.439ppm, and from 0.068ppm to 0.603ppm with an average of 0.225ppm

around the columns. In the open water pond area the concentration varies from 0.075ppm to 0.741 with an average of 0.419ppm. The spatial variation map shows that Cobalt concentration is more in the main area and open area of the study site (figure 19g). No standard limits for Cobalt.

4.1.8 Molybdenum

In the main area, the concentration level of Molybdenum varies from 0.04ppm to 0.33ppm with an average of 0.173ppm. Around the columns, it varies from 0.042ppm to 0.451ppm with an average 0.216ppm, and it varies from 0.049ppm to 0.049ppm with an average of 0.559ppm. The spatial variation map shows that Molybdenum concentration is more in the open area of the study site (figure 19h). Typical commercial and industrial sources of waste molybdenum include pigments, lubricants, catalysts, fertilizer, and corrosion control chemicals

4.1.9 Barium

Barium concentration varies from 0.59ppm to 6.12ppm with an average of 2.67ppm, and from 0.528ppm to 2.93ppm with an average of 1.68ppm in the main area. Open water pond area has concentration level varies from 0.63ppm to 7.39ppm with an average of 3.82ppm. The spatial variation map shows that Barium concentration is more in the open area of the study site (figure 19i). Barium is used in different industries such as manufacturing electronic components, metal alloys, glass making and well drilling operations.

4.2 Weather Impacts in Sabkha Al-Fasl Wetalnd

Wetland ecosystems are vulnerable to climatic variation and extreme weathering events. In arid and semi-arid areas, the hot and dry summer reduces the water level in wetlands in which it increases the concentrations of pollutants where they will settle in bottom of wetlands such as industrial chemicals, natural salts, and air pollutants. Any variation in temperature or water supply can cause adverse impacts on wetland biota. For example, high temperatures and low concentrations of oxygen allow an undesirable plant species to grow was well as growth of the botulism bacterium. On the other, precipitation fluctuations can cause plants declination (vegetation cover) or reduce the number of animals that depend on a specific amount of water in their life cycles such as waterfowl whose depend on both plants and water (www.ec.gc.ca/eau-water/).

Sabkha Al-Fasl wetland is affected by arid climate in terms of high temperature in summer and low in winter. On the other hand, wastewater is discharged to Sabkha Al-Fasl from October to May in which it will dry-up during the summer, but this will be substituted during the rainy seasons in which water volume will be increased. The high temperature increases the evaporation, transpiration from growing plant, and surface outflow which in turn lead to lose of water. So, any variation in climate that increases evaporation with low precipitation is likely result in drying out of the wetland.

Figure 21 shows the average atmospheric temperature for 5 years from year 2010 to 2014. Year 2014 has the highest average temperature 27.7°C with maximum temperature of 39.9°C, whereas, 2011 has the lowest temperature 25.9°C with maximum of temperature 45.6°C as shown in figure 23. In terms of precipitation, the lowest precipitations were in

year 2010 and 2012 (0.8mm), and the highest was in year 2014 (4.4mm) as shown in figure 22. These fluctuations show that the study site is strongly affected by the climate conditions through the 5 years which resulted in affecting the water volume in the Sabkha from 2010 to 2014 as shown in figure 24 as will be explained later.

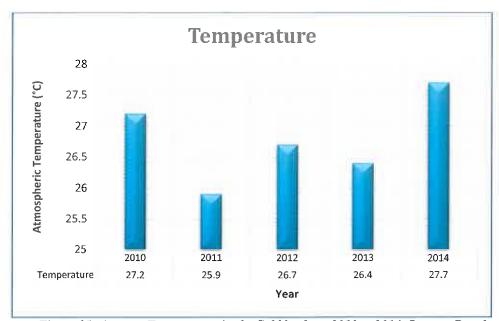


Figure 21 Average Temperature in the Sabkha from 2010 to 2014. Source: Royal Commission Environmental Control Department

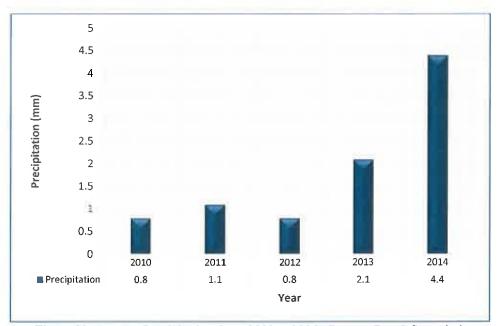


Figure 22 Average Precipitation from 2010 to 2014. Source: Royal Commission Environmental Control Department

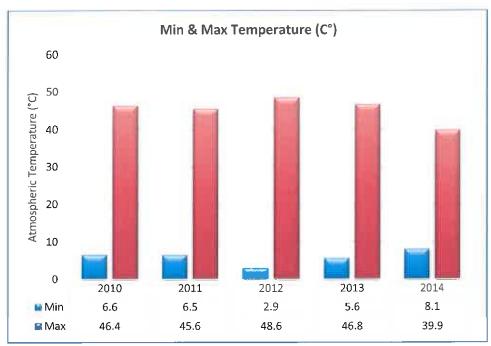
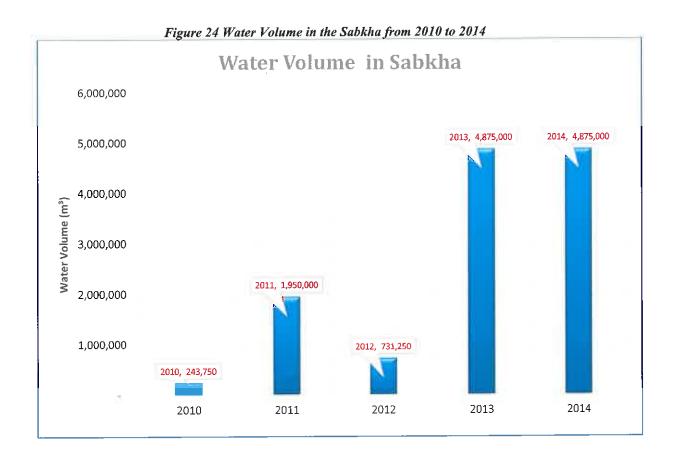


Figure 23 Minimum and Maximum Temperature in the Sabkha from 2010 to 2014. Source: Royal Commission Environmental Control Department

Table 8 Volume of Water in the Sabkha from 2010 to 2014

	•		-		
Year	% Water Coverage	Total Area (m²)	Average Depth (m)	Total Water Volume (m³)	
		13,000,000	0.375	4,875,000	
2010	5%	13,000,000	0.019	243,750	
2011	40%	13,000,000	0.15	1,950,000	
2012	15%	13,000,000	0.056	731,250	
2013	100%	13,000,000	0.375	4,875,000	
2014	100%	13,000,000	0.375	4,875,000	



4.2.1 Impact of Year 2010 Weather Condition

The main area of the Sabkha was almost dried with a very limited amount of water, whereas the open water pond was completely dried. The main purpose of the open water pond is to receive the excess of water from the main area. The average temperature in the this year was 27.2°C with maximum temperature of 46.4°C, and average precipitation of 0.8mm. According to figure 25, the estimated water coverage of the area approximately was 5% with water volume of 243,750m³ as shown table 8. Therefore, low precipitation, and high temperature which increased the evaporation process as well as the consumption of the

irrigation water within the industrial city led to dry up most of the Sabkha as shown Table 8 and Figure 25.

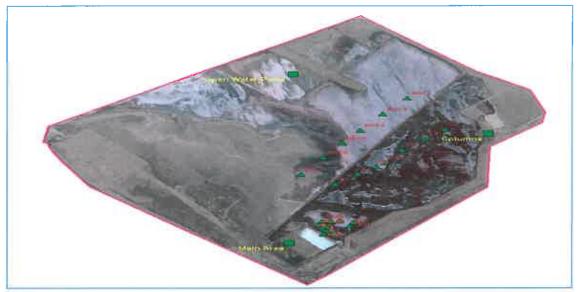


Figure 25 GIS Layer Map of the Sabkha in year 2010, Source: King Abdul Aziz City for Science & Technology

4.2.2 Impact of Year 2011 Weather Condition

The main area had water and with limited quantity of water in the open water pond. The level of water in the main area was not sufficient to overflow to open water pond. The average temperature in 2011 was 25.9°C and maximum temperature of 45.6°C, the average precipitation was 1.1mm. Based on figure 26, the estimated water coverage of the area approximately was 40% with water volume of 1,950,000m³ as shown table 8. In this year, they started to install the electrical pylons which changed the land cover of the Sabkha in terms of destroying some of surrounded vegetation and losing some of water.

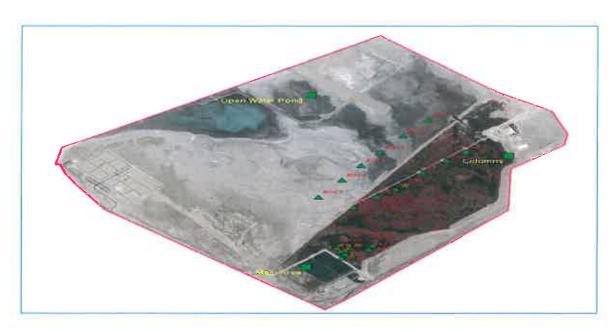


Figure 26 GIS Layer Map of the Sabkha in year 2011, Source: King Abdul Aziz City for Science & Technology

4.2.3 Impact of Year 2012 Weather Condition

Totally the open water pond was dried, whereas the main area had some water with dryness in some parts of it. The average temperature was 26.7°C and maximum temperature of 48.6°C, and the precipitation was 0.8mm. As shown in figure 27, the estimated water coverage of the area approximately was 15% with water volume of 731,250m³ as shown in table 8. This indicates that the area was suffering shortage of water in which it reduced the vegetation cover as well as the other living organisms.

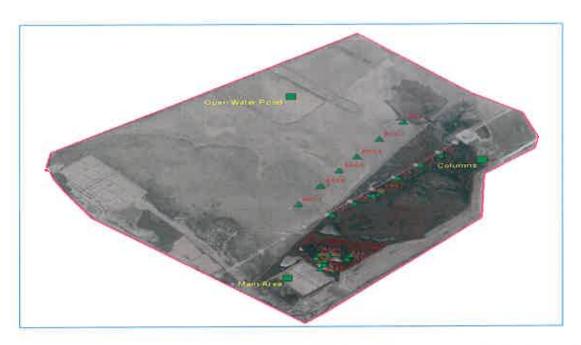


Figure 27 GIS Layer Map of the Sabkha in year 2012, Source: King Abdul Aziz City for Science & Technology

4.2.4 Impact of Year 2013 Weather Condition

The Sabkha was full of water in 2013 in which both main area and open water pond were full of water. In this year, the precipitation (2.1mm) was the maximum compared with the previous years. In addition, the maximum temperature was 46.8°C and average temperature was 26.4°C. Figure 28 shows that the area was full of water (4,875,000 m³) as shown in table 8. Therefore, this level of precipitation helped to maintain the water level in the Sabkha even with this high temperature.

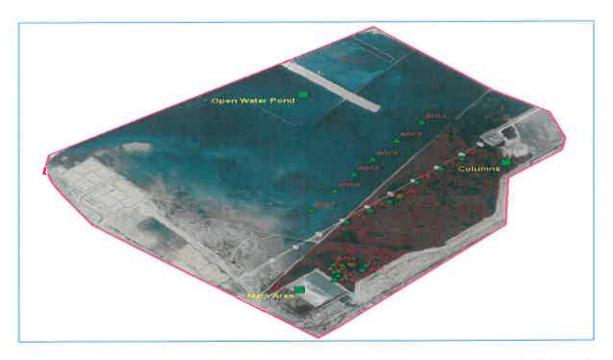


Figure 28 GIS Layer Map of the Sabkha in year 2013, Source: King Abdul Aziz City for Science & Technology

4.2.5 Impact of Year 2014 Weather Condition

The Sabkha was full of water in 2014 in which both main area and open water pond were full of water. In this year, the precipitation (4.4mm) was the maximum compared with the previous years. In addition, the maximum temperature was 39.9°C and average temperature was 8.1°C. Figure 29 shows that the area was full of water with total volume of 4,875,000 m³ as shown in table 8. Therefore, this level of precipitation helped to maintain the water level in the Sabkha even with this high temperature.

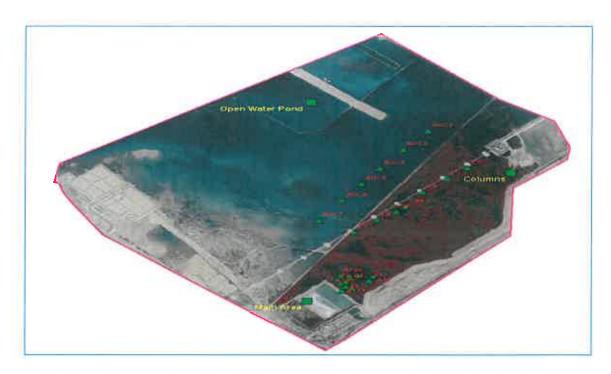


Figure 29 GIS Layer Map of the Sabkha in year 2014, Source: King Abdul Aziz City for Science & Technology

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

The study demonstrates that wetlands are one of the most important ecosystems on the Earth as they provide many important services to human society and vital functions to the living organisms. Additionally, in recent years, wetlands are recognized internationally as the most threatened ecosystem environments and become as a critical environmental issue. This indicates that there is a need to develop and implement a national wetland policy to assess and monitor such natural resources in terms of developing wetland conservation and restoration. Sediment is considered as one of the major life support systems in which it provides critical services for the life of different living organisms. Different types of pollutants can contaminate the sediment; among these pollutants are trace metals. Trace metals have great negative impacts on the sediment due to their toxicity, persistence and bioaccumulation. Through food chain, these pollutants can affect the humans due to bioaccumulation in plants and animals.

This study shows that trace metals concentrations level in Sabkha Al-Fasl including Cr, Ni, Cu, Zn, and Pb are within the permissible limits of local sediment and international guidelines, whereas there are no standard limits for V, Co, Mo and Ba. This indicates that Sabkha Al-Fasl is an ideal habitat for different types of living organisms. On the other hand, the study shows that there is a strong relationship between temperature, precipitation and water level where these two factors affect the water level in the study area in which high temperature and low precipitation reduce the water level in Sabkha Al-Fasl. Additionally, by application of GIS we are able to determine the pattern distribution of the trace metals concentrations which coincide with water inlet, columns and water pond (open area) in the study area which shows that the water flow starts from main area to columns

area toward water pond. In relation to GIS application, this application shows that there are some metals are having the same pattern of concentration distribution across the study area such as Cr, V, Zn, Co, whereas Ni, Pb and Ba are having the same concentration distribution pattern. On the other hand, Mo and Cu are having different distribution pattern than the other metals, where each one of them is having its own pattern. However, these concentration levels of trace metals can be considered as natural background levels and as a guide for future pollution monitoring.

So, it is recommended that on continual basis, more research studies need to be carried to monitor Species distribution, water quality and trace metals distribution. Applying GIS as a powerful tool used in managing environmental issues to monitor vegetation cover, land use and species distribution in the study area and other wetlands. Additionally, developing and implementing a national wetland policy to assess and monitor such natural resources in terms of developing wetland conservation and restoration. Also, strengthening decision makers and local scientific institute's responsibility for sustainable use of wetlands in terms of the connection between the wetland ecological condition, services and benefits for people and other loving organisms they provide. Finally, to protect the area from the urban expansion and to list it under national and international convention as an important habitat of migratory waterfowl

APPENDIX A

A CHECKLIST OF BIRDS SEEN AT SABKHAAL-F ASL, JUBAIL FROM 1994 - 2003

Order PODICIPEDIFORMES Family PODICIPEDIDAE

Genus Tachybatptus

Tachybaptus ruficollis - little grebe

Order PELECANIFORMES

Family PHALACROCORIDAE

Genus Phalacrocorax

Phalacrocorax carbo - great cormorant

OrderCICIFORMES

Family ARDEIDAE

Subfamily BOTAURINAE

Genus Ixobrychus

Ixobrychus mmulus -little bittern

Subfamily ARDEINAE

Genus Nycticorax

Nycticorax nyctcorax - night heron

Genus ArdaJa

Ardeola ralloides - squacco heron

Genus Buhulats

Bubukus ibis - cattle egret

Genus Egretta

Egretta gularis - western reef heron

Egretta garzetta -little egret

Egretta alba - great white egret

Genus Ardea

A rdea cinerea - grey heron

A rdea purpurea - purple heron

Family CICONIIDAE

Genus Ciconia

Oania nigra - black stork

Family TI-IRESKIORNI1HIDAE

Subfamily TI-IRESKIORNI1HINAE

Genus Plegadis

Plegadis falcinellus glossy ibis

Subfamily PIA TALEINAE

Genus Platalea

Platalea kucorrxlia - spoonbill

Order PHOENICOPTERIFORMES

Family PHOENICOPTERIDAE

Genus Phoenicopterus

Phoenicopterus ruber - greater flamingo

Order ANSERIFMORMES Family ANATIDAE

Genus Cygnus

Cygnnus bewickii - tundra swan

Genus Anser

Anser anser - greylag goose

Genus Tadoma

Tadoma fenuginea - ruddy shelduck

Tadoma tadorna - shelduck

Genus Anas

Anas pene/ojx - wigeon

Anas strepera - gadwall

Anas mro:t - teal

Anas platyrhyndxJs, -mallard

Anas aatta - pintail

Anas querquaiula – garganey

Anas dypeata - shoveler

Anas angustrastris - marbled teal

Genus Aythya

Aythya ferina - pochard

A ythya nyroot - ferruginous duck

A ythya fidif}lla - tufted duck

Genus Netta

Netta rnfina - red-crested pochard

Order ACCIPITRIFORMES Family ACCIP1RIDAE

Genus Milvus

Milvus migrans - black kite

Genus Ciraus

Ciraus aerugirwsus - marsh harrier

Ciraus macrourns - pallid harrier

Ciraus pygargus - montagu's harrier

Genus Accipiter

Accipiternisus - sparrowhawk

Genus Buteo

Buteo butro - steppe buzzard

Genus Aguila

Aquila clanga - spotted eagle Aquila

rapax - steppe eagle

Aquila heliaca - imperial eagle

Family P ANDIONIDAE

Genus Pandion

Pandion haliaetus - osprey

Order FALCONIFORMES Family FALCONIDAE

Genus Falco

Fala ncumamzi - lesser kestrel Falco tinnunadus - kestrel Falco subbutm - hobby Falco perrgrinus - peregrine

Order GALLIFORMES

Family PHASIANIDAE

Genus Cotumix

Cotumix cotumix — quail

Order GRUIFORMES

Family GRUIDAE

Genus Grus

Grus grus = grey crane

Family RALLIDAE

Genus Rallus

Rallus aquatiats - water rail

Genus porzana

Porzana porzana - spotted crake porzana parm - little crake porzana pusilla - baillon's crake

Genus Gallinula

Gallinula chlaropus - moorhen

Genus Fulica

Fulica atra - coot

Order CHARADRIFORMES

Family RECURVIROSTRIDAE

Genus Himantopus

Himantopus himantopus - black-winged stilt

Genus Reaurvirostra

Reaurvirostra avoseta - avocet

Subfamily GLAREOLINAE

Genus Glareola

Glareola pratincola - collared pratincole Glareola nardmanni - black-winged pratincole

Family CHARADRIIDAE Subfamily CHARADRIINAE

Genus Charadius

Charadius dubius - little ringed plover Chtradius hiatiaula - ringed plover Chtradius akxandrinus - Kentish plover Chtradius mongolus - lesser and plover Chtradius leschenaultii - greater sand plover

Genus Pluvialis

pluvialis daninitca - Pacific golden plover pluvialis squatarola - grey plover

Subfamily VANELLINAE

Genus Chettusia

Chttusia leucura - white-tailed plover

Family SCOLOPACIDAE

Subfamily SCOLOP ACINAE

Genus Calidris

Calidris alba - sanderling

Calidris minuta - little stint

Calidris tonminckii - temminck's stint

Calidris sulminuta -long-toed stint

Calidris fenugin&. - curlew sandpiper

Calidris alpina - dunlin

Genus Limicola

Limicola falcinellus - broad-billed sandpiper

Genus Philanachus

Philomachus pugnax = ruff

Subfamily GALLINAGINIAE

Genus Lymnocrypts

Lymnocrypts minimus - jack snipe

Genus Gallinago

Gallinago gallinago - snipe

Gallinago stenura - pintail snipe

Subfamily TRINGINAE

GenusLimosa,

Limosa limosa - black-tailed godwit

Limosa lapponica - bar-tailed godwit

Genus Numerius

Numerius phaeopus - whimbrel

Numerius arquata - curlew

Genus Tringa

Tringa erythropus - spotted redshank

Tringa totanus - redshank

Tringa stagnatilis - marsh sandpiper

Tringa nebu!aria- greenshank

Tringa ochropus – green sandpiper

Tringa glareola - wood sandpiper

Genus Xenus

Xenus cinereus - terek sandpiper

Genus Actitis

Actitis hypoleucos - common sandpiper

Subfamily ARENARIINAE

Genus Arenaria

Arenaria interpres - turnstone

Subfamily PHALAROPODINAE

Genus Phalaropus

Phalaropus lobatus - red-necked phalarope Pha/aropus fulicarius - grey phalarope

Family LARIDAE

Genus Larus

Larus ichtyaetus - great black-headed gull Larus ridibundus - black-headed gull Larus genei - slender-billed gull Larus fuscus -lesser black-backed gull Larus cachinnans - yellow-legged gull

Family STERNIDAE

Genus Gelochelidon

Gelochelidon nilotica - gull-billed tern

Genus Sterna

Sterna caspia - caspian tern

Sterna himndo - common tern

Stema a/bifrans / saundersi-little / saunders'tern

Genus Chlidonia

Chlidonias hybridus - whiskered tern Chlidonias leucopterus - white-winged black tern

Order COLUMBIFORMES

Family COLUMBIDAE Subfamily COLUBINAE

Genus Columba

Columba livia - rock dove

Genus Streptopelia

Streptopelia decaocto - collared dove

Strepropelia turtur - turtle dove

Streptopelia senegalnsi.s - palm dove

Genus Oena

Oena capensis - namaqua dove

Order STRIGIFORMES Family TYTONIDAE

Genus Tyto

Tyto alba - barn owl

Family S1RIGIDAE

Subfamily BUBONIDAE

Genus Otus

Otus brucei - striated scops owl

Genus Bubo

Bubo bubo - eagle owl

Order CAPRIMULGIFORMES Family CAPRIMULGIDAE Subfamily CAPRIMULGINAE

Genus Caprimulgus

Caprimulgus europaeus - nightjar

Order APODIFORMES

Family APODIDAE Subfamily APODINAE

Genus Apus

Apus apus - swift

Apus pallidus - pallid swift

Apus melba - alpine swift

Order CORACIIFORMES

Family ALCEDINIDAE Subfamily ALCEDININAE

Genus Alcedo

Alcedo atthis — kingfisher Ceryle rudis —pied kingfisher

Family MEROPIDAE

Genus Merops

Merops superciliosus - blue-cheeked bee-eater Merops apiaster - European bee-eater

Family CORACIIDAE

Genus Coracias

Coracias garrulus - roller

Family UPOPIDAE

Genus Upupa

Upupa epops - hoopoe

Order PICIFORMES

Family PICIDAE Subfamily JYNGINAE

Genus Jynx

Jynx torquilla - wryneck

Order P ASSERIFORMES Suborder PASSERES

Family ALAUDIDAE

Genus Eremopterix

Eremopterix nigriceps - black-crowned finch lark

Genus Alaemon.

A laemon alaudipes - hoopoe lark

Genus Galerida

Galerida cristata - crested lark

Family HIRUNDINIDAE

Genus Riparia

Riparia riparia - sand martin

Genus Hirundo

Hirundo rustica - barn swallow

Hirundo daurica - red-rumped swallow

Genus Delichon

Delichon urbica - house martin

Family MOT ACILLIDAE

Genus Anthus

Anthus - richard's pipit

Anthus campestris - tawny pipit

Anthus cervinus - red-throated pipit

Anthus spinoletta - water pipit

Anthus trivia/is - tree pipit

Genus Motacil1a

Motacilla f/ava - yellow wagtail

Motacil1a cetreola - citrine wagtail

Motacilla cinerea - grey wagtail

Motacilla alba - white wagtail

Family PYCNONOTIDAE

Genus Pycnonotus

Pycnonotus leucogenys - white-cheeked bulbul

Family TURDIDAE.

Genus Cercotrichas

Cercotrichas galactotes - rufous bush chat

Genus Luscinia

Luscinia svecica - bluethroat

Genus Irania

Irania gutturaris - white-throated robin

Genus Phoeniatrus

Phoeniatrus phoenicums - redstart

Genus Saxicila

Saxicola rubetra - whinchat

Saxico1a torquata - stonechat

Genus Oenanthe

Oernanthe isahdlina - isabdline wheatear Oernanthe Oemantlx - wheater

Oernanthe pkschanka - pied wheatear

Oerrianthe hispanica - black-eared wheatear Oernanthe ckserti = desert wheatear Genus Turdus

Turdus phikmdas - song thrush

Family SYLVIIDAE

Genus Prinia

Prinia gracilis - graceful warbler

Genus Locustella

Locusrella luscinioides - savi's warbler

Genus Acrocephalus

Acrocephalus palustris - marsh warbler

Acrocephalus scirpaceus - reed warbler

Acrocephalus srenoarius - clamorous reed warbler Acrocephalus arundinaceus - great reed warbler

Acrocephalus griseldis - Basra reed warbler

Genus Hippolais

Hippolais pallida - olivaceous warbler

Hippolais languida - upcher's warbler

Genus Sylvia

Sylvia mystecea - menetries' warbler

Sylvia nana - desert warbler

Sylvia hortensis - orphan warbler

Sylvia nisoria - barred warbler

Sylvia curruca - lesser whitethroat

Sylvia communis - whitehroat

Sylvia atricapilla - black-cap

Genus Phylloscopus

Phylloscopus collybita - chiffchaff

Phylloscopus trochilus - willow warbler

Family MUSCICAPIDAE

Genus Muscicapa

Muscicapa striata - spotted flycatcher

Family REMIZIDAE

Genus Remiz

Remix pendulinus = penduline tit

Family ORIOLIDAE

Genus Oriolus

Orio!us oriolus oriolus - golden oriole

Family LANTIDAE

Genus Lanius

Lanius isabdlinus — isabelline shrike Lanius collurio - red-backed shrike

Lanius minor - lesser grey shrike

Lanius meridianalis - southern grey shrike Lanms pallidirostris - steppe grey shrike

Lanius senator - woodchat shrike

Lanius nubicus - masked shrike

Family CORVIIDAE

Genus Corvus

Corvus splmckns - Indian house crow Corvus ruficollis - brown-necked raven

Family STURNIDAE

Genus Sturnus

Sturnus vulgaris = starling

Family PASSERIDAE

Genus Passer

Passer domesticus - house sparrow

Passer moabiticus - Dead Sea sparrow

Family ESTRILDIDAE

Genus Euodice

Euodice malabrica - Indian silverbill

Family EMBERIZIDAE

Genus Emberiza

Emberiza hartu!nuna - ortolan bunting

Emberiza schoemichus - reed bunting

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