Integrated Water Quality Management and its Impact on the Population of Mawyah District

A thesis submitted to the Water and Environment Center at Sana'a University in fulfillment of the requirements for the

Master degree in Integrated Water Resources Management

by

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DECLARATION

This is to certify that this thesis entitled “Integrated Water Quality Management and its Impact on the Population of Mawyah District” Submitted in partial fulfillment of the requirements for the award of the degree of MSc in IWRM to the Water and Environment Center at Sana'a University, done by Ms. Randa Al-Thabel is an authentic work carried out by her under our guidance. The matter embodied in this project work has not been submitted earlier for the award of any degree or diploma to the best of my knowledge and believe.

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DEDICATION

To my parents, Brothers and sisters

To my teacher "Abdallah Saleh"

Randa Ali Al-Thabel

June 2012

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ACRONONYMS

EC	Electrical Conductivity
GARWSP	General Authority of Rural Water Supply Projects
IWQM	Integrated Water Quality Management
IWRM	Integrated Water Resources Management
IWRMP	Integrated Water Resources Management Plan
KOMEX	Canadian Consulting Company
LC	Local Corporation
l/s	liter/second
meq/l	milliequivalent per liter
mg/l	milligram per liter
MIWRMP	Mawyah Integrated Water Resources Management Plan
MLC	Mawyah Local Council
MWUA	Mawyah Water Users Associations
NWRA	National Water Resources Authority
pH	Hydrogen Ion Concentration
ppm	part per million
SFDP	Social Fund Development project
Talk	Total Alkalinity
TDS	Total Dissolved Solids
TH	Total Hardness
WDM	Water Demand Management

WHO	World Health Organization
WRCF	Water Resources Constraint Force
YDWQS	Yemeni Drinking Water Quality Standard

Abstract

Mawyah as a district of Taiz represent a model of limited water resources with high intensive use of groundwater especially for Qat irrigation.

The random use of such scarce water resources lead to water quantity, quality, social, and economic problems. Flourosis is one of those problems in Mawyah.

IWRM approach is used to identify, evaluate, and propose solutions for such problems. The Study focused more in the IWRQM of the drinking water supply wells in order to determine the health, socio economic impact of high fluoride concentration, and the interference of the IWRM decision makers in Mawyah district.

Drinking water supply wells were identified, samples collected based on certain criterias, and the samples analyzed an assessed based on IWRM.

Various GIS maps, such as base map, water points location map, sub district map, geology map, topography map, and water chemistry map of Mawyah district were produced using previous and present field survey data.

The hydrochemistry results indicate that Electrical conductivity is high in 37% of the samples. Total Hardness is high in 46% of the samples. Calculated dissolved solids are high in 33% of the samples. Anions concentrations in the samples are high for Bicarbonate, Chloride, Sulfate, and Nitrate to 31%, 7%, 35%, and 7% respectively. The cation concentrations in the samples are high for Calcium, Magnesium, and Sodium to 4%, 2%, and 9% respectively. Fluoride concentration is high in 35% of the samples. It ranges between 1.6 to 16.1 mg/l which is exceeding the maximum limit of WHO (1.5 mg/l) and Yemeni standards (1.5 mg/l).

The social, health and economic results indicate that 74% of the people have fluorosis in their teeth. 94 % do not know the cause of the fluorosis problem. 95% feels negative effects from the change of the teeth color. 96% don't reception their teeth color. 97% want to remove the color of their teeth. 9 % visited the dentist to remove the fluorosis from their teeth. 95% feel that the fluorosis is a normal thing. 4% could not visit the doctor due to the high cost.

The study includes 14 interviews with the Decision makers to explain IWRM aspects.

79% of the decision makers answered that high fluoride concentration in drinking water is acute problem. 21% of the visited institutions have database for the fluoride concentration. 43% of the institutions collected fluoride data by chemical analysis and use Yemeni standard. 72% of the decision markers know the effects of the high fluoride concentration. 57% of the decision markers saw the flourisis effects on the people. 50% from the institutions think about future plan to resolve the health effect of the flourosis, while 42% of the institution already has a future plan.

IWRQM study concludes that the main water supply source in Mawyah district is the alluvium aquifer. Water in the alluvium aquifer is recent fresh water recharged from rainfall and floods seepage. Alluvium aquifer is highly stressed by abstraction mainly for Qat irrigation. Increase of some parameters such as EC, TH, and TDS are caused by of heavy groundwater abstraction, dry seasons, and pollution.

IWRM is still in the first stage in Mawyah district. Until know, there is not water resources management plan for Mawyah district. IWRM institutions in Mawyah district are very week in both institutional structure and capacity building.

Chapter 1: Introduction

1.1 BACKGROUND

Mawyah is a district in Taiz governorate. It is located in the northeast of Taiz governorate and Taiz city. Mawyahis facing many problems related to water resources which are natural, social, economic, and legal aspects. The natural aspects are related to geology, hydrogeology, and hydrological problems; in other words poor water quality and water scarcity. Social problems are related to the high population of about 131716 inhabitants (CSO, 2004), with a high population growth exceeding 3% per year. The economic problems are linked to limited chances of job opportunities. The jobs are connected to Qat cultivation that depends mainly on ground water resources for irrigation. Legal problems are related to limited capacity and capabilityof the local council in implementing the laws.

The model used to resolve such water problems in Yemen is Integrated Water Resources Management (IWRM). The IWRM principle was first implemented in Yemen in 1990 and in Taiz governorate in 1997 in particular. Implementing IWRM in Mawyah district has started in 2009 through a well inventory study.The water law and bylaw implementation was started bythe National Water Resources Authority in Taiz (NWRA-

Taiz),Mawyah Local Council (MLC), and Mawyah Water Users Associations (MWUA).

This study is accomplished to move forward in the IWRM implementation in Mawyah district. The study covers the Integrated Water Quality Management (IWQM) as part of IWRM in Mawyah. It focuses mainly on flourosis in Mawyah district. In order to identify flourises in Mawyah the study focused on water quality of water supply wells. The water supply wells are selected from the well inventory results created by NWRA-Taiz (NWRA-T 2009). Water chemistry samples were collected from 57 water supply points. The water supply points are selected in a basis of identified criteria's. The collected samples were analyzed for all water chemistry parameters included fluoride. The intake from drinking water is highly significant for fluoride (10-50%), and to high concentration of this element can in many areas limit the use of groundwater for drinking purposes (Appelo et al, 1993). Flourises effects on the people were evaluated by a social survey study. Asocial survey questioners were filled from men and women. It covers 180 people using the selected water supply points. The study covers the decision makers actions and point of few about IWRM in

Mawyah district. It is done by field survey questioners. The survey covers 14 decision makers in Mawyah district water sector.

"Water quality can be thought of as a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics. To determine water quality, scientist's first measure and analyze characteristics of the water such as temperature dissolved mineral content, and number of bacteria. Selected characteristics are then compared to standards and guidelines to decide if the water is suitable for a particular use" *http://water.usgs.gov/nawqa.*

"Fluor (Fl) is the most electronegative and reactive of all elements. It appears as fluoride in drinking water. It occurs as fluoride ions in soils and natural waters due to chemical weathering of some fluoride containing minerals (Totsche et al, 2000)". High fluoride concentrations are often found in Syenites, granitoid plutonic rocks, alkaline volcanic. Fluoride can also occur in sedimentary formations that contain fluoride-bearing minerals derived from the parent rock, fluoride-rich clays, or fluor apatite (David L. Ozsvath, 2008).

"Fluoride in small amounts is an essential component for normal mineralization of bones and formation of dental enamel (Bell and Ludwig, 1970)". Fluorine due to its strong electro negativity is attracted by positively charged calcium in teeth and bones (Susheela et al. 1993).The fluoride concentration appears in human body as dental fluorosis, skeletal fluorosis, increased rates of bone fractures, decreased birth rates, increased rates of urolithiasis (kidney stones), impaired thyroid function, and lower intelligence in children(David L. Ozsvath, 2008).Besides skeletal and dental fluorosis, excessive consumption of fluoride may lead to muscle fiber degeneration, low hemoglobin levels, excessive thirst, headache, skin rashes, nervousness, depression, …etc.(Meenakshi, 2006).

According to the World Health Organization (WHO) Guidelines for Drinking Water Quality (WHO, 2008) the limit value for fluoride is 1.5 mg/l. This is a guiding value, which may be changed based on climatic conditions like temperature, humidity, volume of water intake, fluoride from other sources…. etc. for different regions of the world (Viswanatham, 2008). The Yemeni Standard specifies the desirable and permissible limits for fluoridein drinking water as 1.0 and 1.5 mg/l respectively (Yemen S, 1999).

1.2 Statement of the Problem

Yemen has scarce water resources especially in the mountainous areas. Taiz is one of those high scarce water resources areas. Mawyah as a district of Taiz represent a model of limited water resources with high intensive use especially for Qat irrigation.

The random use of such scarce water resources lead to water quality and quantity problems as well as social and economic problems. To resolve such problems an integrated water resources management approach should be used.

Part of the water resources problems is water quality. Flourosis is one of those problems in Mawyah.

1.3 Objective of the Study

The study will deal with the following objectives:

- Identify the drinking water supply wells from NWRA-Taiz 2009 well Inventory of Mawyah district.
- Assessment of the Water supply quality in18 sub-districts of Mawyah.

- Determine the health and socio economic impact of high fluoride concentration in 18 sub-districts of Mawyah.
- Determine the interference of the IWRM decision makers in Mawyah district.

CHAPTER 2: LITERATURE REVIEW

The ingestion of large amounts of fluoride, whether via water or food, can cause serious health problems for humans and animals.

These problems range from discolored teeth (i.e.dental fluorosis) to aching joints, brittle bones, stunted growth and deformed limbs (i.e. skeletal fluorosis). Non-skeletal fluorosis can also have severe symptoms.

The range also includes gastro-intestinal problems and neurological disorders. Fluoride can damage unborn babies and adversely affect the intelligence of children. As it can affect the pelvic bones, pregnant women often have to undergo caesarean operations.

The symptoms of fluorosis may also be alleviated by:

1. drinking more milk to provide calcium to strengthen bones
2. eating fruits (especially citrus, alma, tamarind) and vegetables to increase vitamin C intake
3. Water can also be treated to reduce fluoride levels using filters that can be bought commercially, or using simple household methods like the Nalgonda technique (*http://www.irc.nl/page /37797*).

2.1 Previous studies on Water Quality Management globally

"As water has become the shortest resources in arid, semi-arid and rapid urbanization areas when the water resources utilization has approached or exceeded its threshold, water resources system slows down the socio-economic growth rate and destroys the projected targets to eradicate poverty and realize sustainable development. We put forward the concept of Water Resources Constraint Force (WRCF) and constructed a conceptual framework on it. Conceptual models on the interactions and feedbacks between water resources and socio-economic systems in water scarce regions or river basins indicate that, if the socio-economic system always aims at sustainable development, WRCF will vary with a normal distribution curve. Rational water resources management plays an important role on this optimistic variation law. Specifically, Water Demand Management (WDM) and Integrated Water Resources Management (IWRM) are considered as an important perspective and approach to alleviate WRCF" http://www.springerlink.com/content/a245g48747481771/.

In China: "A case study in the Hexi Corridor of NW China indicates that, water resources management has great impact on WRCF both in Zhangye and Wuwei Region, and also the river basins where they are located. The drastic transformation of water resources management pattern and the experimental project – Building Water-saving Society in Zhangye Region alleviated the WRCF to some extent. However, from a water resources management view, WRCF in Zhangye Region still belongs to the severe constraint type. It will soon step into the very severe constraint type. In order to shorten the periods from the very severe constraint type finally to the slight constraint type, WDM and IWRM in the Hei River Basin should be improved as soon as possible. However, in the Shiyang River Basin, WRCF belongs to the very severe constraint type at present due to poor water resources management in the past. Though the socio-economic system adapted itself and alleviated the WRCF to some extent, the Shiyang River Basin had to transform the water supply management pattern to WDM, and seek IWRM in recent years. It is concluded that WDM and IWRM is a natural selection to alleviate the WRCF on the socio-economic system and realize sustainable development"(Chuang-lin. F.et al 2006).

In Argentina: Historically, the arid conditions of La Rioja, Argentina have been the main controlling factor in its development. The shortage of surface water, which is fully used, makes groundwater a potential source for development. The government encouraged investment in early 1979, resulting in a 20-fold increase of groundwater extraction by 1998 (0.076–1.450 m^3/s, respectively) to cover related needs of agriculture, industry and population growth. This extraction created unjustified uncertainties derived from negative results obtained in hydrological balances. However, a 0.5 m lowering of the water-table surface was experienced. A knowledge of groundwater functioning was required to establish a reliable frame of reference for development and, at the same time, to find possible scenarios of feasible economic activities in harmony with accessible water resources and aptitude of the environment. The flow regime was found to be composed of three main systems: a regional, an intermediate and several local (S. E. Martinez et al 2003).

In Japan: A sinking of the land surface due to the pumping of groundwater has long been recognized as an environmental issue in the Shiroishi plain of Saga, Japan. Land subsidence can have several negative economic and social implications such as changes in groundwater and surface water flow patterns, restrictions on pumping in land subsidence prone areas, localized flooding, failure of well casings as well as shearing of structures. To minimize such an environmental effect, groundwater management should be considered in this area. In this study, a new integrated numerical model that integrates a three-dimensional numerical groundwater flow model coupled with a one-dimensional soil consolidation model and a groundwater optimization model was developed to simulate groundwater movement, to predict ground settlement and to search for optimal safe yield of groundwater without violating physical, environmental and socio-economic constraints. It is found that groundwater levels in the aquifers greatly vary from season to season in response to the varying climatic and pumping conditions. Consequently, land subsidence has occurred rapidly throughout the area with the Shiroishi plain being the most prone. The predicted optimal safe yield of the pumping amount is about 5 million m^3. The study also suggests that pumping with this optimal amount will minimize the rate of land subsidence over the entire area (Nguyen. C. D. et al, 2005).

In the southwestern United States: The southwestern United States—this paper's study region—is home to large urban centers and features a thriving agro-industrial economic sector. This region is also one of the driest in North America, with highly variable seasonal and inter-annual precipitation regimes and frequent droughts. The combination of a large demand for usable water and semi-arid climate has led to groundwater overdraft in many important aquifers of the region. Groundwater overdraft develops when long-term groundwater extraction exceeds aquifer recharge, producing declining trends in aquifer storage and hydraulic head. In conjunction with overdraft, declines in surface-water levels and stream flow, reduction or elimination of vegetation, land subsidence, and seawater intrusion are well documented in many aquifers of the southwestern United States. This work reviews case studies of groundwater overdraft in this region, focusing on its causes, consequences, and remedial methods applied to counter it (S. Zektser ,et al, 2005).

Maku area, northwest of Iran: The analysis of groundwater samples collected from 40 basaltic and 32 nonbasaltic springs and wells in Maku area in the northwest of Azarbaijan province, northwest of Iran show high concentrations of fluoride. Inhabitants of the area that obtain their drinking water supplies from basaltic springs and wells are suffering from dental fluorosis. Regional hydrogeochemical investigation indicates that water-rock interaction is probably the main reason for the high concentration of ions in groundwater. Hence, it is not suitable for consumption without any prior treatment (Asghar. A. M *et al.* 2007).

Halaba (SNNPR, Ethiopia): In Halaba district in Southern Ethiopia fluoride levels from boreholes are high (2.6 to 7.0 mg/l), yet the incidence of fluorosis is modest. Drinking water users living in the vicinity of four drinking water systems that have been in operation for more than 35 years were surveyed. Out of 625 persons 5 percent had severe dental fluorosis and

42 percent had mild forms – which is considerably less than results of other areas with comparable fluoride levels. The incidence was highest in the older age groups. Possible explanations may be the continued large dependence on rain water harvesting ponds for human consumption alongside the use of water from the public borehole systems, but more investigations would be required to confirm this proposition (Frannk.V.S*et al* 2011).

In India: The most serious natural groundwater-quality problem in India was studied, in terms of public health, derives from high fluoride concentration. Hydrogeochemical investigation of fluoride contaminated groundwater samples from Kolar and Tumkur Districts in Karnataka are undertaken to understand the quality and potability of groundwater from the study area, the level of fluoride contamination, the origin and geochemical mechanisms driving the fluoride enrichment. The majority of the groundwater samples did not meet the potable water criteria as they contained excess (>1.5 mg/L) fluoride, dissolved salts (>500 mg/L) and total hardness (75-924 mg/L) (Mamatha, P and Rao, Sudhakar M. 2010).

In Marathon County, Wisconsin: A study of the water samples from 2,789 private water-supply wells in Marathon County, Wisconsin reveal that fluoride concentrations in the crystalline bedrock range from <0.01 to 7.60 mg/L. Felsic rocks have significantly higher fluoride concentrations than mafic rock. Syenites yield the most fluoriferousground waters, but the highest median concentration occurs in sodium-plagioclase granite. A relationship between plagioclase composition and fluoride concentrations suggests that dissolved fluoride levels are controlled by fluorite solubility and that higher fluoride concentrations are found in soft, sodium-rich groundwater (David L. Ozsvath, 2010).

2.2 Previous studies on Water Quality Management in Yemen

In Marib : The study area can be characterized as an agricultural area, where more than 90% of the populations are farmers. Crude birth and infant mortality rates are high, which is typical for most developing countries. The natural population growth figure 3.6%

The high prices of agricultural inputs constitute a serious problem for most farmers and limit the profitability of agricultural activities. The margin between real market prices and crop costs has been assumed to decline at 2% annually.

Marketing is a major problem for farmers, especially for those in the most eastern part of the wadi. Governmental intervention in this matter is requested by farmers as to solve these marketing problems.

The income situation is not very rosy, as the numbers of households whose expenditures exceed earnings is almost 47.4%. However, income figures have to be interpreted very carefully as only a minor part of the respondents answered questions concerning income developments.

The introduction of the scheme may sharpen the already existing conflicts between particular groups in the area.

In Taiz Region: The region is characterized by subsistence agriculture which is the major employer of rural labor. Nearly 47% of the surveyed population was employed in the sector. Employment opportunities in other sectors were limited. Only 1.4% of the surveyed population was employed in the non-farm sector and another 1.3% was migrant workers who had left the area in search for employment. Earnings of migrants working abroad were higher but workers in this category were fewer than 10% of the total migrants. This suggests that agriculture will remain the primary means of sustenance for a large number of rural households. A decline in agriculture due to depletion of groundwater resources will bring much hardship on the population of the area.

Although agriculture absorbed a large share of rural labor force, most people engaged in agricultural work were employed part-time. According to results of this survey, only 12.6% of the household members were employed full-time in this sector and another 34%were employed on a part-time basis. This is possibly due to the dominance of low-value cereal crops, which typically had very low yields in the area and a limited potential for labor absorption.

In Sana'a Basin: In 2007, 150 water samples of four different aquifers (limestone, sandstone, volcanic and alluvial) in Sana'a Basin were analyzed and results were compared with the hydro-chemical results of 1986.The comparison shows significant deterioration of some water quality parameters such as SO4, HCO3, Ca, Cl, while positive changes have been observed in other parameters. The worst occurrences of water quality are: Wadi Sanhan in the southern part of the basin, the area between Wadi Zahr and WadiIqbal on the western side of the basin, and the area between Wadi Al-Sirr and Wadi Asir on the eastern side of the basin (ESBWMP2010).

In Wadi Hadhramawt: KOMEX Company has carried out a set of technical studies in 2001 that contributed to better understanding of water quantity and quality in Wadi Hadhramawt with a growing competition between different water sectors. In 2011, the Seyun Branch Office of NWRA has collected a total of 123 water samples. The results of chemical analysis of the newly collected water samples are compared against the KOMEX's hydrochemical data in order to examine an evolution of groundwater salinity and chemical composition over the last decade. No significant changes in groundwater salinity patterns are reported between 2001 and 2011 except for an expansion of the elevated salinity areas located in the southern tributary wadis. The expansion of elevated salinity water did not link, however, with a general increase of chloride- and sodium-rich waters in these areas. There is some evidence of a decrease in salinity at the outlet of the main valley east of Tarim that might be explained by an increase of fresh groundwater recharge contributing to the main valley from WadiIdim, especially due to the heavy flood event reported in 2008(NWRA, 2011).

In Wadi Surdud: The analyses results of 121water samples collected from dug and drill wells indicated two types of chemical water types in the study area {indiscriminate ions and (Na+K)(SO_4+Cl)}. These types of water are concentrated in the upstream and downstream respectively indicating the absence of upstream recharge, at least during the last few years. The high concentration of Na &Cl downstream indicates that this area is affected by seawater intrusion. According to the evaluation of water samples, about 74% of the supply wells are classified as unsuitable for drinking water, and only 26 % of these wells do not exceed the Yemeni standard for drinking water (NWRA, 2009).

In Marib area: Chemical analysis and graphical representations of 22 ground water samples collected from different locations and depths in Marib area revealed that all samples are suitable for drinking and irrigation uses, except two samples. Farmers used nitrogen fertilizers which are chiefly urea, causing an increase to the concentration of nitrate in ground water. In the north-eastern zone, differences in the electrical conductivity of ground water were observed. These differences may be due to the difference in pumping rates (As Sayyagh, 1992).

In Sa'dah Region: The sample analysis of 60 groundwater samples proved that salinity is still acceptable, in spite of the heavy water abstraction. The determination of halide (Br, F, I) has not provided significant evidence of high concentration higher than WHO standard. As for iron, the WHO threshold is overcome in 20 cases and this may affect the health of local people if the water used for drinking. The determination of various forms of nitrogen (nitrates, nitrites, ammonium) has highlighted a worrisome diffusion of nitrates, with an average of 33.1 mg/l in 60 samples. In particular, the threshold of 50 mg/l (WHO value guideline) has been overcome in 15 cases, and in 13 cases values ranged between 20 and 50 mg/l. The presence of nitrates is surely due to the widespread use of nitrogenous fertilizers (NWRA, 2003).

In Taiz Region: In this study 57 groundwater samples were collected from Wadi Al-Ghayl watershed, Wadi Warazan Watershed, and Hajdah area in Taiz region. The analyses present the highest average salinity was recorded in wadi Warazan watershed (1316 mg/l) and the lowest salinity in wadi Al-Ghayl watershed (788 mg/l). The iron concentration exceeded the WHO threshold for drinking standards in three cases while various forms of nitrogen (nitrates, nitrites, ammonium) has highlighted a worrisome presence of nitrates, especially in the outskirts of Hajdah area, with an average of 30.6 mg/l in 57 samples. In particular, the threshold of 50 mg/l (WHO value guideline) was overcome in 7 cases and may be referred to the widespread use of nitrogenous fertilizers(NWRA, 2003).

It is observed that the inhabitants in some areas of Yemen suffer from fluorosis, amongst which is Taiz governorate. A study revealed that, the villages of JabalSabir, Hawban, Hethran, Al-Buryehey as well as Taiz city, are the most affected areas by high fluoride concentration reached to 10 mg/l in groundwater (Alamry, 2009).

In Al-Dhala governorate: The highest concentration of fluoride values reached to 18.3 mg/l was observed in the districts of Al-Dhala, Qat'abah, Al-Husha, and Al-Azareq (Alamry, 2009).

2.3 Summary review (Yemen)

Previous water resources quality studies in Yemen were limited to technical issues specifically identifying the water chemistry parameters of groundwater in most governorates. The analysis concluded that abstracted water in some areas is resent recharge water to the aquifers. This is especially for alluvium aquifers in the mountainous areas. Pollution is observed in some aquifers especially those laying in sewerage bound areas in addition to salt water intrusion in most aquifers connected to the sea. The water quality in sandstone aquifers is good. Alluvium aquifers have good quality water except in areas that are affected by pollution through recharge from pollution sources. Low water quality of volcanic aquifers is indicated by high minerals. Nitrogen fertilizers are widely used in Marib area, Sa'dah and Taiz causing an increase in the concentration of nitrate in ground water. Higher concentrations of some minerals such as sodium, chloride and fluoride appear in some areas like Taiz, Hadramawt, and Al-Dhala.

Social economic studies present that many people reached to more than 45% are working in agriculture. Most agricultural crop income is low except for Qat. Aquifers in all the districts are highly stressed by ground water abstraction for agriculture irrigation.

CHAPTER 3: METHODOLOGY

0.1 Selection of study area

This study targets 18 out of 23 sub districts of Mawyah districtin Taiz governorate (Assrar, Al-Thohra, Al-Shisha, Al-Kmaheda, Amaema, Asawda, Al-Owman, SharkiSwrak, Sa'elatSwrak, Swrak, Qrina, Maber, Kmaeda, KhlawatAkhrak, Maria, Khder Al-Burihi, Ogwa, Hwamera).Theremaining 5 sub districts were excluded as they are highly steep slope mountainous areas and therefore not easily accessible. The study area was chosen for the observed water quality and quantity deterioration.

0.2 Well inventory review

A well inventory in Mawyah district was reviewed to determine drinking water wells.Data were obtained from a study carried out earlier in 2009.Wells for water quality assessment were chosen according to following criteria:

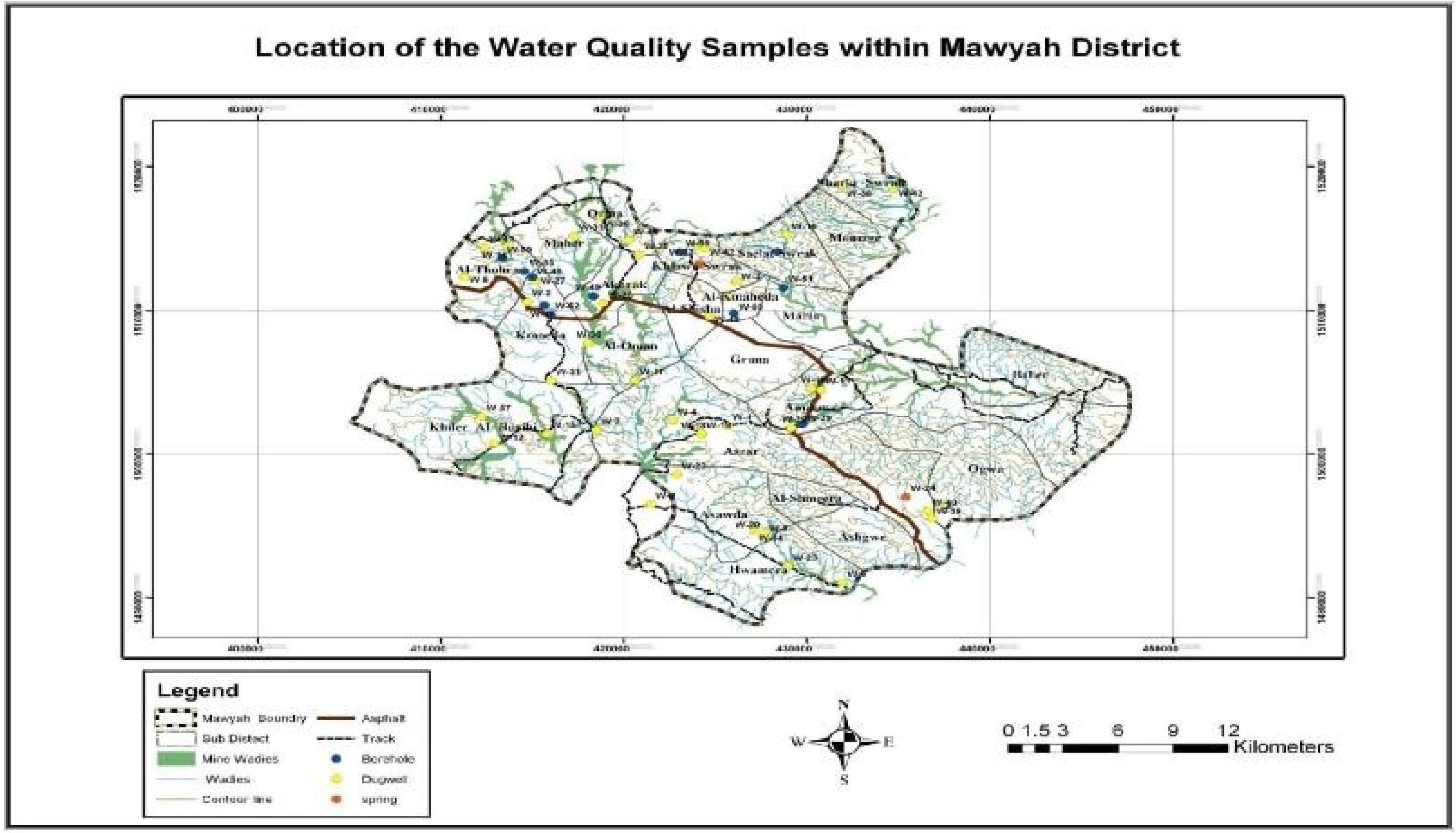
1. All boreholes are public water supply (projects of GARWSP).
2. All agriculture wells that are used as drinking water sources.
3. Wells that have operating pumps at present.
4. Wells of different depths to water levels.

5. Water samples from different depths of wells.

In the light of these criteria 57 water points out of the 282 drinking public and private water wells presented in the Mawyah well inventory study were selected. The 57 water points consist of 12 borehole wells, 43 dug wells and two springs (Table 1). The location of water points are shown in map 1.

Table 1: Selected water sources

#	Sub District	No. of Sampling Wells	Type of Source			#	Sub District	No. of Sampling Wells	Type of Source	
			Spring	Dug	Borehole				Dug	Borehole
1	Assrar	**8**	**1**	**7**	**0**	10	Al-Shisha	**1**	**1**	**0**
2	SharkiSwrak	**2**	**0**	**2**	**0**	11	Al-Kmaheda	**2**	**1**	**1**
3	Sa'elatSwrak	**2**	**0**	**2**	**0**	12	Maria	**1**	**0**	**1**
4	Swrak	**5**	**0**	**3**	**2**	13	Al-Owman	**2**	**2**	**0**
5	Qrina	**2**	**0**	**0**	**2**	14	Khder Al-Burihi	**3**	**3**	**0**
6	Maber	**1**	**0**	**0**	**1**	15	Amaema	**4**	**4**	**0**
7	Al-Thohra	**5**	**0**	**1**	**4**	16	Ogwa	**2**	**1**	**1**
8	Kmaeda	**6**	**0**	**6**	**0**	17	Asawda	**5**	**5**	**0**
9 #	Khlawat Akhrak	**4**	**1**	**3**	**0**	18#	Hwamera	**2**	**2**	**0**
Sub-Total		**35**				Sub-Total		**22**		
Total		57								



Map 1: Location of water quality samples within Mawyah district

0.3 Water sample collection

1. Samples were taken from wells either by pump or by bail.
2. Two liter polythene bottles were first rinsed with water from the source and then completely filled with water samples.
3. Sampling time, date, location, and number were recorded on a label, and attached securely to the sealed bottles.

0.4 Water quality assessment

3.4.1 On site

The purpose of making measurements in the field is for convenient rapid assessment and to provide control for laboratory measurements. The latter is important as the physical conditions of a sample may change between the time of sampling and the laboratory measurements. The parameters measured in the field were TDS, pH, and temperature using part of the Spectrum field instrument (DR-850).

3.4.2 In laboratory

After rapid field assessment water samples were transported to NWRA-Taiz lab for chemical analysis as shown below (Table 2):

Table 2: The chemical analysis parameters

Parameter	Reagent	Technique
T. Alk	the phenol phethalyn , methyl orange index and Hydrochloric Acid (0.02N)	**Titration**
TH, Ca	The buffer solution, EBT index and EDTA solution.	
HCO_3	T.A*1.22	**Calculated**
Mg	T.H-(Ca*2.5)/4.11	
Na K	Deferent concentration of sodium and potassium solution.	**Flame photometry**
Cl	Titration with AgNO3	**Spectral analysis**
SO_4	SulfaVer® 4 Sulfate Reagent	
NO_3	NitraVer®5 Nitrate Reagent	
F	SPADNS Reagent for Fluoride	
Fe	FerroVer®Iron Reagent	

0.5 Diagrams

Diagrams are tools used for classifying the analysis results with similar characteristics into homogenous groups. In this study Piper, Durov, and stiff diagrams were used.

3.5.1 Piper Diagram

The Piper diagram shows graphically the nature of a given water sample, and dictates the relationship to other samples. In Piper diagrams the concentrations are expressed as meq/l. Piper diagramswere plotted for ion concentrations to seven distinct hydrochemicl facies (water type) to identify the water type of samples under study based on Langguth (1966) classifications namely:

- Normal earth alkaline water with prevailing bicarbonate.
- Normal earth alkaline water with prevailing bicarbonate and sulfate or chloride.
- Normal earth alkaline water with prevailing sulfate or chloride.
- Earth alkaline water with increased portions of alkalis with prevailing bicarbonate.
- Earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride.

- Alkaline water with prevailing bicarbonate.
- Alkaline water with prevailing sulfate or chloride.

The Rockwark 2004 software program was used to plot the samples in this study.

3.5.2 Durov Diagram

This diagram has advantages over the Piper diagram because it reveals some geochemical processes that could affect groundwater genesis.

A summary about the theory behind the divisions in the diagram is given (Lloyd and Heathcoat, 1985) below:

- Field (1): HCO_3 and Ca dominant, frequently indicates recharging waters in limestone, sandstone, and many other aquifers.
- Field (2): This water type is dominated by Ca and HCO_3 ions. Association with dolomite is presumed if Mg is significant. However, those samples in which Na is significant, an important ion exchange is presumed.
- Field (3): HCO_3 and Na are dominant, indicates ion exchanged water, although the generation of CO_2 at depth can produce HCO_3 where Na is dominant under certain circumstances.

- Field (4): SO_4 dominates, or anion discriminant and Ca dominant, Ca and SO_4 dominant, frequently indicates a recharge water in lava and gypsiferous deposits, otherwise a mixed water or water exhibiting simple dissolution may be indicated.
- Field (5): No dominant anion or cation, indicates water exhibiting simple dissolution or mixing.
- Field (6): SO_4 dominant or anion discriminate and Na dominant; is a water type that is not frequently encountered and indicates probable mixing influences.
- Field (7): Cl and Na dominant is frequently encountered unless cement pollution is present. Otherwise the water may result from reverse ion exchange of Na-Cl waters.
- Field (8): Cl dominant anion and Na dominant cation, indicate that the ground waters be related to reverse ion exchange of Na-Cl waters.
- Field (9): Cl and Na dominant frequently indicate end-point waters.

The major ion concentrations of groundwater samples were plotted on Durov diagram using "Aquachem" software.

3.5.3 Stiff Diagram

Stiff diagrams (Hem, 1985) are constructed by recalculating the analysis in meq/l and then plotting anions and cations on three axes. The advantages of Stiff- diagram are dual. Firstly, different shapes which are recognized at first glance. Secondly, the absolute concentrations are visualized by the width of the figure (Appelopostma, 1993).

Stiff diagram is used for representing chemical analysis by parallel axes. Concentrations of cations are plotted to the left of a vertical zero axes and anions to the right; all values are in meq/l. the resulting points, when connected, form an irregular polygonal pattern; waters of similar quality define a distinctive shape (Todd, 1980).

Stiff diagram shows

Na + K in the first line (left), Ca in the second line (left)

Mg in the third line (left) , Fe in the fourth line (left)

Surface area of visual figure represents the total salinity of the sampleif total cations and total anions are in balance the left area and the right area should be equal.

The samples were plotted on stiff diagram using “Aquachem” software.

0.6 Socio-economic study

Well constructed questioners were prepared to evaluate IWRM aspects related to water impacts on the population (**annex 1)**The evaluation of the IWRM was done based in two types of study:

1. Face to face
2. Distribution of questioners

3.6.1 Interviews

Face to face interviews were conducted with the decision makers of the:

1. Health office in Mawyah district,Taiz governorate.
2. Local Corporation (LC) /Taiz governorate.
3. General Authority for Rural Water and Sanitation Projects (GARWSP) /Taiz governorate.
4. National Water Resources Authority (NWRA)/Taiz governorate.
5. Yemen Standard Authority.
6. Public Work Office.
7. Social Fund Development project.
8. Water and Sanitation and Local Cooperation.
9. Water Users Associations.

In total 14 interviews were done, 8 with the decision makers in Taiz, and 6 with the decision maker in Mawyah district. The interviews aimed to identify the cause of the problem, current mitigation methods, and proposed long term solutions.

3.6.2 Questionnaires

The questionnaires collected from 180 adults (men/ and women) and children at ages 7-18 years that used the selected sampling wells. The total number of the questioners divided equally among the wells sampled. Questioners that targeted interviewers how do not read and write were filled by the surveyor (Table 3).

Table 3: Group target and numbers

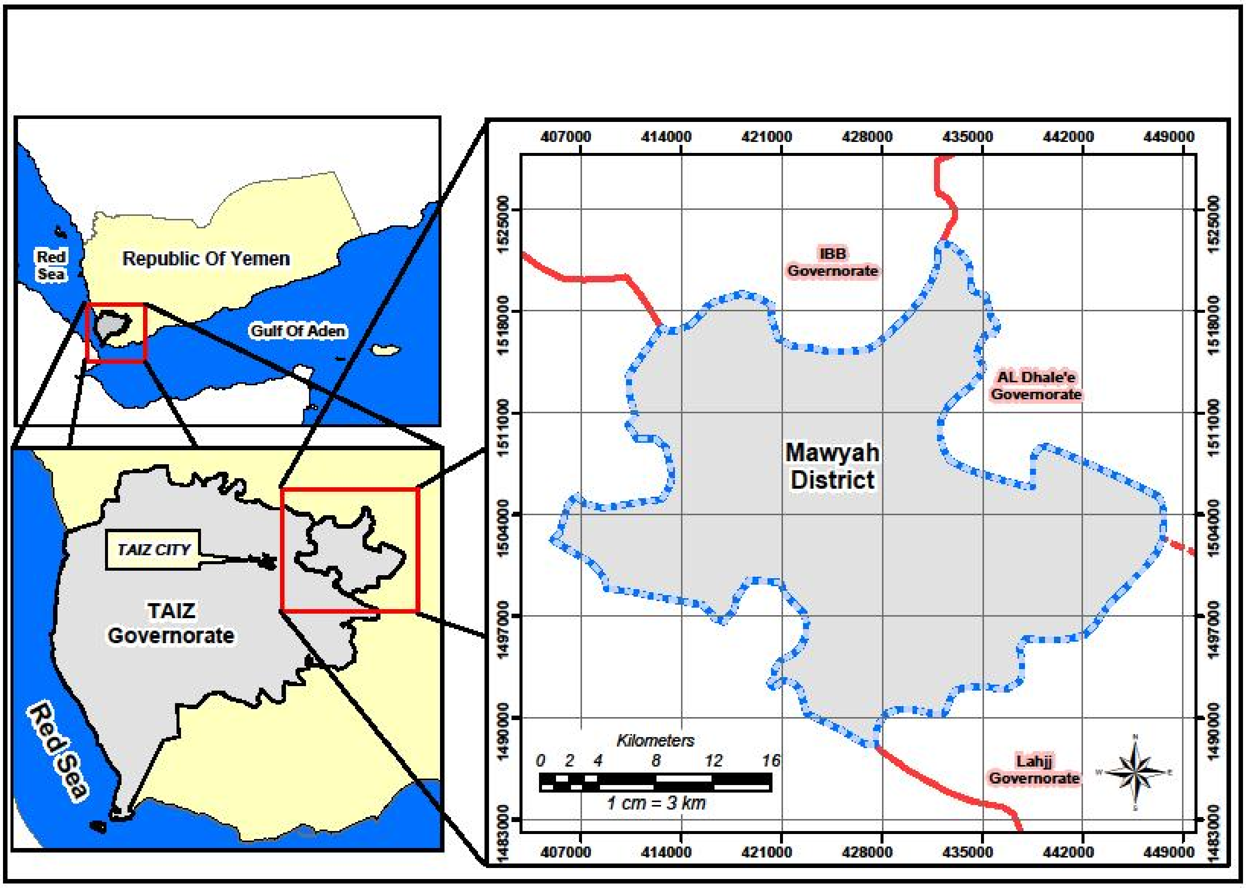
Group Target	Number of questioner or interviews	
	Female	Male
7 -10	10	10
10 -15	24	12
15-20	18	16
20-25	14	6
25-30	10	13
30-35	8	5
35-40	1	12
40-45	8	1
45-50	5	4
50-60	2	1

CHAPTER 4: Background of the Study Area

4.1 Location

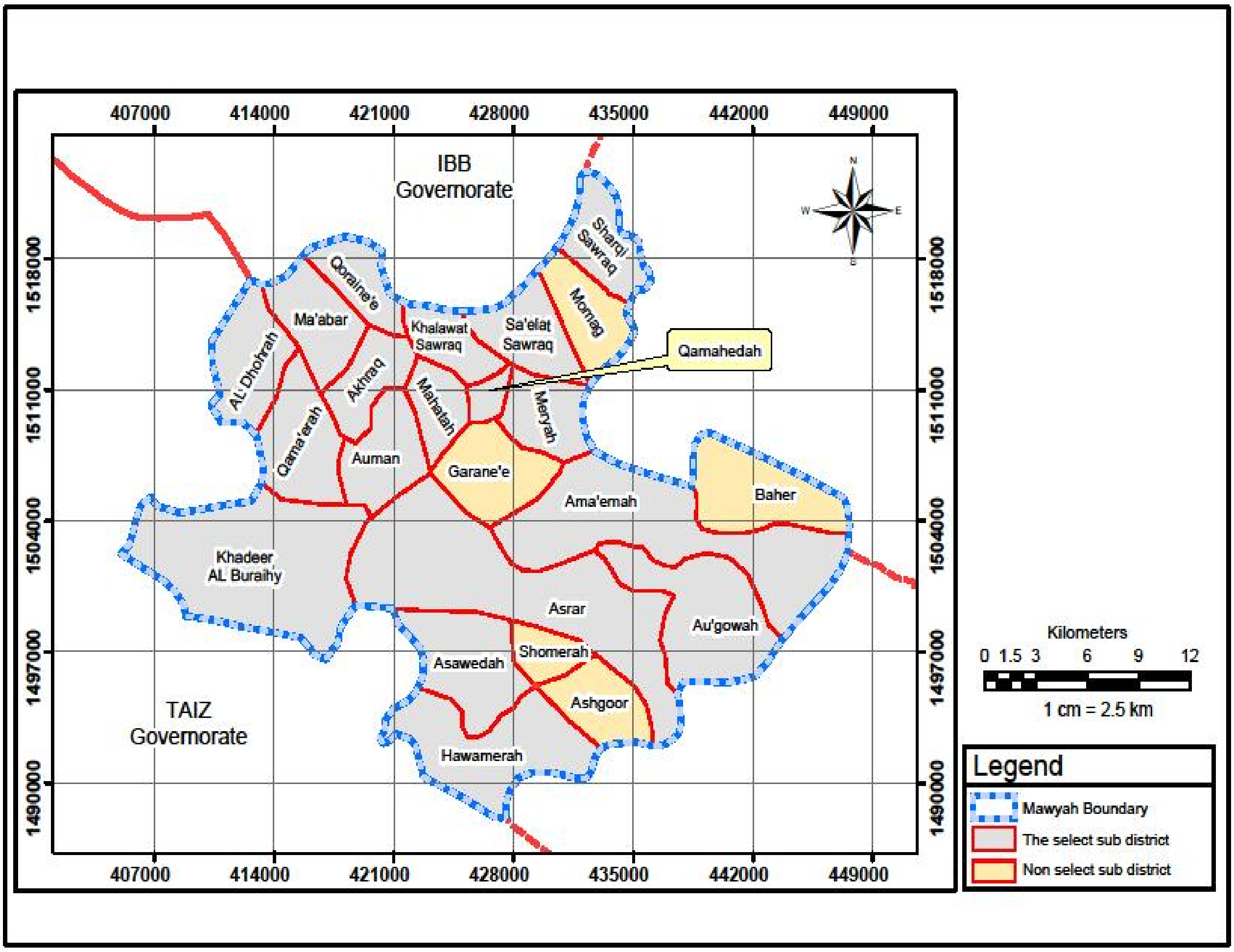
Mawyah district is one of the 23 districts in Taiz governorate. The district is located between longitudes of 133000, 134500 meast, and latitudes of 441500, and 444500 m north. It is bordered by Al Seprah, and Al Syani districts in Ibb governorate from the north, Kadeer, and part of Tuban districts (lahj governorate) from the south, part of Al husha (al Dhala governorate(, Tuban district (in Lahj governorate from the east, and Al Tazziah district from the west.

Map2: The location map of Mawyah District.



4.2 Area and population

The area of Mawyah district is about 670 km^2. The population is about 131716(CSO, 2004). It consists of 23 sub districts named Assrar, Al-Thohra, Al-Shisha, Al-Kmaheda, Amaema, Asawda, Al-Owman, SharkiSwrak, Sa'elatSwrak, Swrak, Qrina, Maber, Kmaeda, KhlawatAkhrak, Maria, Khder Al-Burihi, Ogwa, Hwamera, Momag, Garane'e, Baher, Shamerah, Ashgoor.This study was carried out in only 18 sub districts. Five sub districts were excluded because they are highly steep slope mountainous area.



Map 3: Sub districts of Mawyah.

4.3 Topography of the study area

Topography of the district can be divided into several units with different topographic features as follows:

4.3.1 Mountainous areas

Mountains occupy a large part of the total study area. Consist the Sawraq mountainous which covers the northern part of the study area with an elevation up to 2720 meters above sea level,Ama'emah , Hawamerah, and Garane'e mountains constitute the southern and eastern part of the study area with an elevation up to 2120 meters above sea level.

4.3.2 The hills and volcanic plateaus

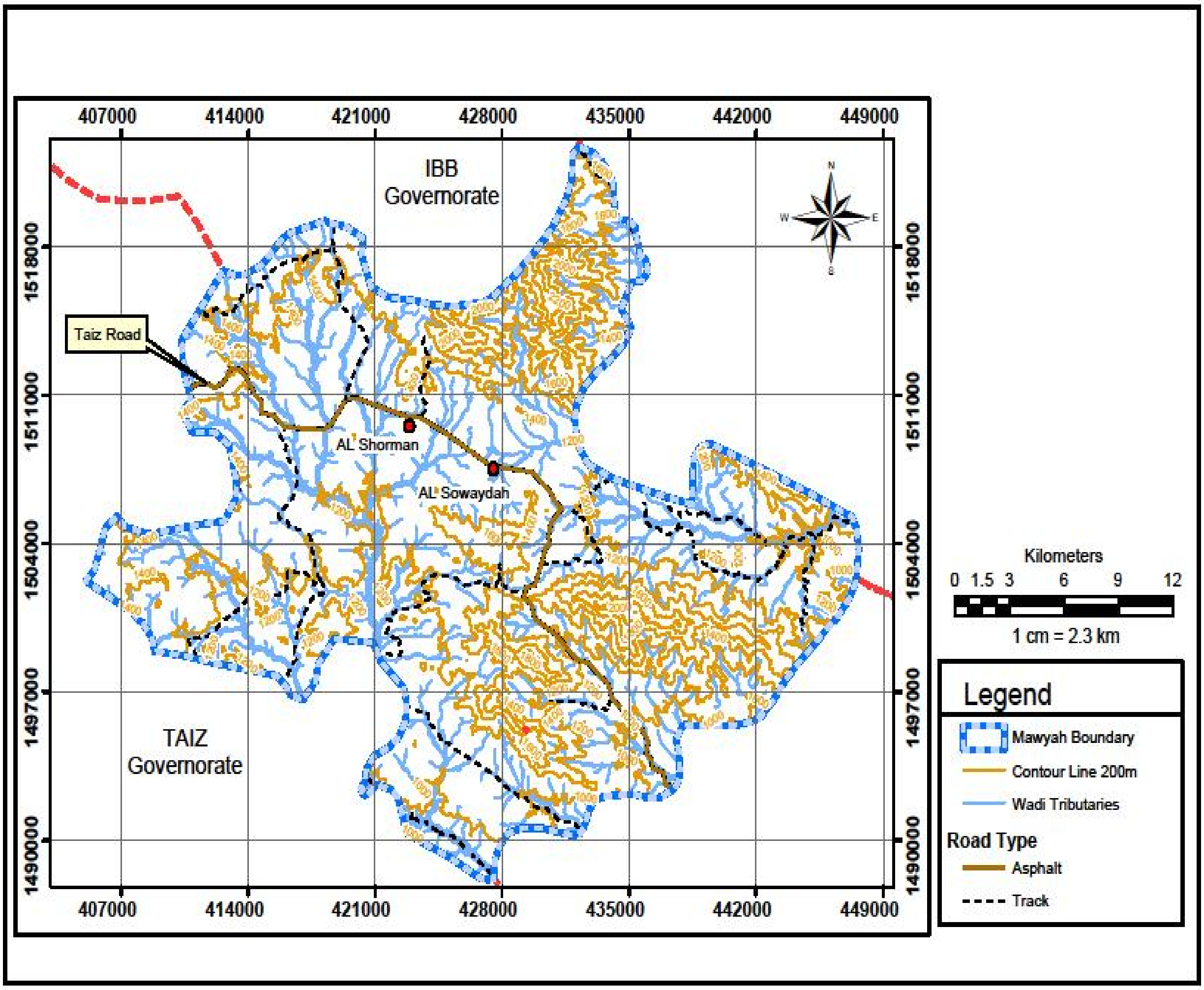
These are more prevalent in the western, to south-western and southern parts of Mawyah.

4.3.3 The Wadies

Qa'admm is the most important basin in the study area. It is surrounded by Sawraq mountain ranges from the north,Garane'e mountain from the south, and volcanic hills and plateaus from the west and east.

The main road in Mawyah cuts the Qa'admm basin into two parts. The northern part flows into the east and the southern part flows into the west.

The Kholbanwadi is a low land with a limited area. it's surrounded by alluvium plateau from the south and mountains from the north.Some Small wadis also cross the mountains, plateaus, and hills. The most important wadies are Al-Saudan, Al-Lassab, Akhrak, Sawraq, Al-Damoom, Al Khawelef, and Al Haribah.



Map 4: The Topographical map of Mawyah District

4.4 Geology of the study area

The geology of the study area has not been studied on a larger scale. Specific information about geological characteristics were derived from 'The Robertson Map' that puts emphasis on the lithology and was created mainly on the basis of satellite imagery with very limited field work, (Map 5) and from water points inventory report (NWRA,2010).

Generally, the geology of the study area can be described simplistically as follows:

4.4.1 lithostratigraphic units

The lithostratigraphic sequence of study area comprise mainly Cenozoic era rocks furthermore Precambrian complex only in subsurface.

Actually, an area subjected to long periods of hiatus and result that the lithological variety is so limited.

The stratigraphy of the study area is from oldest to recent as below:

Precambrian basement rocks

This rock unit hasn’t outcrops at ground surface in study area but based on subsurface data that reveal the presence of basement rocks especially within the central part of study area represented with wadi Qa’adam (NWRA drilling reports,2006-2010).

The subsurface basement rocks have been encountered at depths between 450 and more than 600 m. They are fractured and thus slightly water productive.

Tertiary Volcanic Group

The tertiary volcanic group is the dominant lithological unit outcropping over the most part of the study area especially in the southern, western and north easternparts. They form waved plateaus, sharp hills and mountains such as theAmma'amahSeries extending from east to west. This group was created under the influence of the tectonic uplift and movements at the end of the Mesozoic era that extended throughout most of the Cenozoic. These tectonic movements were accompanied by intense volcanic and intrusive activity. The tertiary volcanic group consists mostly of basalt, and sites porphyries and somewhere alternating by bedded different types of tuffs and also comprises at short scale Ryolite and Trachyte.

The surface case of this group differs from place to another but is mostly fractured and Tuff rocks are high weathering. In the subsurface sequence,it underlies the quaternary alluvial deposits in the central part of the area as has been confirmed by lithological well data (drilling reportsNWRA,2006-2010). This group is important major aquifer in the study area.

Granitic intrusions

The granite rocks unit covers about 20% of the study area and its outcrops spread exactly to the north of the central part. It formed consequently SawraqMountain. This unitwas subjected to post intensive tectonic movements resulting in to many fracturing systems found in subsurface and intercalated by volcanic rocks. The fractured granite is considered as the minor groundwater reservoir especially in Miryah and Aljounyedvillages.Furthermore many spring.

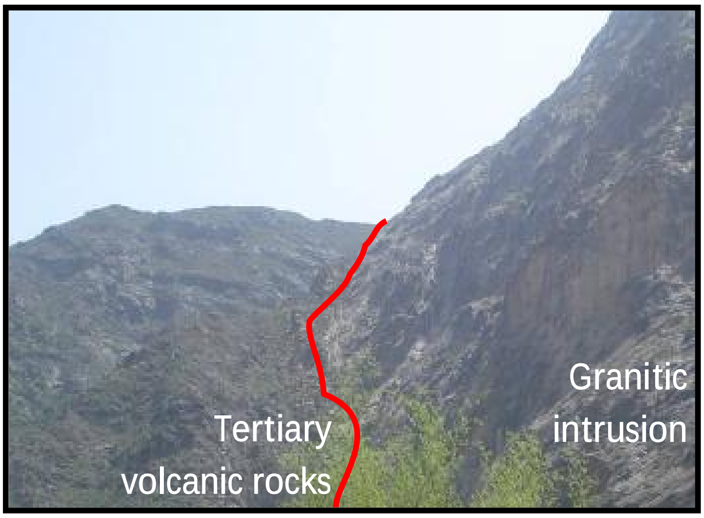


Photo 1 Sharp contacts line between Granitic intrusion and tertiary volcanic rocks.

Quaternary Alluvial Deposits

It consists of alternating coarse grained horizons (mainly silty sand and gravel) and very fine-grained horizons (mainly silty sand and silt). It has a thickness of 15-60 m and overlies the Tertiary volcanic group. These deposit mainly the eastern part and interior wadis.

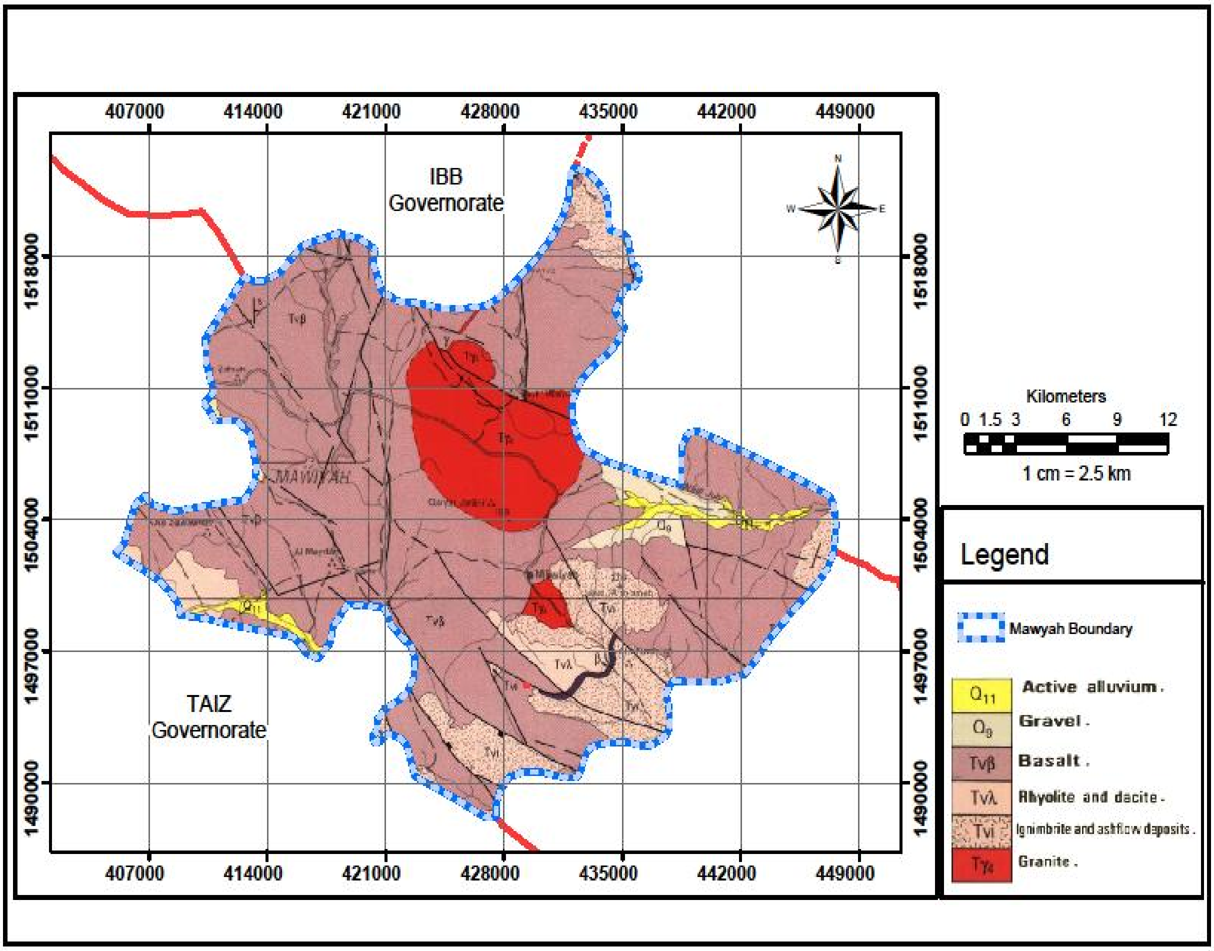
Even though, this unit was considered as a good water resource at the past periods but it became depleted recently.

Photo 2 Alluvial deposits outcrop in western part.

4.4.2 Surface Structures

The study area is subjected to extremely tectonic activities therefore the structural setting is very complicated. According to geological map (Map 5), the main structural elements of the study area are dominantly faults as well as joints and both of them play a major role in the geological and hydrogeological characteristics and the geomorphologic form. The most fault systems are recognized as:

- **NW-ES faults**: these resulted in the Qa'adam depression and some valleys in the western part. This type of faults is running almost parallel to red sea.
- **W-E faults:** Includes most valleys in the study area.



Map 5: **The Geological map of Mawyah District**

4.5 Hydrology of the study area

4.5.1 Surface water resources

Rain water is the main water source in the study area. Table (4) presents monthly measured rainfall data (mm) collected from automatic rainfall station in Mawyah district. The station is located on the roof of Mawyah

Local Council building. It is located at the last point of the main asphalt road of Mawyah.

Table 4: The rainfall in mm

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2006*	-	-	-	-	-	-	-	-	27.2	16.0	0.0	34.6	77.8
2007**	3.4	0.0	4.2	4.4	8.6	1.6	16.4	10.6	11.2	0.2	0.0	5.5	66.1
2008	0.3	0.0	0.0	0.0	82.0	46.0	111.3	26.8	72.3	0.0	0.0	0.0	338.7
2009	0.0	0.0	9.8	21.6	17.8	44.5	74.3	120.7	56.0	6.0	0.0	0.0	350.7
2010	0.0	11.8	40.3	47.8	53.8	65.5	45.3	120.0	208.0	18.5	0.0	0.0	611

* Construction year.
** Incomplete data (Battery of memory is not working).
- missing data.

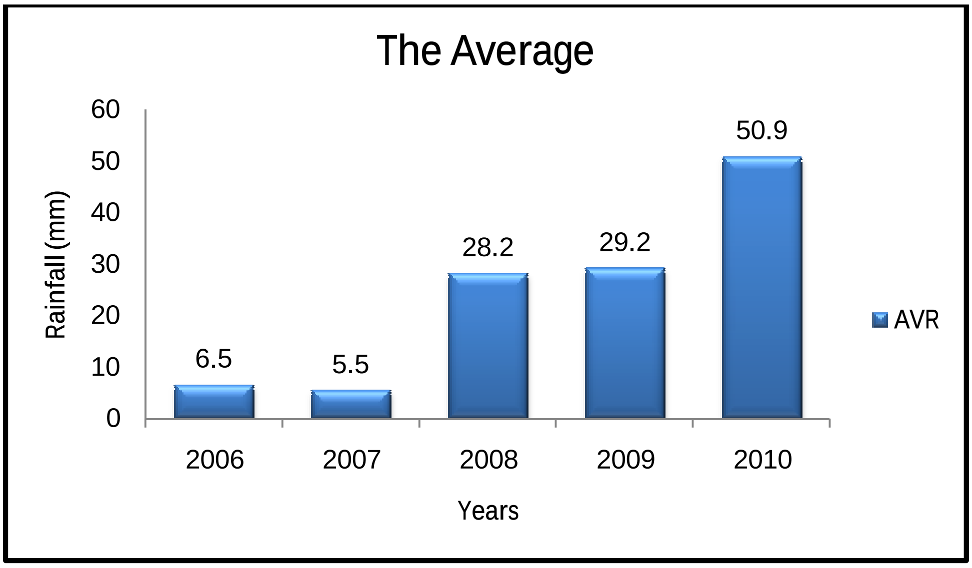


Figure 1: The average rainfall in Mawyah District from (2007-2010)

Many springs are found in the study area there are like Al-mssrab and Al-Thar Figure 1 The average rainfall in Mawyah District from (2007-2010) in Oshari Wadie. Many seasonal small low productive springs are located in the southern mountains. Baseflow alsoappears with seasonal low production such as Al Khawileef and Al Rakabwadies.

4.5.2 Surface water structures

In the study area the governorate of Taiz has built three small dams. Al-dammom damthat is located in the west of Mawyah district between longitude of 1504008m east, and latitude of 410170 m north with design storage capacity of 160,000 m^3. Al-khaliv dam that is located in the south of Mawyah district between longitude of 1493572 m east, and latitude of 424987 m north with storage capacity of 170,000 m^3.Al Rukiab dam that is located in the west of Mawyah district between longitude of 1509090 m east, and latitude of 413442 m north.

4.6 Hydrogeology of the study area

Four ground water aquifers are identified from the well drilling in Mawyah district, the alluvium aquifer, fractured granite aquifer, fractured volcanic aquifer, and the upper part of basement complex rocks. The present drilling depths of wells exceeded 800 m in Mawyah district especially in the fractured volcanic aquifer. The aquifers can be described from the newest to oldest as follows:

4.5.1 Alluvium aquifer

Alluvium aquifer presents the upper parts of the wadies bed and the plateau. The main hydrogeological characteristics of the aquifer in Mawyah district are small - in both depth and space – isolated scattered aquifer. The thickness of the aquifer can reached to 80m in some places. Most of the aquifer thickness is already dry. In some parts during the dry season water in the aquifer appears as small stream flow at the most bottom of the aquifer. The aquifer is highly affected by rainfall and flood as recharge and pumping as abstraction during each year. This type of aquifer could be found in Al Khazagah, Allssiab, and Al Khawilif. In Kaadmm, Mariah, BaneeObidan, Akhrak, and allssap as dry aquifer.

4.5.2 Fractured granite aquifer

The aquifer has located in many parts of Mawyah district. Well drilling activities identify the aquifer in different places such as Muriah, and Al Juniad. The water is manly found in the fractures of the granite.The depth of the wells in the graniteexceed 300 m in some areas. The production of the aquifer is low with less than 3 l/s.

4.5.3 Fractured volcanic aquifer

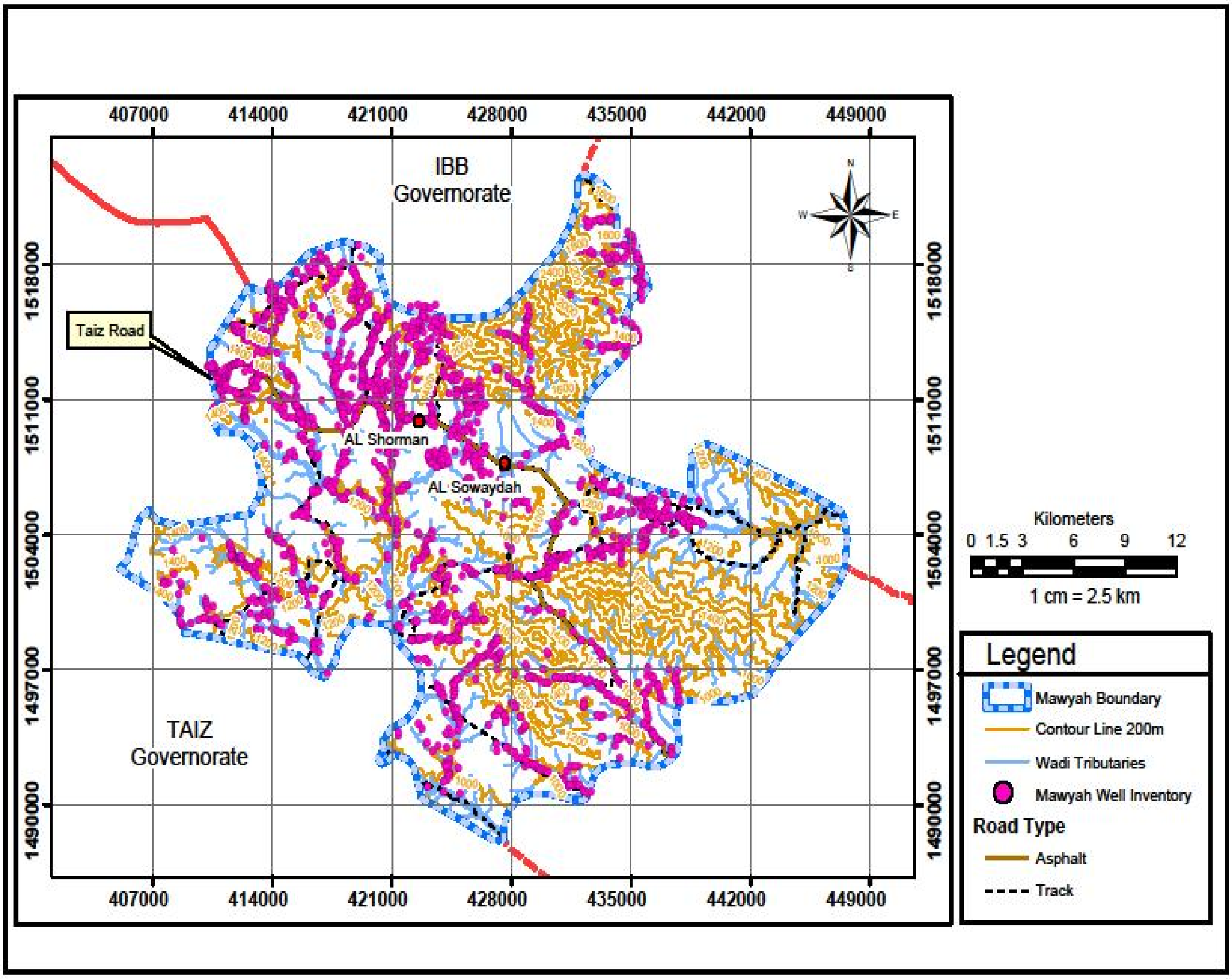
The fractured volcanic aquifer is found in many areas in Mawyah district. Water in volcanic is found in the fractured or caves only. The productivity of the aquifer is low. It is not exceeding 5 l/s. The water quality is low with an EC exceeding 2000µS/cm. The depth of the wells in the volcanic reached between 200 to 300 m.

4.5.4 The upper part of basement rocks

Water have been found in the upper part of the basement in the contact with the volcanic or granite. This contact is called the basement aquifer. The weathered surface of the upper part of the basement and the lower part of the upper formation give chance to form an aquifer in the basement.

Water wells

National Water Resources Authority Taiz branch conducted water point survey in Mawyah district in 2009. The survey covered most of Mawyah district except small areas of the high land in the south eastern part of the district. The survey covered 2433 water points as dug wells, drilled wells, and springs. Most of the drilled wells are dry or very low production. The dug wells are highly affected by rain as positive effect as recharge and negative effect as pumping. The spacing between wells are very small in some areas could reached to 100 or 50 m. The survey water points are appears in Map (6) below.



Map 6: The well inventory map of Mawyah District

4.7 Water points

4.7.1 Number and type of water points

Around 89% of water points in Mawyah are dug wells, 10% boreholes, and the rest (dug/borehole, springs, others) 1%. All the dug wells are in the alluvium shallow aquifer. It is excavated by hand. The alluvium aquifer is a main aquifer affected highly by recharge from rain and flood. The dug wells are spread in Assrar, Amaema, Asawda, Al-Owman, SharkiSwrak, Sa'elatSwrak, Swrak, Qrina, Maber, KhlawatAkhrak, Khder Al-Burihi, Ogwa, Hwamera, Momag, Baher, Shamerah, Ashgoor and parts ofAl-Thohra, Al-Shisha, Al-Kmaheda,Kmaeda, Maria sub districts.10% of water point are berhole wells and spread in parts of Al-Thohra,Al-Shisha, Al-Kmaheda, Kmaeda, Maria sub districts. The rest 1% of water point are springs, dams and rainfall water harvesting storage.

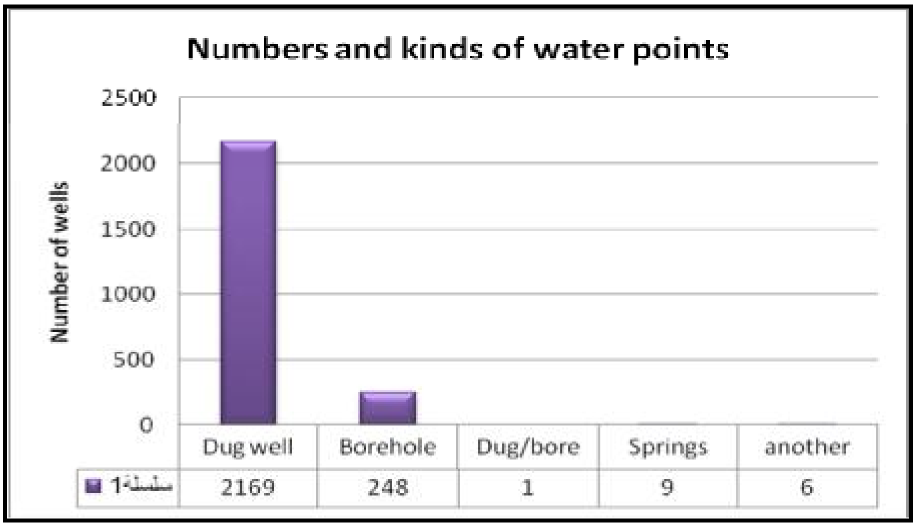


Figure 2: Numbers and kinds of water points in Mawyah District

4.7.2 Water use in Mawyah district

The different kinds of water resource are a result of the geomorphological contrast in the study area. Groundwater is the main water source in Mawyah districts except in the south eastern high mountainous areas of Mawyah districts. The mountainous areas depends on rainfall water harvesting.

Irrigation use

Qat is main groundwater irrigated crop all over Mawyah districts except in the mountainous areas. In the mountainous areas irrigation depends on rainfall and floods. The main irrigated crops are sorghum, millet, wheat and small areas of qat.

Domestic use

Only12% of the wells in the district are used for domestic purposes Women use donkeys to transport water from the source to the house.

Photo 3 Women and children transport the domestic water

People in the mountainous areas construct water tanks for rainfall harvesting. Rainfall water harvesting mainly used for drinking prepossesses. Most of the rainfall harvesting tanks is constructed with the support of SFDP.

Photo 4 Exclusive rainfall storage

CHAPTER 5: Results and Discussion

5.1 Electrical Conductivity (EC)

The electrical conductivity (EC) is a measure of the total salt content of water based on the flow of electrical current through the sample.The higher salt content, the greater the flow of electrical current. The EC is the reciprocal of resistivity (- R-) and is reported in mS/cm or µS/cm. Since the EC and TDS are measurements of the total salt content, they must be directly proportional.

The correlation between these two parameters for the analyzed samples in this study was plotted in Figure 3, which demonstrates a linear correlation with a mathematical approximation of TDS (mg/l) = 0.56* EC (µS/cm).

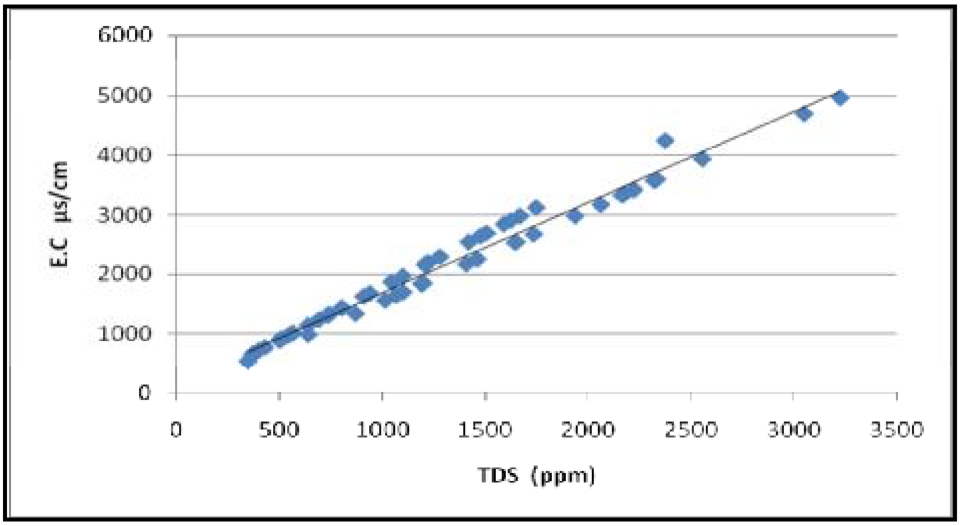


Figure 2: The relation between the EC and TDS values of water samples

The EC values vary between 538µS/cm and 4960 µS/cm in Mawyah District with an average of 2110µS/cm.

Comparing between the analyses results and the Yemeni Drinking Water Quality Standard shows that 36.8% of all samples exceeded the allowed standard value (Fig 4).

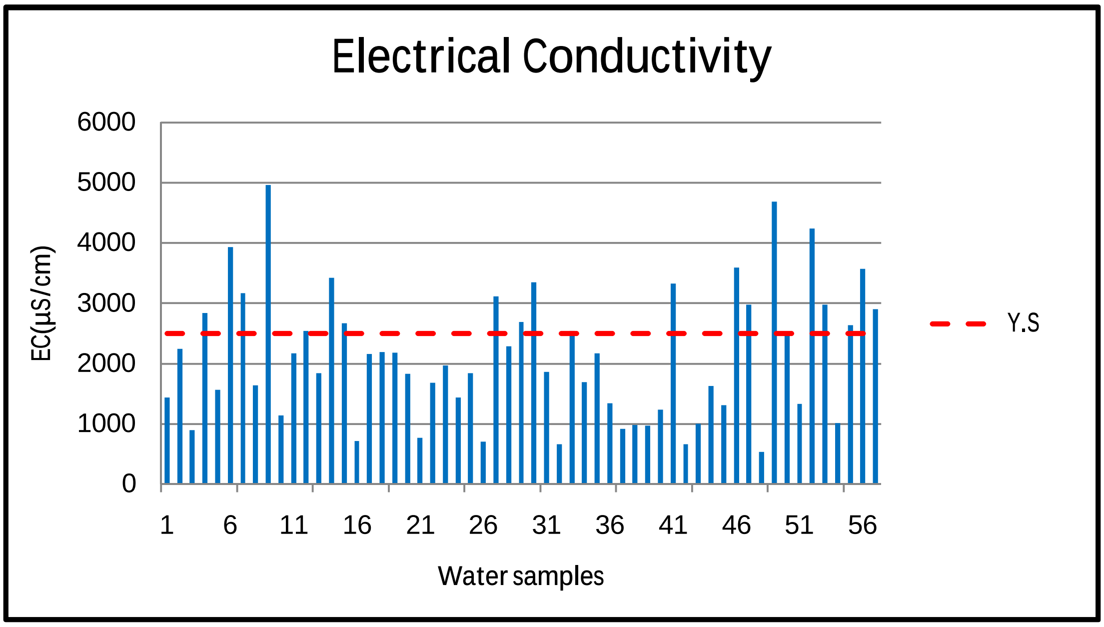
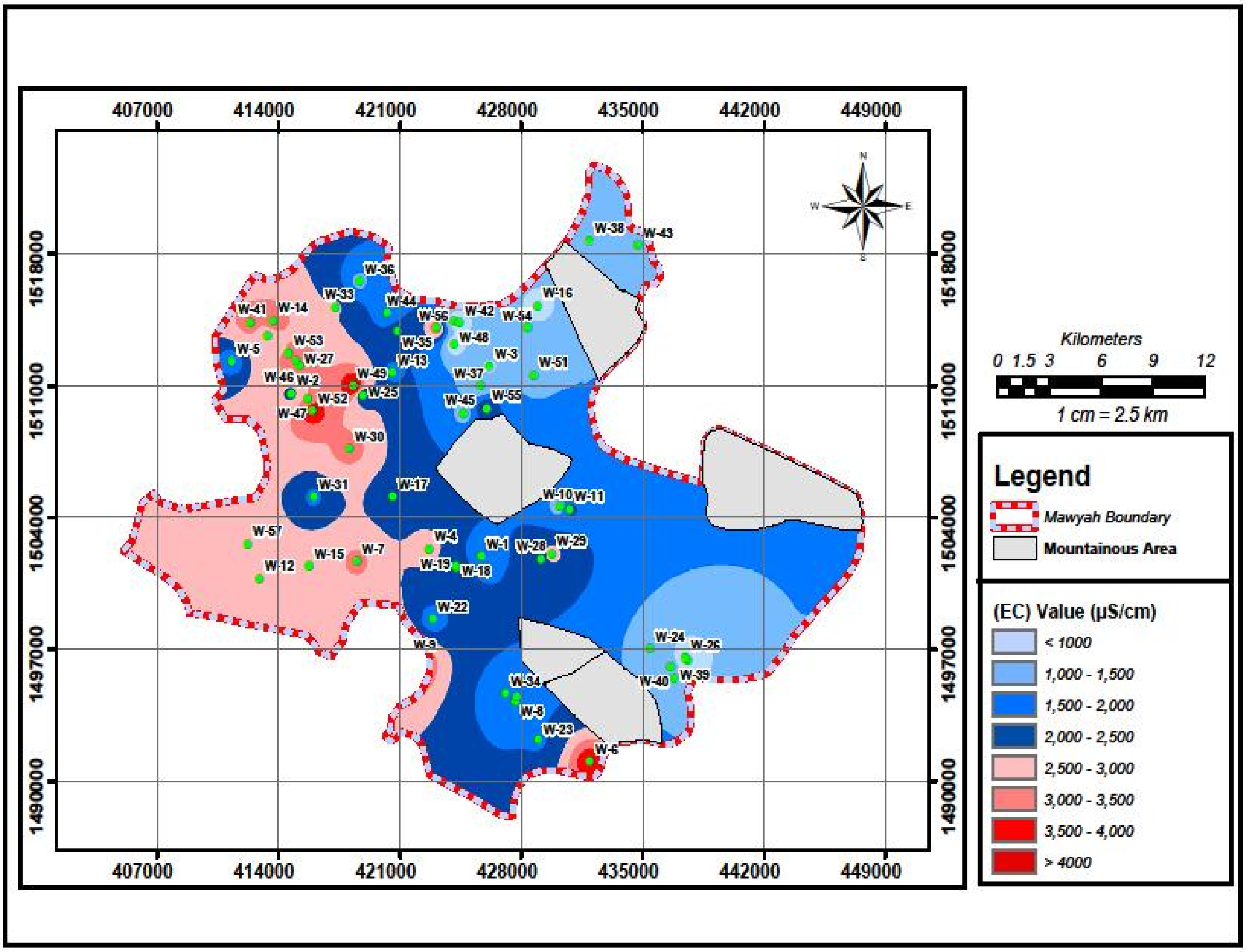


Figure 3: The comparison between the EC analyses result and the Y.S

The highest EC values are found in the western part of Mawyah district at Khder Al-Burihi,Kmaeda, Al-Thohra sub districts, and parts of Hwamera, Asawda, Maber, Akhrak, Assrar, Al-Owmansub districts.

The high EC is due to high stress limited groundwater source highly affected by recharge and abstraction. High abstraction of the limited groundwater in the shallow aquifers concentrates high salts in the wells. Pollution flows into the wells from the surrounding areas of the wells effects in the high salinity of water. Irrigation by high salinity water transported by tankers increase the salinity of land that is leaching into ground water by recharge from rainfall.



Map 7 : Electrical Conductivity Distribution in Mawyah district

5.2 **Hydrogen - Ion Concentration (pH)**

The pH is defined as the negative logarithm to the base 10 of the hydrogen ion with the full pH scale ranging from 1to14.

Water with PH value of 7 at 25^{o}C is called natural water. Excess of hydrogen ions (H^+) indicates acidic water with a corresponding pH value lower than 7. Conversely, an excess of hydroxyl ions (OH^-) indicates alkaline water which has a pH value greater than 7.

The degree of precision of pH measurements, however, requires attention to electrode maintenance, buffer solutions, and temperature.

In the sub districts under study, the pH varies between 6.85 and 8.34 with an average of 7.6.

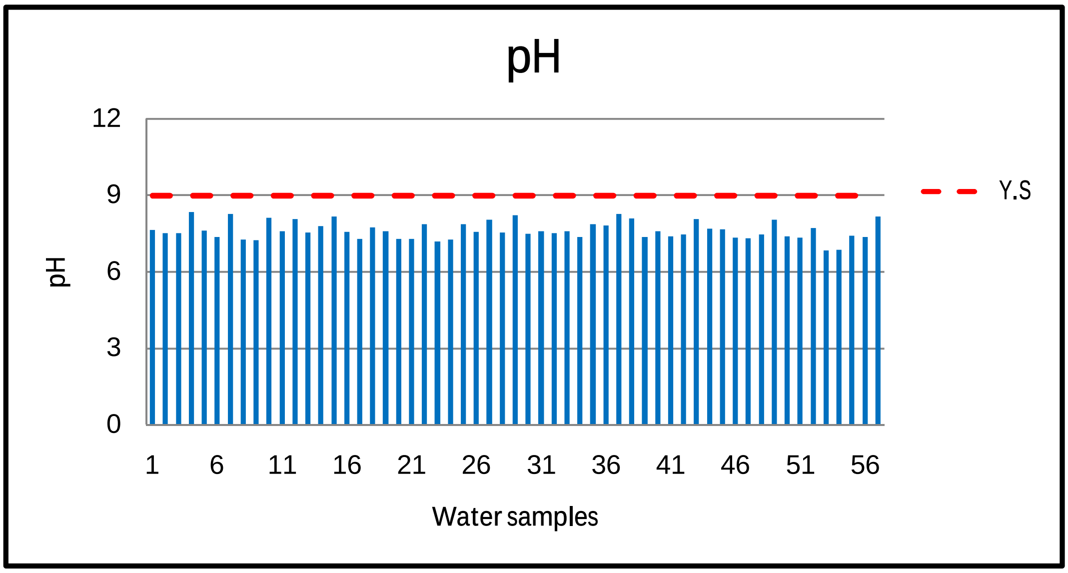
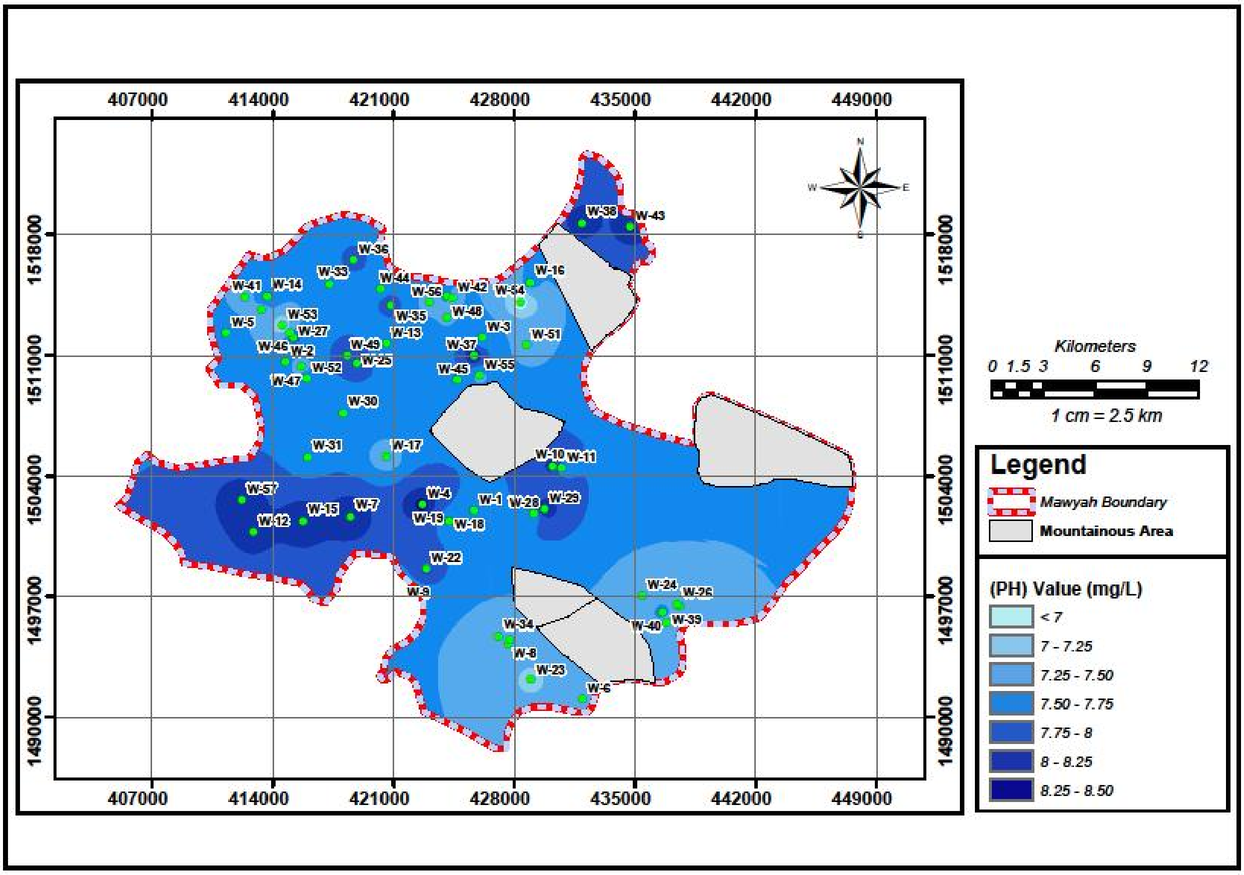


Figure 4 : The pH values of water samples

Map(8) indicates that alkaline water was found at meddle parts of the center, north, and south west of Mawyah districts. It is found inSharkiSwrak, Amaema,Khder Al-Burihi sub districts, and parts of Akhrak, Assrar,Qrina sub districts. This reflects the high pollution around the open dug wells.



Map 8: pH values in Mawyah district

5.3 Total Hardness (TH)

The total Hardness (TH) is conventionally expressed as the total concentration of Ca and Mg (mg/l) equivalent to $CaCo_3$ and associated with water type. It commonly makes soap difficult to rinse and causes scaling in boilers and kettles. Water is designated as being soft or hard if its hardness is less than 60 mg/l or greater than 180 mg/l respectively (Hem, 1985). However this classification is not practical for use. NWRA has set 500 mg/l as the maximum permissible limit for total hardness in (Yemen S, 1999).

In the study area the Total Hardness values in the samples analyses range between 210 and 1257 mg/lwith an average of 537mg/l

The comparison between the analyses resultsand the YDWQS and WHO shows that46% of the samplesexceed the standard

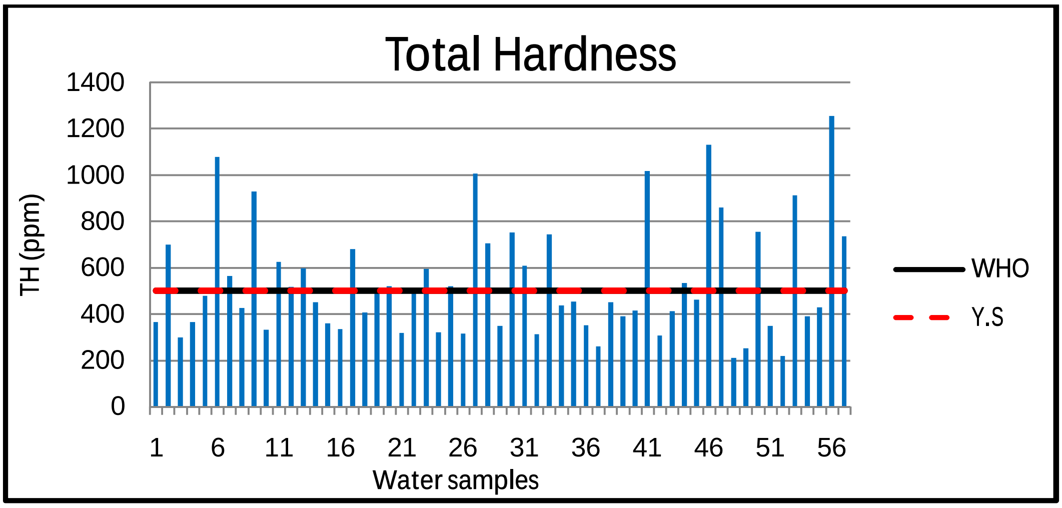
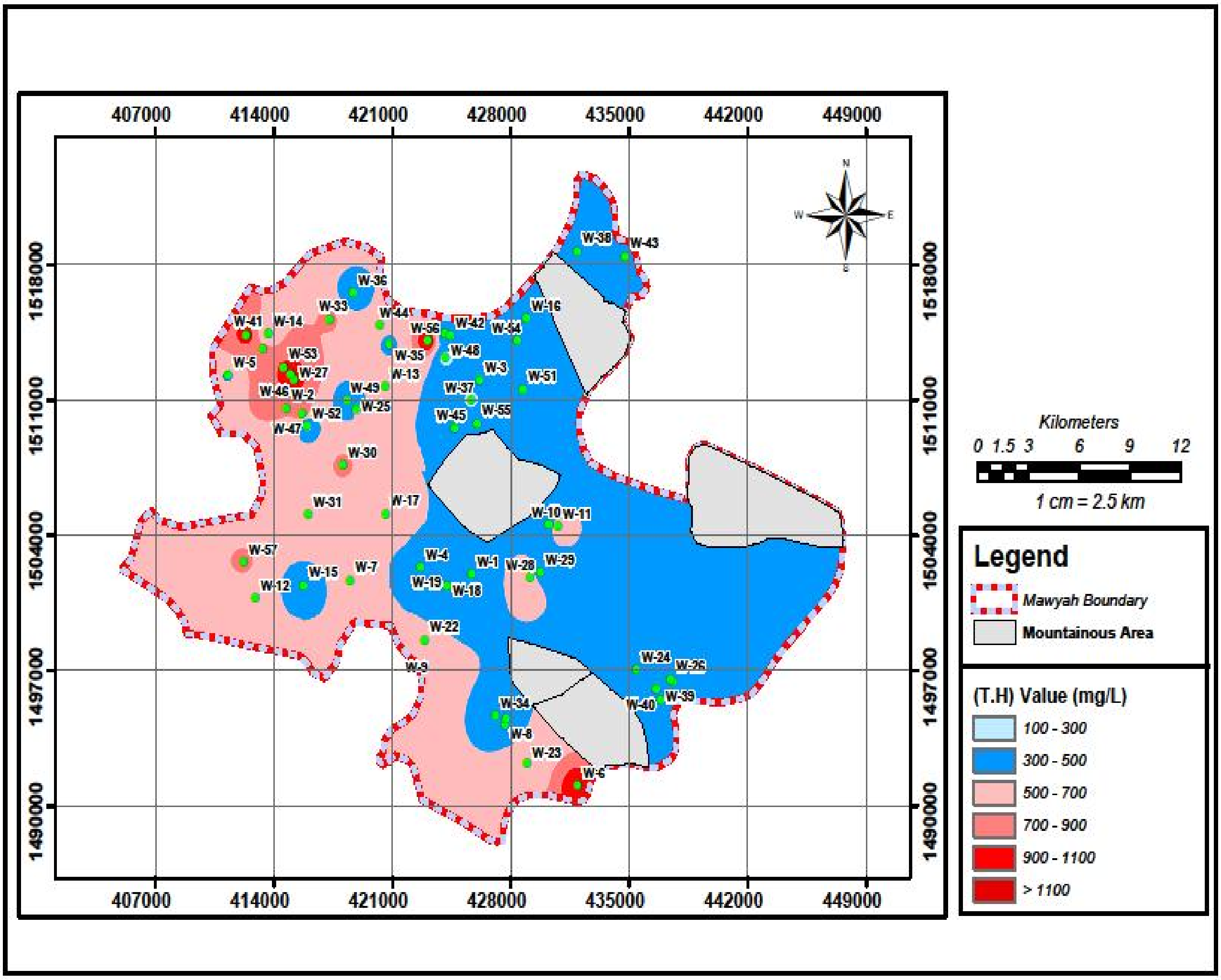


Figure 5 : The comparison between the TH analyses result and the Y.S, WHO



Map 9 : **Total Hardness Distribution in Mawyah district**

Map (9) indicates that the western half of Mawyah has hard water while the eastern part has a moderate hardness, and increase the concentration of Ca and Mg salts.

5.4 Total Dissolved Solids(TDS)

The TDS value is equal to the total amount of positive ions (cations) and negative ions (anions) in addition to other materials.

In the study area the TDS value of water samples range between 349.7 – 3224 ppm with an average value of 1286 ppm this indicates that increas the dissolved solids.

Fig (7) shows that 33% of the total samples exceeds the permissible limit of 1500 ppm and 1000 ppm according to YDWQS and WHO respectively.

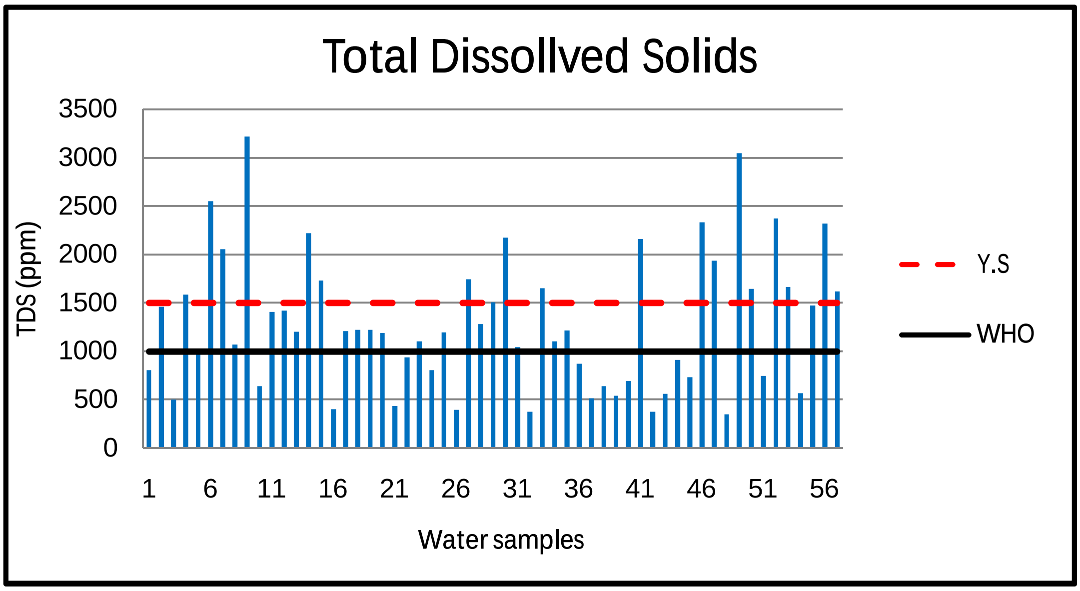
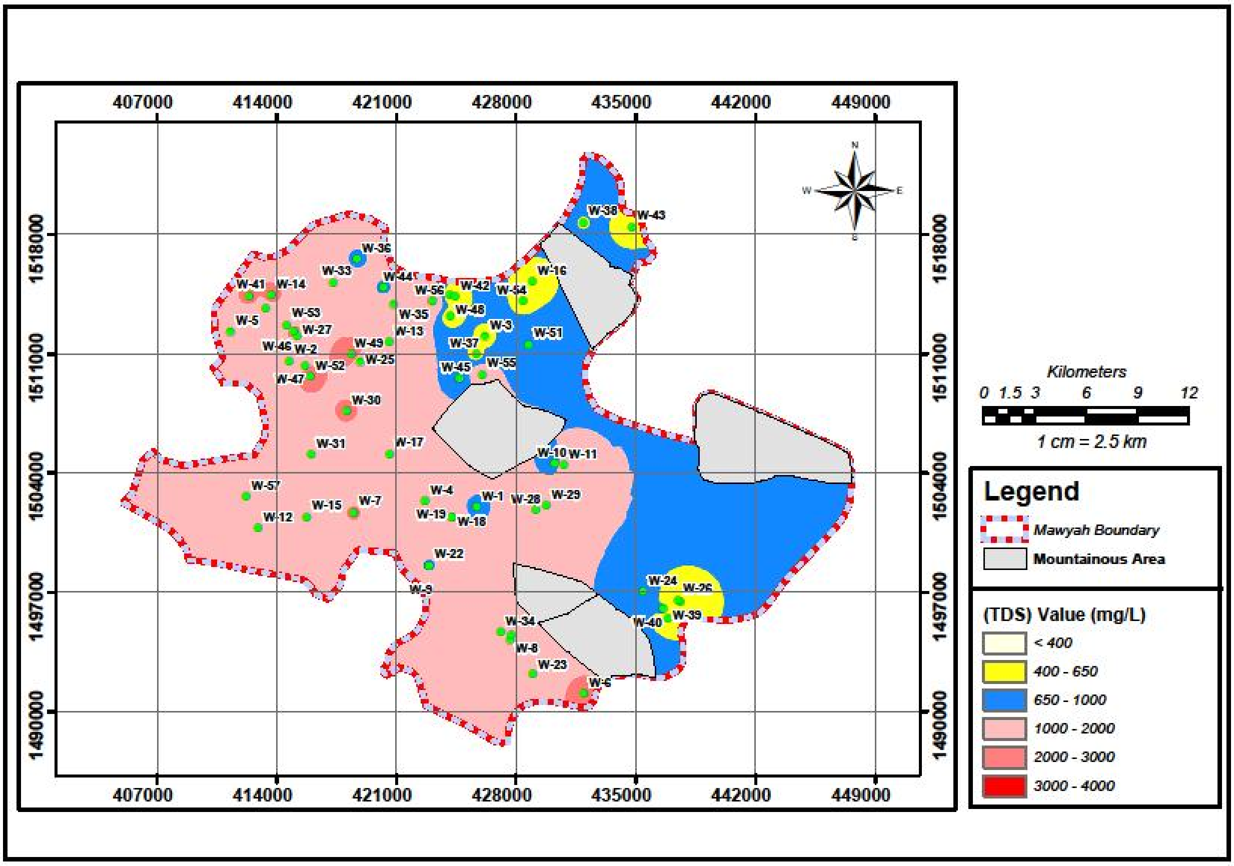


Figure 6: The comparison between the TDS analyses result and the Y.S, WHO



Map 10: Total Dissolved Solids Distribution in Mawyah district

High TDS values were observed in 2/3rds of the study area (western region). These values are in accordance with TH and EC values and may be referred to increase the salts of Ca and Mg.

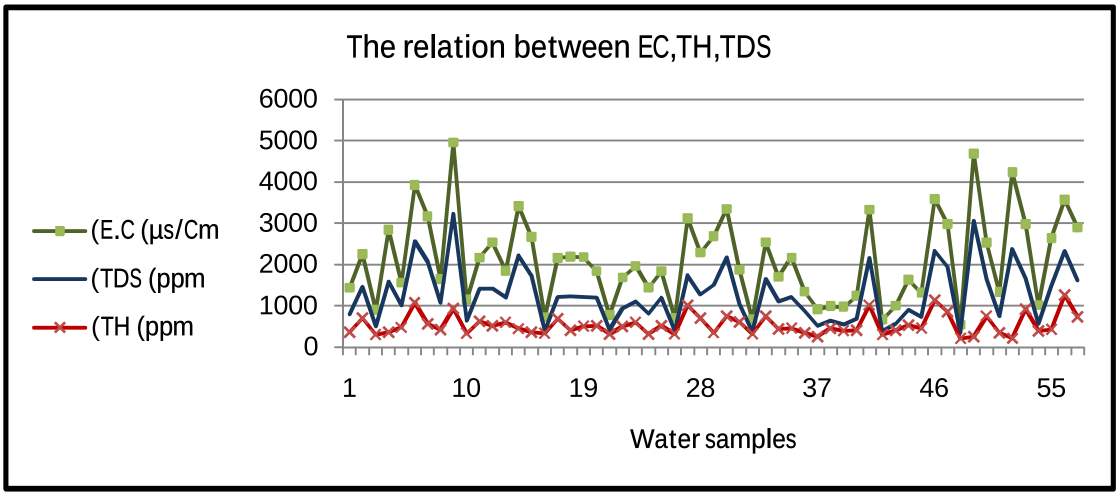


Figure 7: The relation between the EC,TH, TDS

5.5 Total Alkalinity (T.Alk)

In the study area the total alkalinity value in the samples are between 35 and 824 ppmwith an average of430 ppm. This indicates that bicarbonate is available in the water, while carbonate is not, which reflect that water is recent.

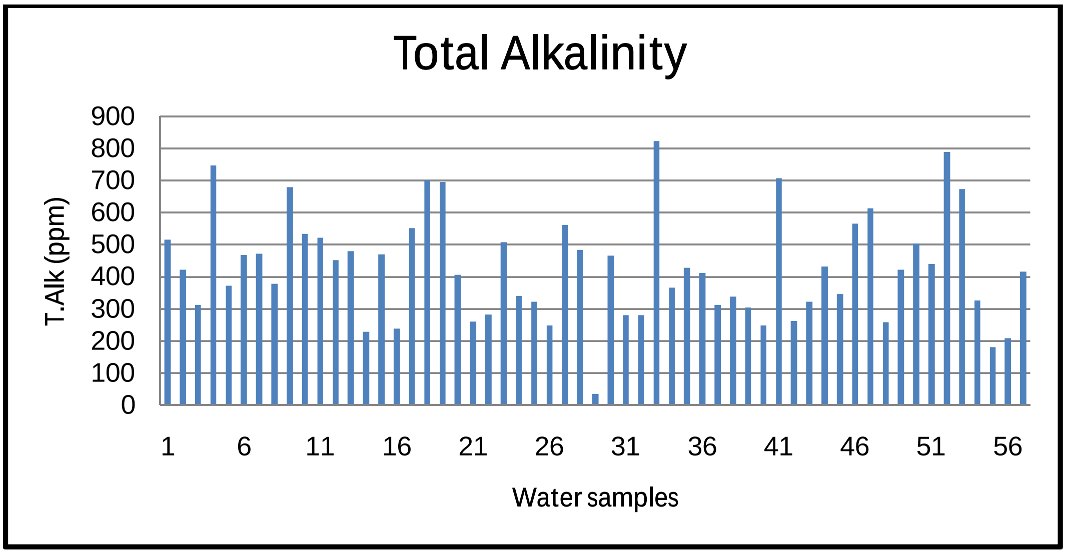
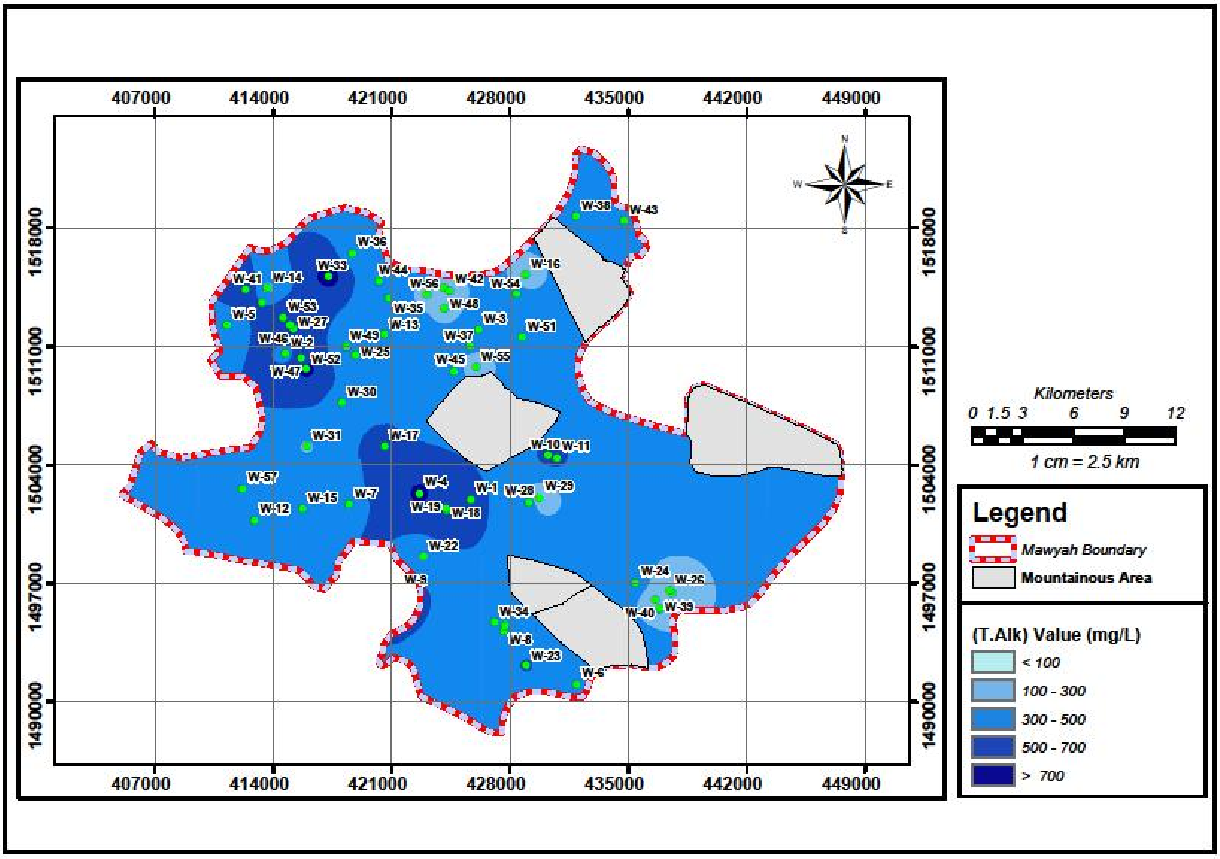


Figure 8 : The Total Alkalinity value



Map 11: **Total Alkalinity Distribution in Mawyah district**

5.6 Bicarbonate(HCO_3^-)

Bicarbonate ions are the main components of natural water and are made up of the reaction of carbon dioxide (CO_2) dissolved in water from volcanic and granite rocks. The proportion of bicarbonate in groundwater is between 50 and 400 ppm, while in the industry are in control and focus, especially in the manufacture of soft drinks and fruit juices.

In the study area the bicarbonate values in the samples range betweens 42.7 – 1005.

Comparison between the analyses result and the Yemeni water quality standard and WHO standard,it can be concluded that31% of the samples are over the limit (Fig 10). Samples containing high bicarbonate concentration are found mainly in the western area of Mawyah, that's recharge from the eastern area (recent water).

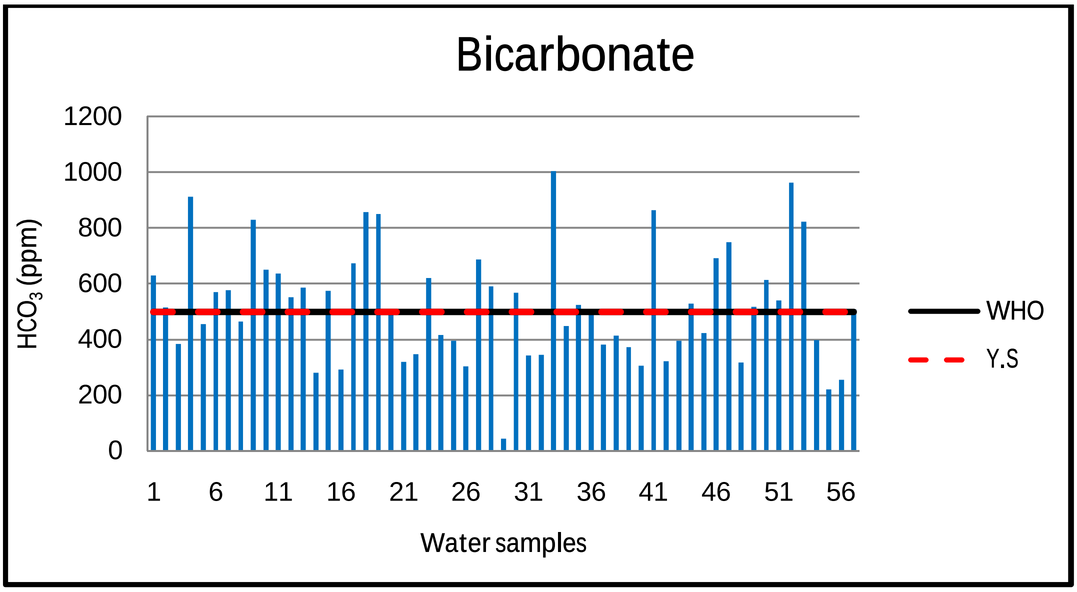
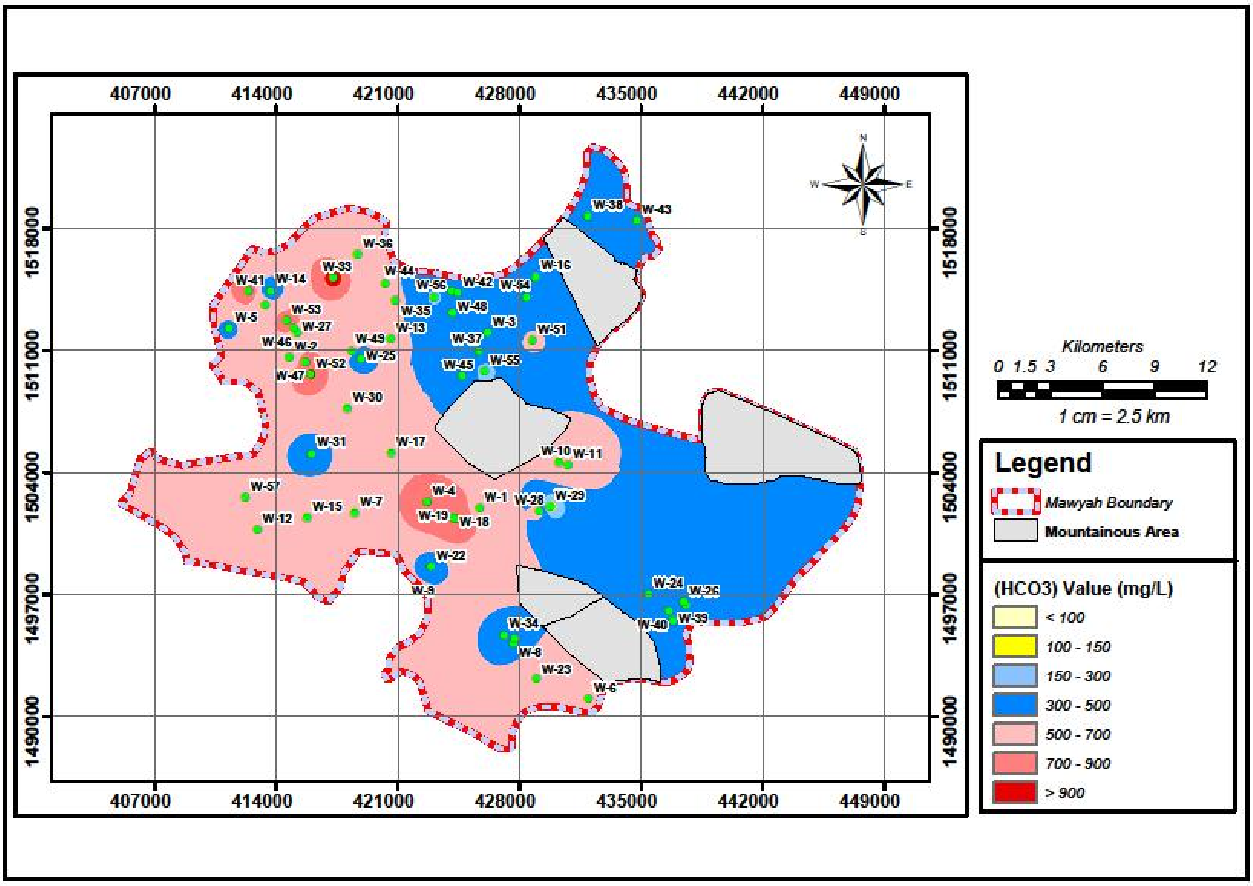


Figure 9: The comparison between the HCO_3 analyses result and the Y.S,WHO



Map 12 : BicarbonateDistribution in Mawyah district

5.7 Calcium(Ca^{++})

Calcium is naturally present in water. It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+} ions. Magnesium is the other hardness determinant.

Some environmental effects of water hardness include hardening of domestic equipment, because high temperatures cause carbonate hardness. This may dramatically decrease the lifespan of equipment, and causes an increase of domestic waste. Calcium carbonate interacts with detergents and cleansing agents. Complex formation causes a decrease in detergent efficiency, resulting in requirement for increased detergent application and softener purchases.

Calcium phosphate is a supporting substance, and it causes bone and tooth growth, together with vitamin D. Calcium is also present in muscle tissue and in the blood. It is required for cell membrane development and cell division, and it is partially responsible for muscle contractions and blood clotting.

Calcium carbonate works as a stomach acid remedy and may be applied to resolve digestive failure.

Calcium carbonate has a positive effect on lead water pipes, because it forms a protective lead (II) carbonate coating. This prevents lead from dissolving in drinking water, and thereby prevents it from entering the human body.

http://www.lenntech.com/periodic/water/calcium/calcium-and-water.

In the study area the Calcium value in the samples ranges between 27 – 471ppm. Only 4% of samples exceeded the Yemeni water quality standard and the WHO standards limits (Fig 11).

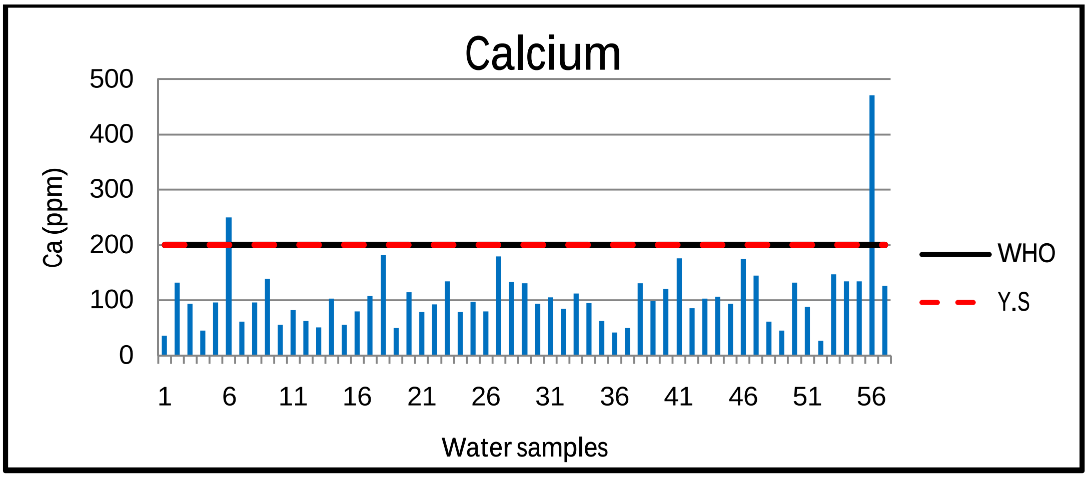
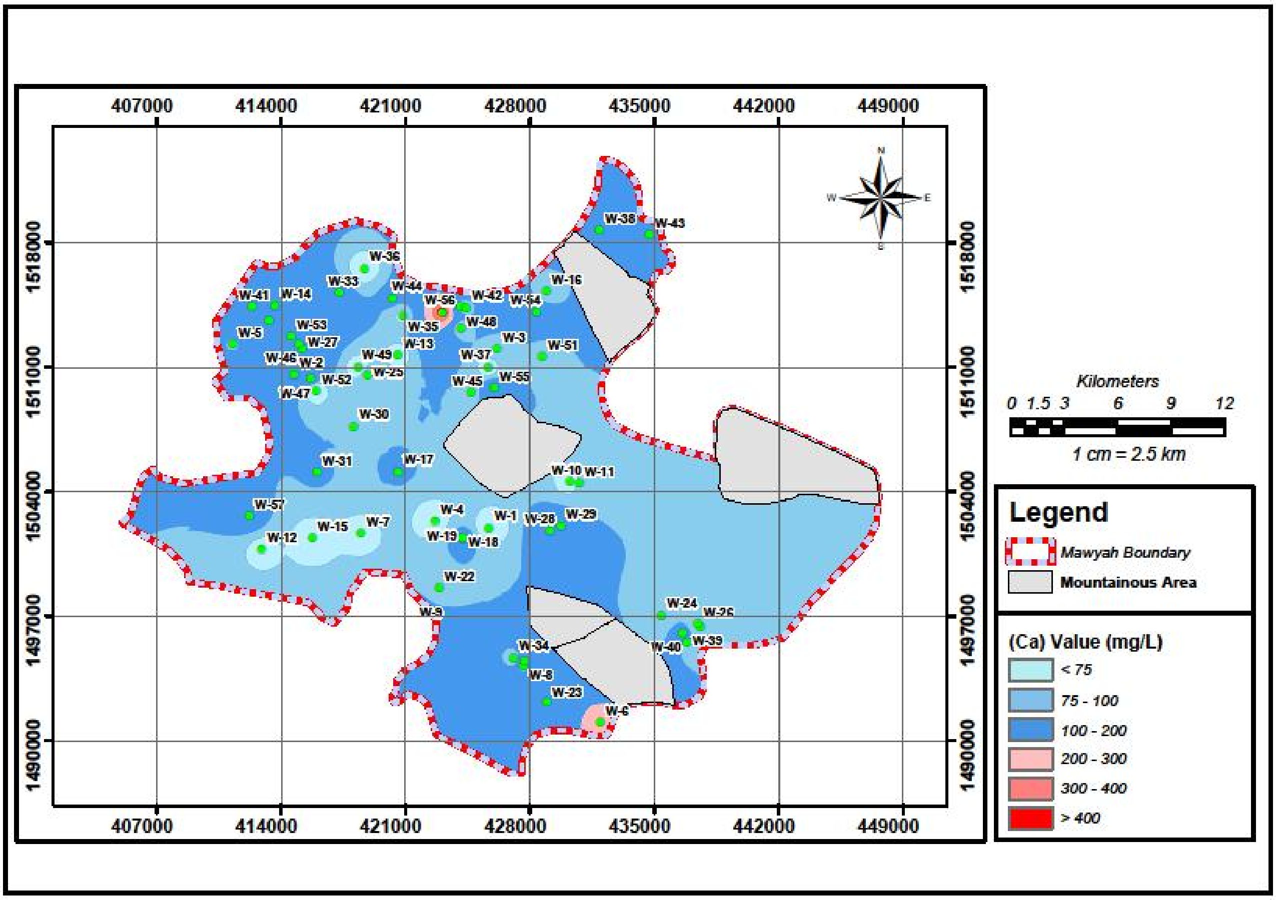


Figure 10: The comparison between the Ca analyses result and the Y.S, WHO



Map 13 : CalciumDistribution in Mawyah district

5.8 Magnesium (Mg^{++})

The main source of magnesium in the water is weathered igneous rocks which contain olivine, pyroxene, amphibole and mica minerals. It is also found in metamorphic and sedimentary rocks and especially in amphibolite schist, dolomite and magnesite. Magnesium is washed from rocks and subsequently ends up in water. The magnesium salts found in groundwater are $MgCO_3$, $Mg (HCO_3)_2$, $MgSO_4$. The presence of magnesium in the groundwater is useful for agricultural purposes as it flocculates the soil colloids and they increase the permeability of the soil(WadiSurdud Water Quality Report 2009). The human body contains about 25 g of magnesium, of which 60% is present in the bones and 40% is present in muscles and other tissue.

http://www.lenntech.com/periodic/water/magnesium/magnesium-and-water.

Only 2 % of the samples in the study are exceeding the YSWQ.

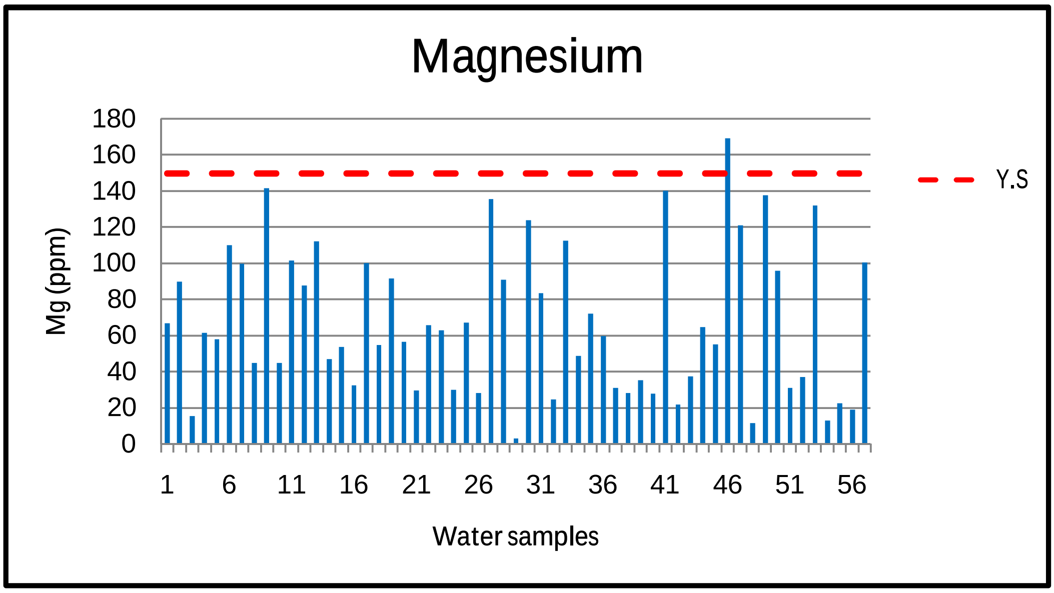


Figure 11: The comparison between the Mg analyses result and the Y.S

5.9 Chloride (Cl^-)

Chloride is one of the most commonly occurring anions in the environment. In natural water, the main source of chloride is from feldspathoidsodalite in igneous rocks. In the study area the Chloride value in the samples ranges between 19 – 827ppm. About 7% and 37% of the samples have higher chloride values than the permitted and WHO standard, respectively (Fig 13).

These are found in SharkiSwrak, Sa'elatSwrak, KhlawatSwrak, Al-Shisha, Al-Kmaheda, Amaema, Maria, Ogwa, Hwamera, sawda, Assrarsub districts in the north west of Mawyah.

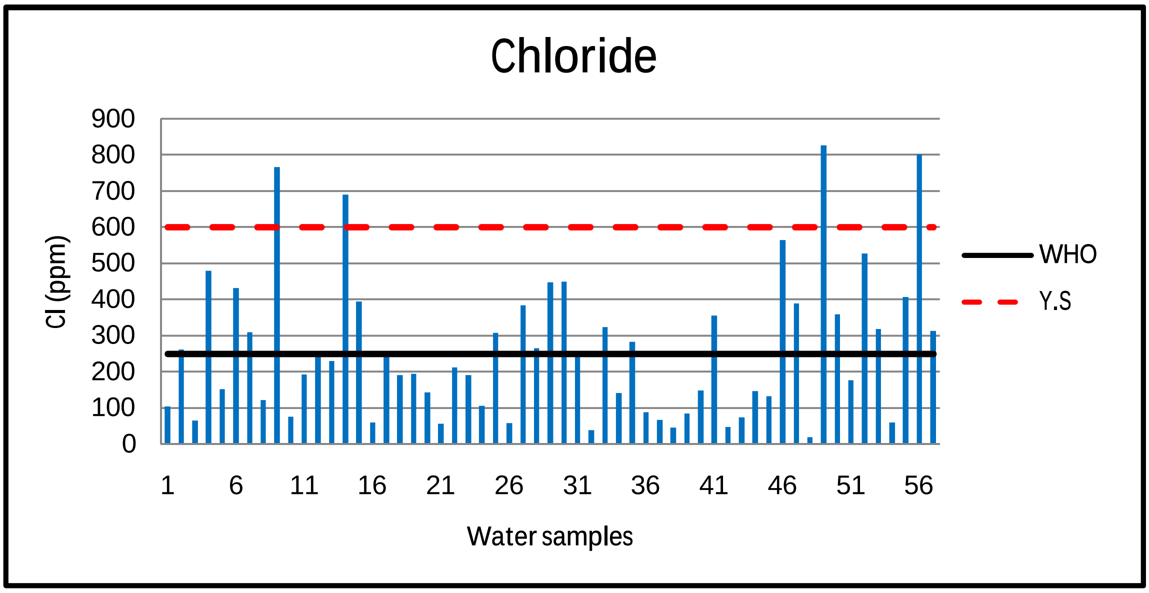


Figure 12: The comparison between the Cl analyses result and the Y.S,WHO

5.10 Sulfate (SO_4^{--})

Sulfate is not a major constituent of the earth's outer crust, but is widely distributed in reduced form both in igneous and sedimentary rocks of metallic sulfides. These sulfides (such as pyrite) are oxidized to yield sulphate ions which are carried off in the water (Hem 1970).In the study area the Sulfate value in the samples ranges between 1 – 940 ppm.About 35% of the samples contain higher concentration according to YSWQ and WHO standards (Fig 14).

Water resources with high sulfate concentrations are mainly found in Maber, Al-Thohra, Kmaeda, Akhrak, Al-Owman, Khder Al-Burihi, Asawda, Hwamerasub districts in the south of Mawyah(Map 14).

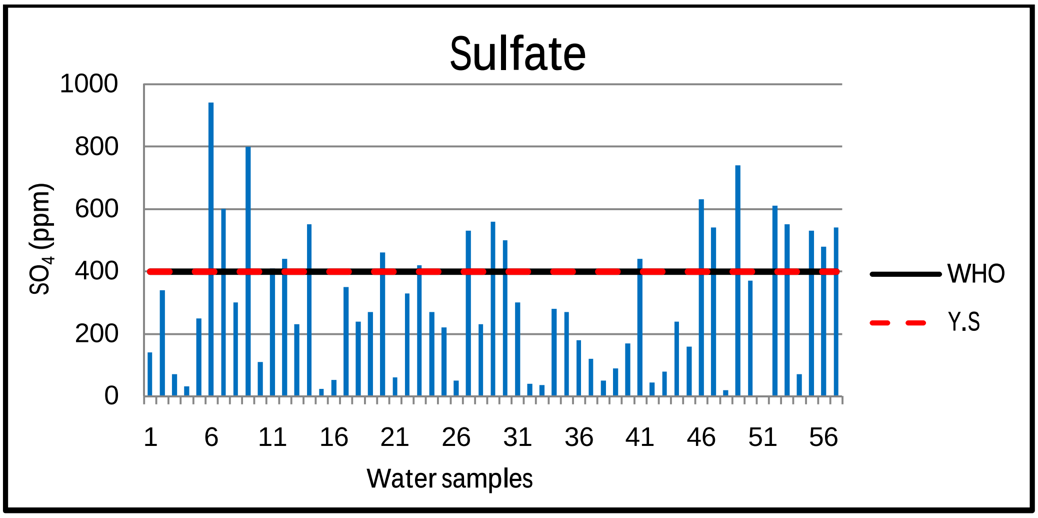
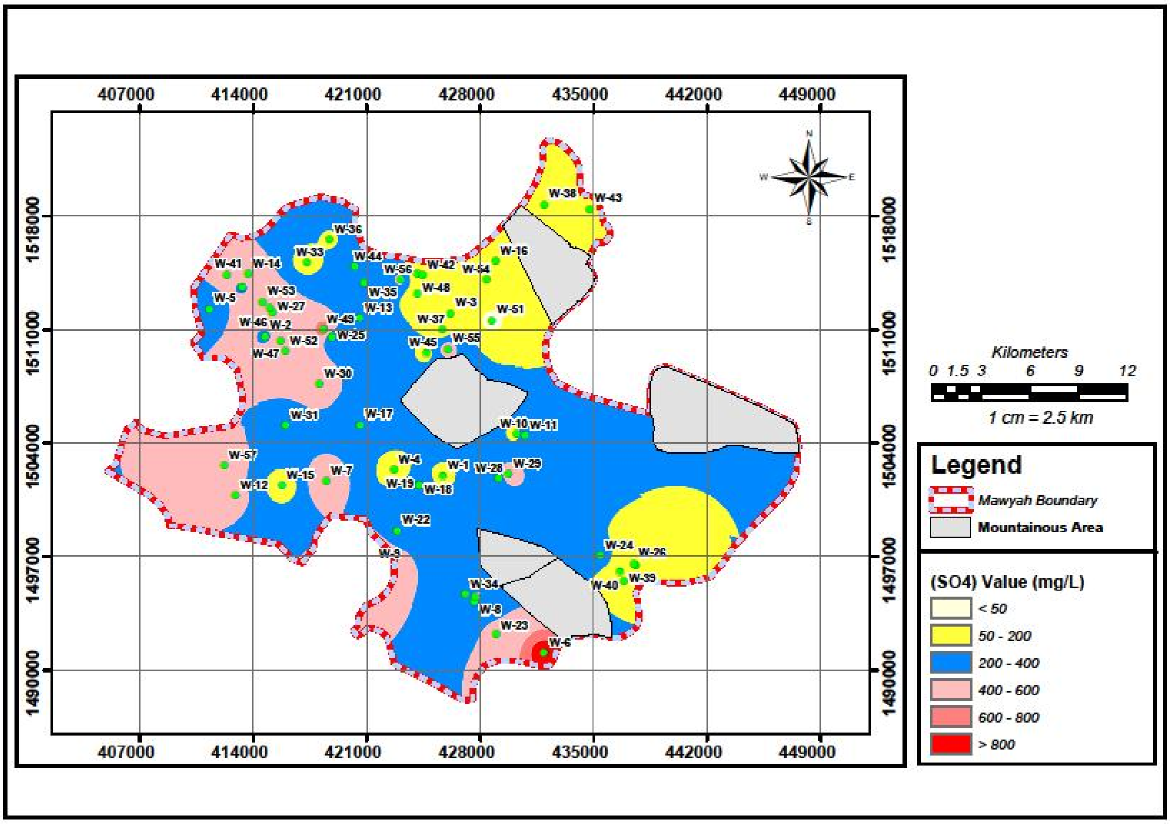


Figure 13: Sulfate concentrations in water samples



Map 14 : Sulfate Distribution in Mawyah district

5.11 Nitrate ($NO3^-$)

Nitrogen constitutes 78 percent of Earth's atmosphere and is a constituent of all living tissues. Nitrogen is an essential element for life, because it is a constituent of DNA and, as such, is part of the genetic code. Excess nitrates and nitrites are known to cause several health effects summarized as

http://www.lenntech.com/periodic/water/nitrate/nitrate-and-water

- Reactions with hemoglobin in blood, causing the oxygen carrying capacity of the blood to decrease (nitrite).
- Decreased functioning of the thyroid gland (nitrate) Vitamin A shortages (nitrate).
- Fashioning of nitro amines, which are known as one of the most common causes of cancer (nitrates and nitrites).

In the study area the Nitrate value in the samples range between (4.4 – 79ppm) and the average 20 ppm.

The comparison between the analyses result and the Yemeni water quality standard and the WHO standards shows that:

A. 7% of the samples over the range.

B. 35% of the samples less than the range(Fig 15).

C. 58% of the samples within the range.

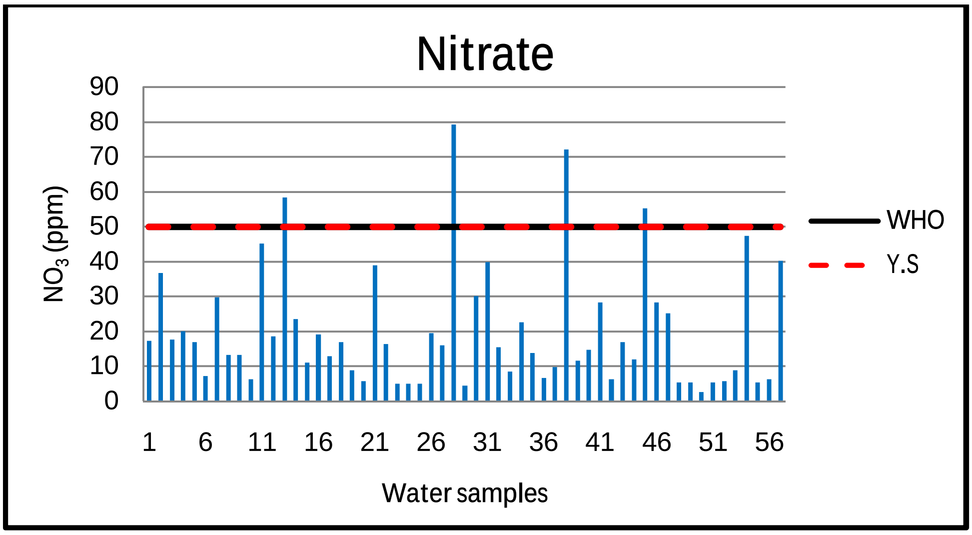
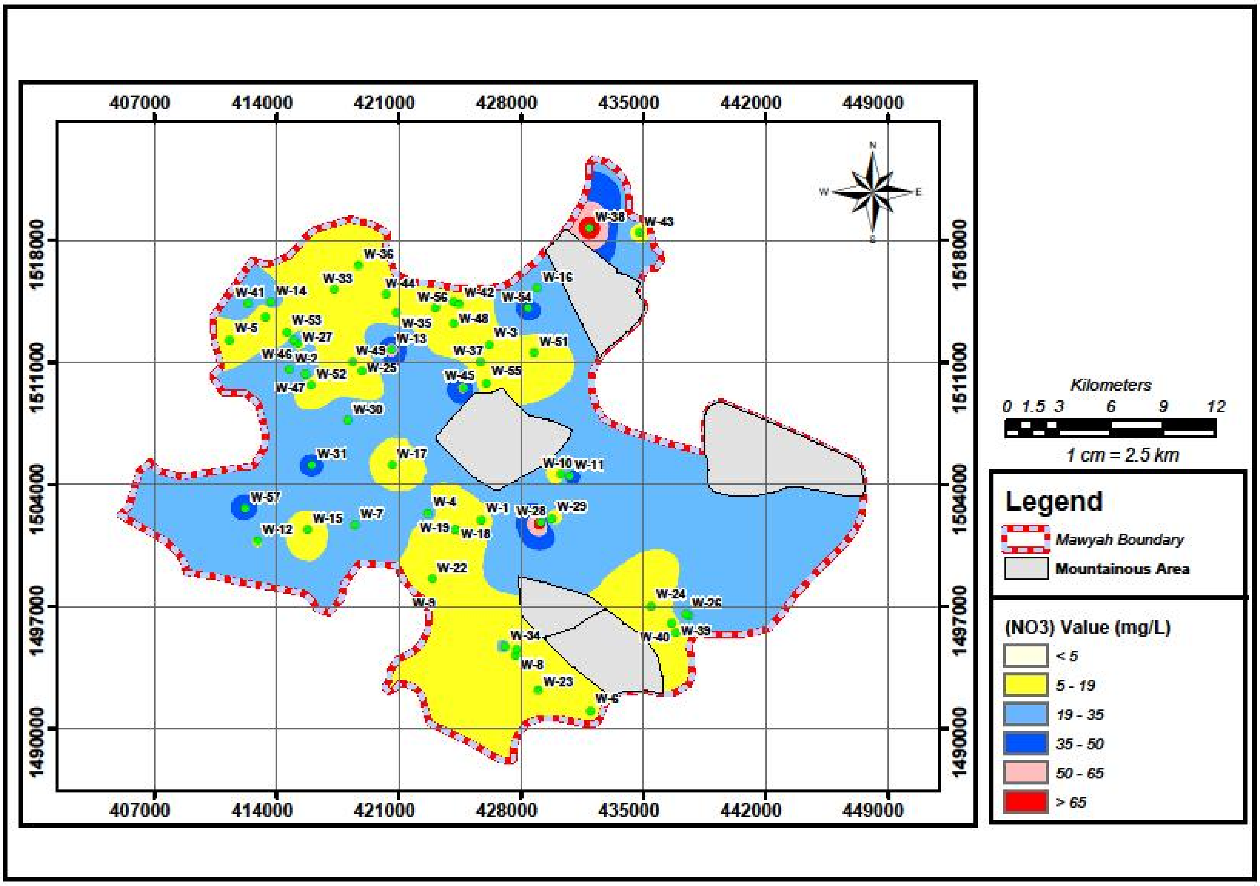


Figure 14: Nitrate concentrations in water samples

Higher nitrate concentrations are found in samples13, 28, 38, 45 inAkhrak,Amaema, SharkiSwrak, Al-Kmahedasub districts due to pollution from waste of the animals around the hole of the wells used for water supply transport.



Map 15 : NitrateDistribution in Mawyah district

5.12 Sodium (Na+)

Sodium is the sixth most abundant element in the Earth's crust, which contains 2.83% of sodium in all its forms. The main source of sodium in groundwater is weathered and dissolved igneous and metamorphic rocks which contain feldspathic minerals. Alluvial deposits yield water with relatively high sodium content. The sodium content in groundwater may increase as a result of cation exchange between sodium from the aquifer and calcium found in water. Sodium salts found in water are NaCl and Na_2SO_4.

In the study area the sodium values in the samples range between 20 – 800 ppm with an average of 251 ppm.

Comparing these results with Yemeni Drinking Water Quality Standard shows that 8.8% of the samples over 400ppm.The comparison between the analyses result and the WHO standard of 200ppm shows that 45.6% of the samples over the range.

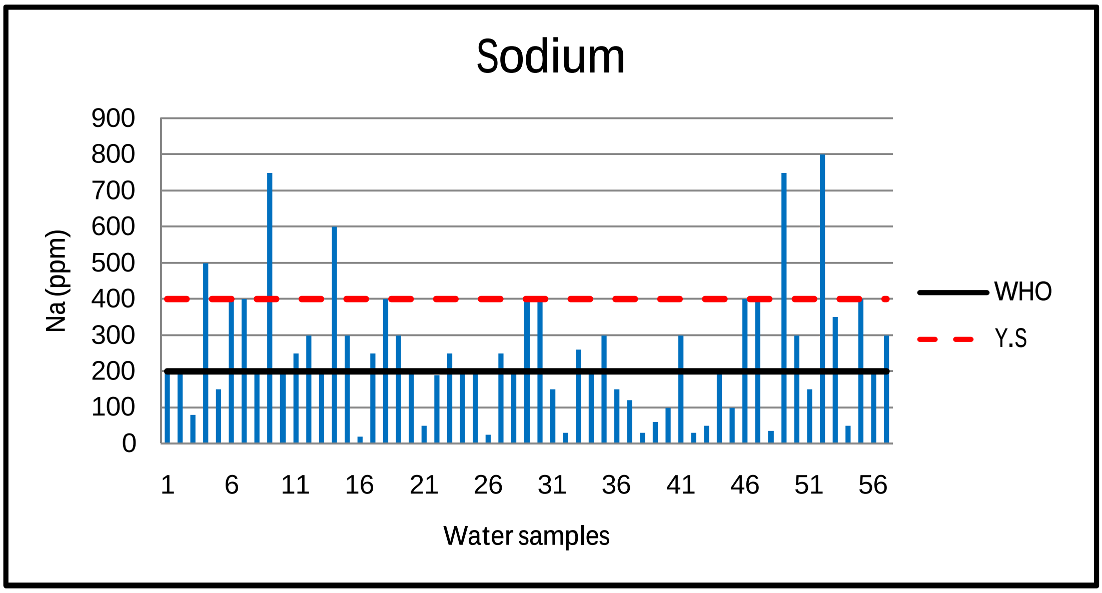
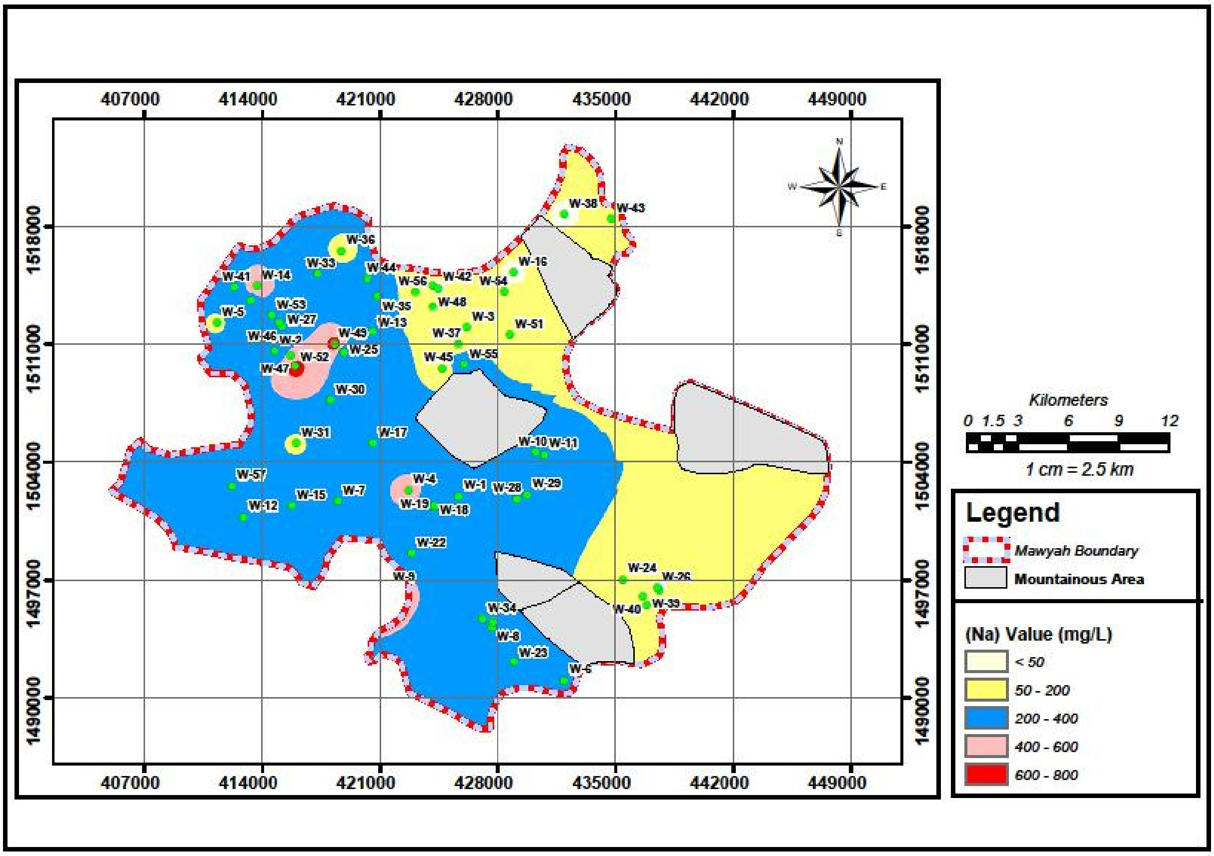


Figure 15: The comparison between the Na analyses result and the Y.S, WHO



Map 16 : Sodium Distribution in Mawyah district

5.13 Potassium (K^+)

Potassium occurs in various minerals, from which it may be dissolved through weathering processes examples are feldspars. Some clay minerals contain potassium.

Potassium is a dietary requirement for the human being. The muscles contain most potassium after red blood cells and brain tissue.The relation of potassium in cells to potassium in plasma is 27:1, and is regulated by means of sodium-potassium pumps.Vital functions of potassium include its role in nerve stimulus, muscle contractions, blood pressure regulation and protein dissolution. It protects the heart and arteries, and may even prevent cardiovascular disease.Potassium loss may be a consequence of chronic diarrhoea or kidney disease, because the physical potassium balance is regulated by the kidneys.

http://www.lenntech.com/periodic/water/potassium/potassium-and-water.

In the study area the potassium value in the samples ranges between 1 – 12 ppm with an average of 3.5 ppm. None of the samples contain sodium concentrations higher than the Yemeni Drinking Water Quality Standard 12ppm (Fig 17).

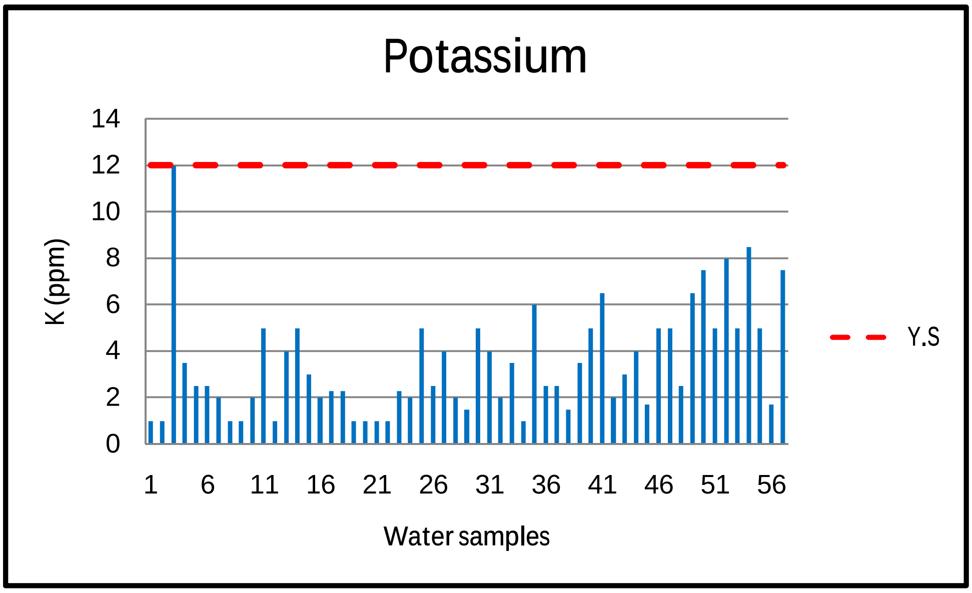


Figure 16: **Potassium concentrations in water samples**

5.14 Iron

Iron forms chelating complexes that often play an important role in nature, such as hemoglobin, a red coloring agent in blood that binds and releases oxygen in breathing processes. Organisms take up higher amounts of binary iron than of tertiary iron, and uptake mainly depends on the degree of saturation of physical iron reserves.

Iron deficits lead to anemia, causing tiredness, headaches and loss of concentration. The immune system is also affected. In young children this negatively affects mental development, leads to irritability, and causes concentration disorder. Young children, pregnant women and women in their period are often treated with iron (II) salts upon iron deficits. When high concentrations of iron are absorbed, for example by haemochromatose patients, iron is stored in the pancreas, the liver, the spleen and the heart. This may damage these vital organs. Healthy people are generally not affected by iron overdose, which is also generally rare. Water soluble binary iron compounds such as $FeCl_2$ and $FeSO_4$ may cause toxic effects upon concentrations exceeding 200 mg.

http://www.lenntech.com/periodic/water/Iron/Iron-and-water.

In the study area the iron value in the samples ranges between 0.01 – 0.94 ppm with an average of 0.01 ppm. None of the samples contain iron concentrations higher than the Yemeni Drinking Water Quality Standard of 1ppm. Comparison between the analyses result and the WHO standard shows that 5% of the samples over than the range.

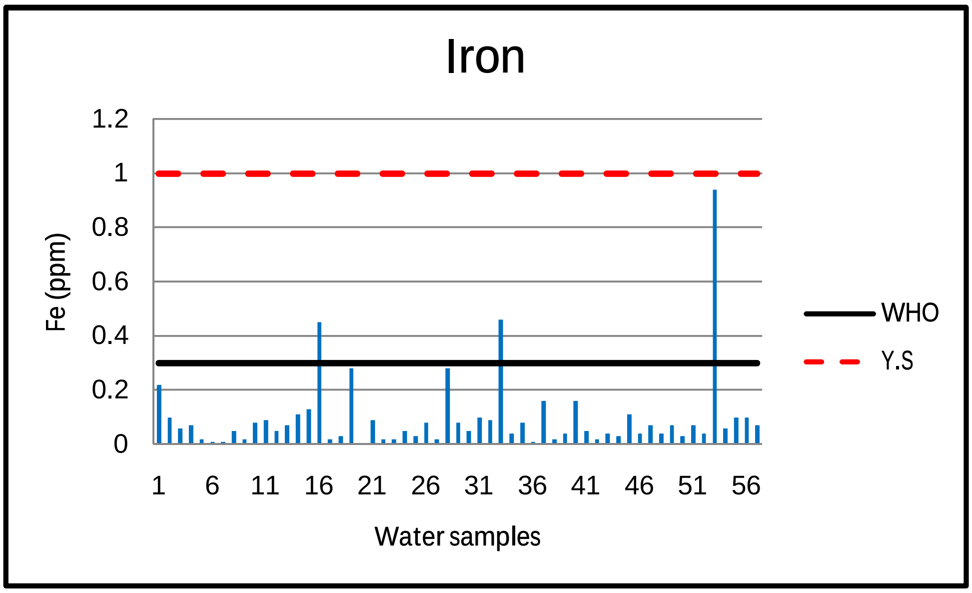


Figure 17: The comparison between the Fe analyses result and the Y.S, WHO

5.15 Fluoride

The presence of this element in drinkable water is of highest importance as it contributes to protect tooth enamel. Tooth discoloration can occur, forming yellow or brown pits and patches on teeth (long term exposure at levels greater than 2.0 ppm). Long term exposure at higher levels (4.0$^+$ ppm) can cause bone spurs and possibly even birth defects.

http:www.chem.duke.edu/~jds/cruise_chem/water/watwhy.html

In the study area fluoride values in the samples ranges between 0.06 – 16.1 ppm with an average of 1.7 ppm.About 35% of the samples have higher fluoride concentration than the Yemeni Dsrinking Water Quality Standard and the WHO standard(Fig 19).

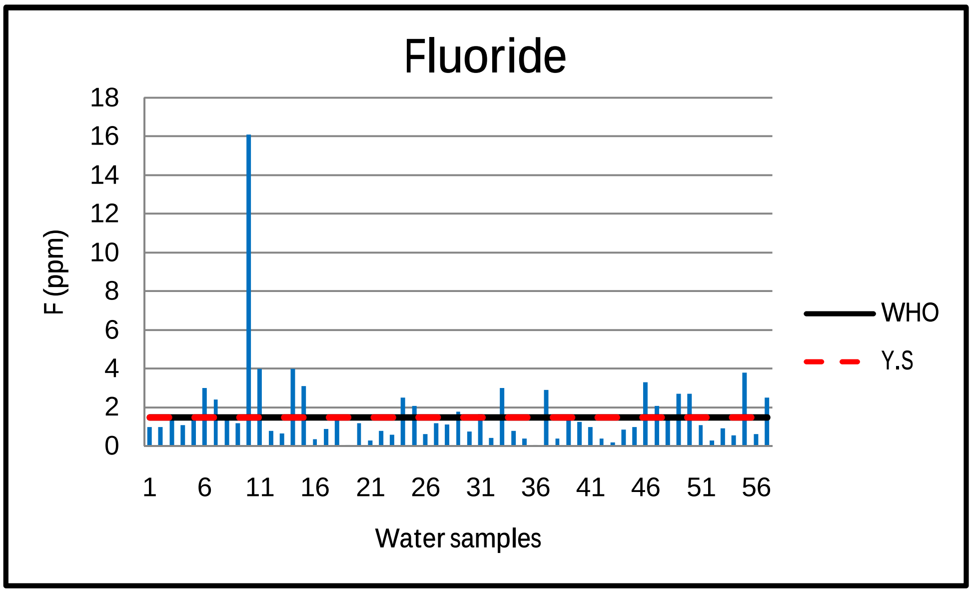
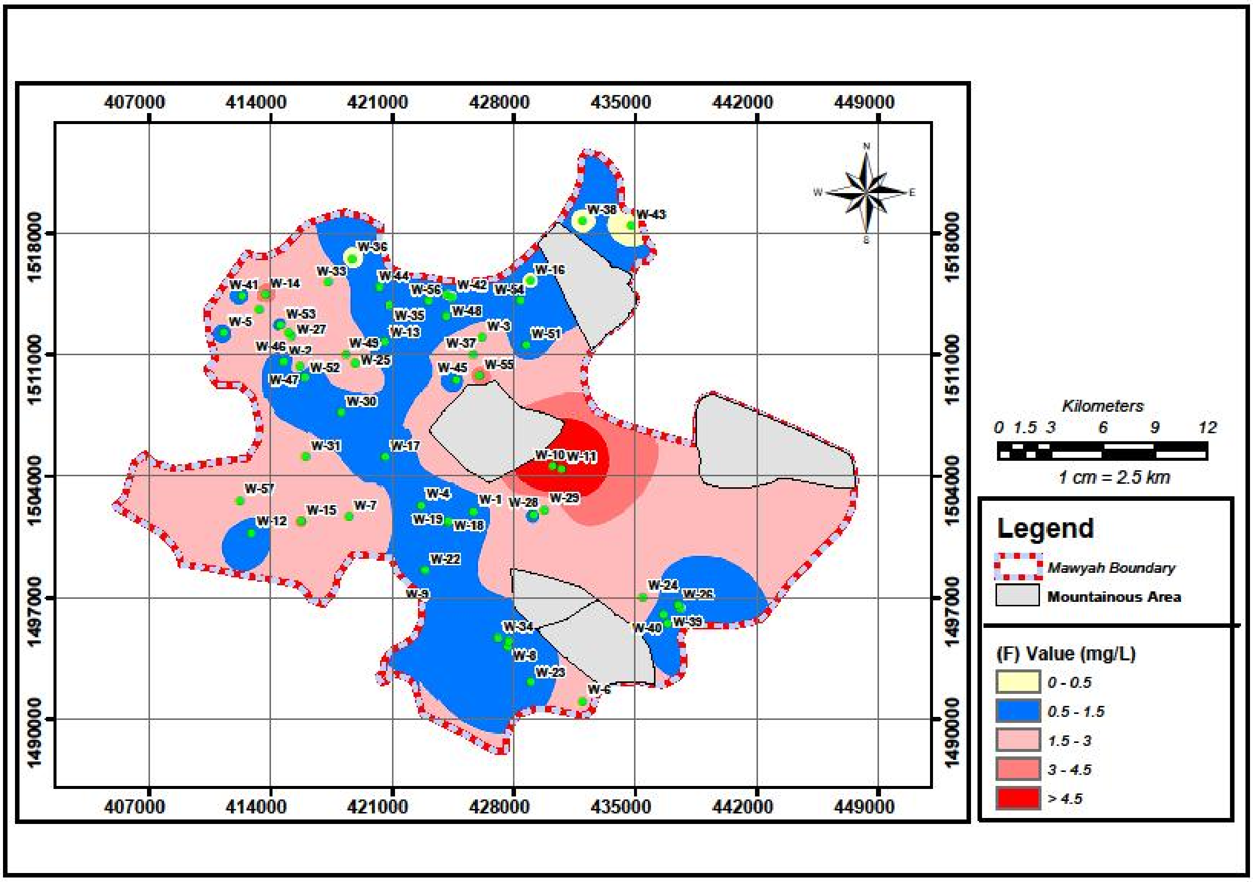


Figure 18:The comparison between the F analyses result and the Y.S, WHO

Higher concentration sare observed in wells no (3,6,7,10,11,14,15,18,24,25,29,31,33,37,46,47,49,50,55,57)whichis concentrated in KhlawatSwrak, Al-Kmaheda, Maber, Al-Thohra, Kmaeda, Al-Owman, Assrar, Amaema, sub district (Map 17)



Map 17 : Fluoride Distribution in Mawyah district

5.16 Chemical water type in Mawyah District

Water samples can be classified into different chemical water type according to different methods as:

- Total Dissolved solids (TDS).
- Total Hardness (TH).
- PH.
- Piper diagram.
- Durov Diagram
- Stiff diagram

5.16.1 Total Dissolved Solids

Water in Mawyah district can be classified into 5 different water types using the total dissolved solids parameter called, very fresh water of 11% (o-500 ppm), fresh water of 26% (500-1000), view salt water of 30% (1000-1500), medium salt water of 16% (1500-2000), and high salt water of 17%(2000-10000).

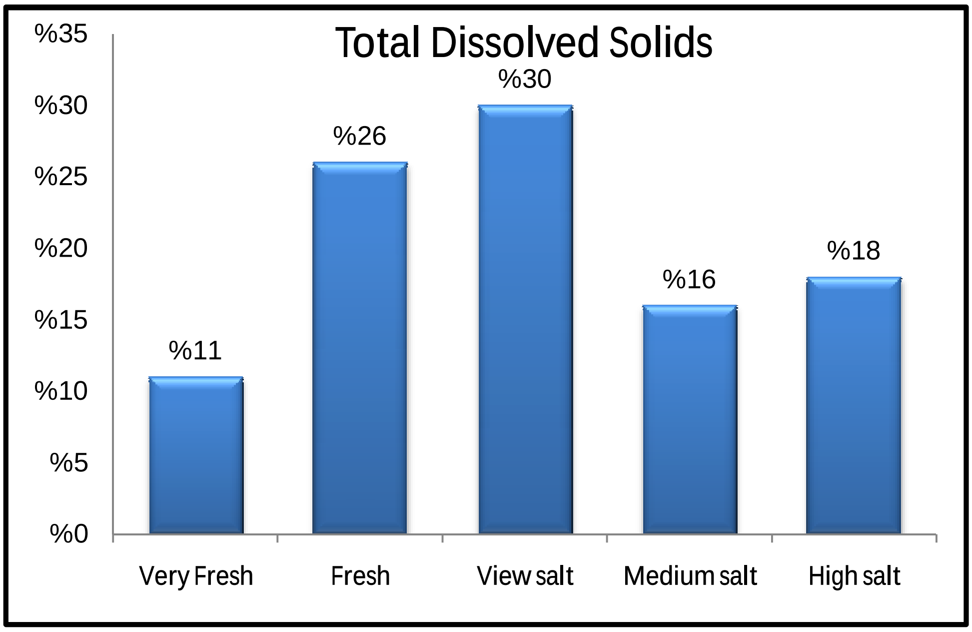


Figure 19 : **Classification water samples by TDS**

5.16.2 Total Hardness

Total hardness parameter is also used for water classification in Mawyah. It is classified into two different types called, hard water presented by 9% of the samples with TH range between 30-150 ppm, and very hard water presented by 91% of the samples with TH greater than 300 ppm.

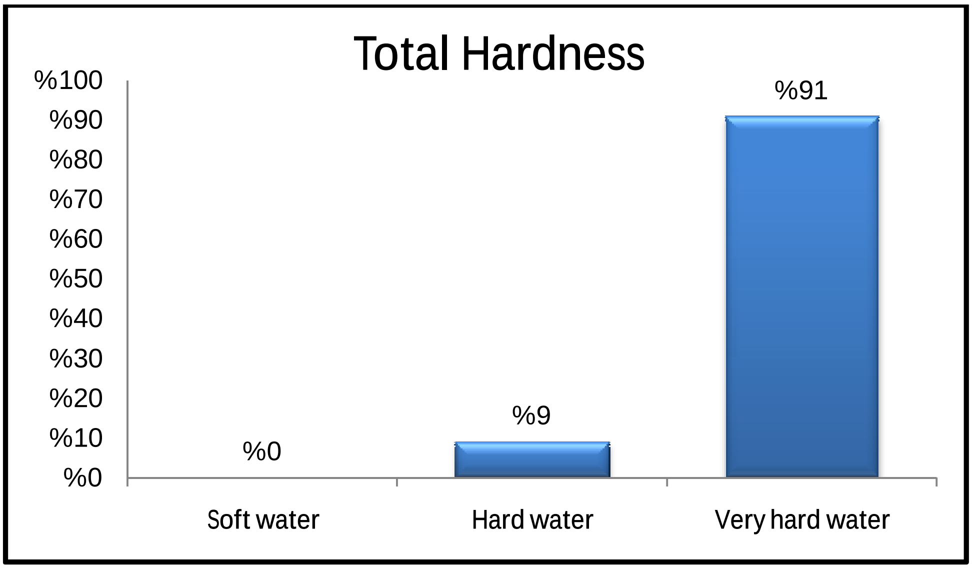


Figure 20 : Classification of water samples by TH

5.16.3PH

Mawyah water is also classified using pH parameter into, acidic water for 4% of the samples with pH 6.5, basic water for 21% of the samples with pH 8.5, and moderate water for 75% of the samples with pH 7.

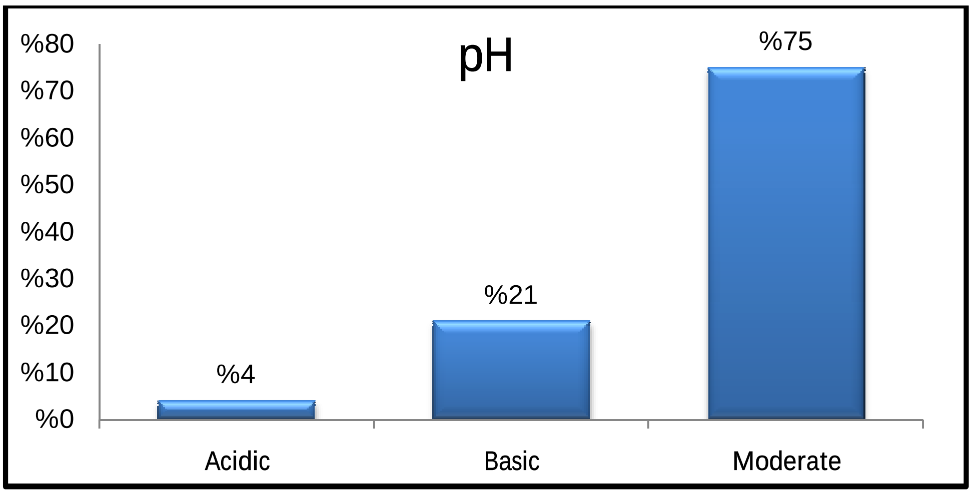


Figure 21: Classification of water samples by pH

5.16.4Piper Diagram

The major ions concentrations of the analyzed samples were plotted on Piper diagram Figure(23).Using Langguth (1996) classification for Piper diagram of the analysis results the water classified into five distinct hydrochemical water type as follows:

- Normal earth alkaline water with prevailing bicarbonate and sulfate or chloride (sample 16).
- Earth alkaline water with increased portions of alkalis with prevailing bicarbonate (samples 3, 23, 29, 36, 39, 40, 42, 43, 48, and 54).
- Earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride (samples 2, 5, 6, 13, 24, 25, 28, 30, 35, 37, 38, 41, 45, 46, and 56).
- Alkaline water with prevailing bicarbonate (samples 1, 10, 18, 19, 33, 34, and 51).
- Alkaline water with prevailing sulfate or chloride (samples 4, 7, 8, 9, 11, 12, 14, 15, 17, 20, 21, 22, 26, 27, 31, 32, 44, 47, 49, 50, 52, 53, 55, and 57).

These groundwater types in the study area explain the role of evaporation in the water composition as the loss by evaporation results in the transfer of salts from soil water to the soils (Drever, 1988 and Karnath, 1997, Rao, 2002). The study area lies in the arid climate, which leads to a high rate of evaporation especially during summer. Most samples are collected from the alluvium shallow water aquifer.The aquifer is also under high stress of abstraction for Qat irrigation. This provision leads to high salinity of water in Mawyah.

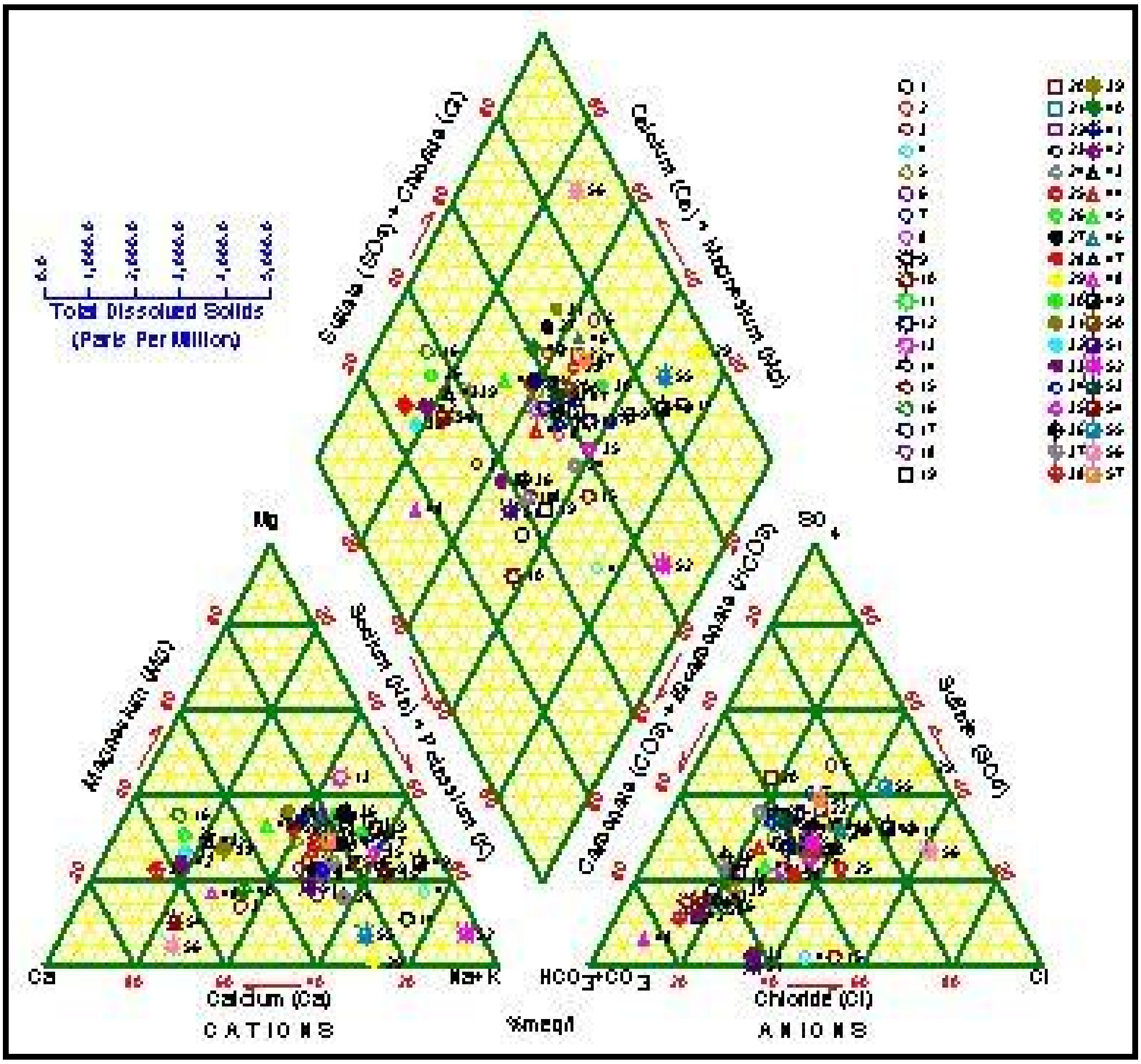
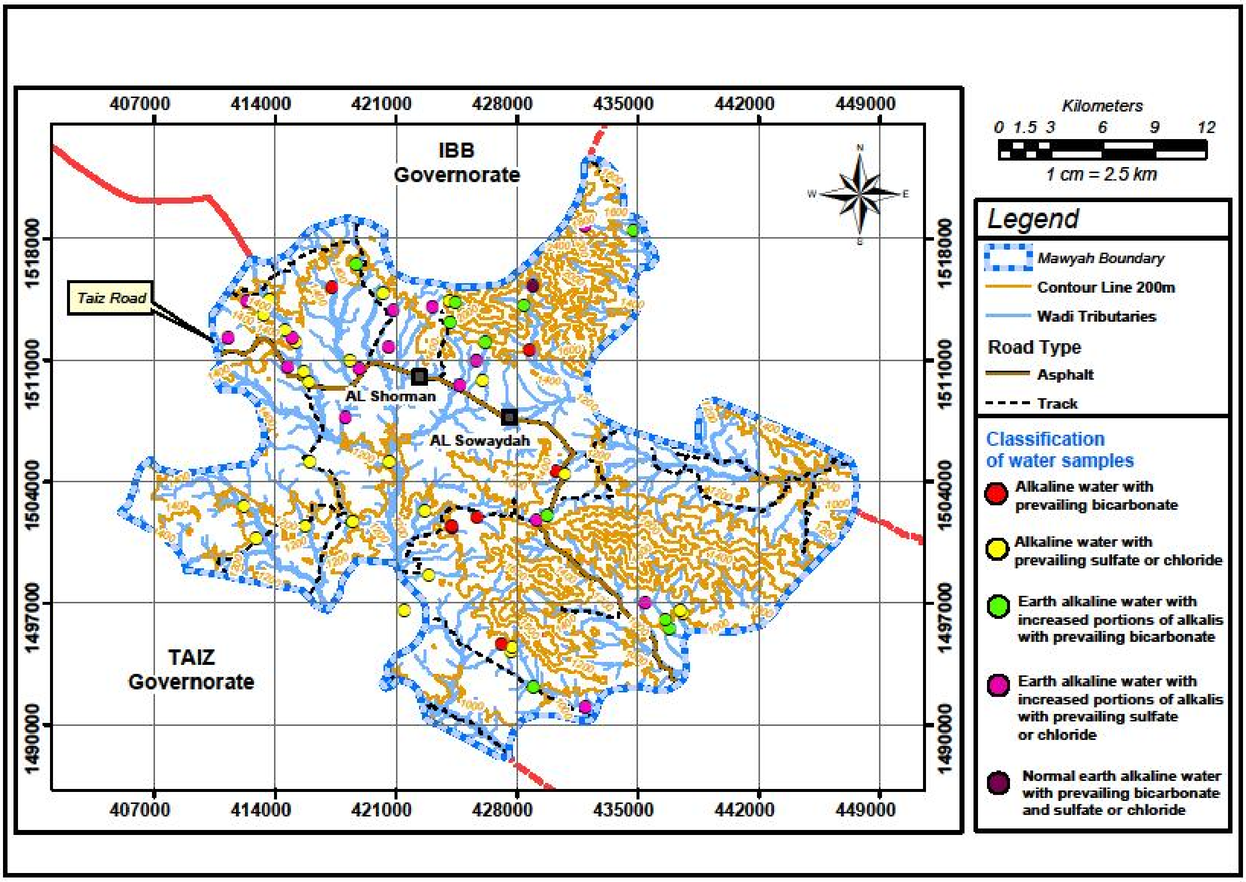


Figure 22: **Piper diagram of the groundwater samples in the study area.**



Map 18 : **Classification of water samples by Piper diagram in Mawyah district**

5.16.5 Durov Diagram

The major ion concentrations of groundwater samples are also plotted on Durov diagram (Fig.24).This diagram has advantages over the Piper diagram in revealing some geochemical processes that could affect groundwater genesis. Most samples plot along the dissolution or mixing line based on the classification of Lloyd and Heathcoat (1985) as shown in annex 2this trend suggests that most water is fresh recent recharge water exhibiting simple dissolution or mixing.

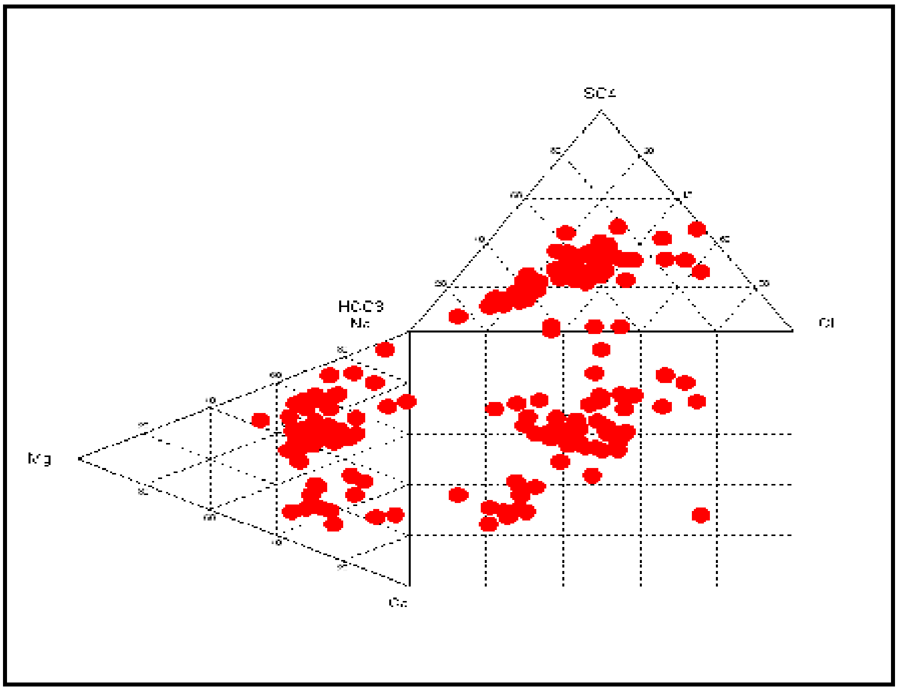


Figure 23 : Durov diagram of ground waters samples in the study area

5.16.6 Stiff diagram

The Stiff diagrams (Hem, 1985) advantages are dual. Firstly, different shapes which are recognized at first glance. Secondly, the absolute concentrations are visualized by the width of the figure (Appelopostma, 1993). The samples were plotted on stiff diagram presented in annex 2

CHAPTER 6: Socio-economic study

The socio economic study for IWRM in Mawyah district was carried out to understand and evaluate the impacts of the water supply use on the society and the intervention of the decision makers to resolve such problems.

6.1 Socio economic impact

The study focused on the effect of high fluoride concentration in the water supply of Mawyah district on the people using this water supply. The high fluoride concentration effect was measured by the presence of fluorosis on the people.

The color of the teeth as an indicator for fluorosis is recognized on Mawyah people male and female. From the data collected 74% of the respondents have yellow, brown, white with brown, white with yellow, and yellow with brown colors as an indicator for fuorosis, while 26 % have white color.

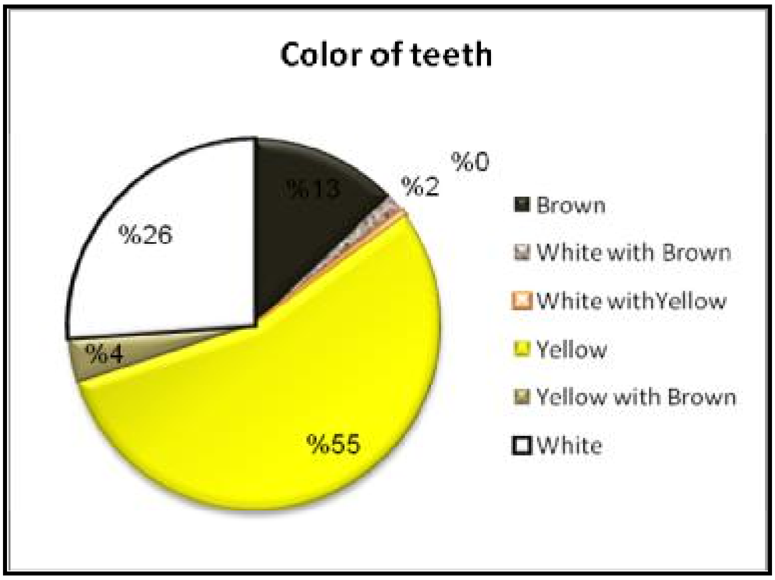


Figure 24: Color of teeth for people in Mawyah district

Photos of teeth color

According to the results of the interviews 94% of respondents did not know the cause of teeth discoloring, while 6% of the respondent knows cause of the problem.

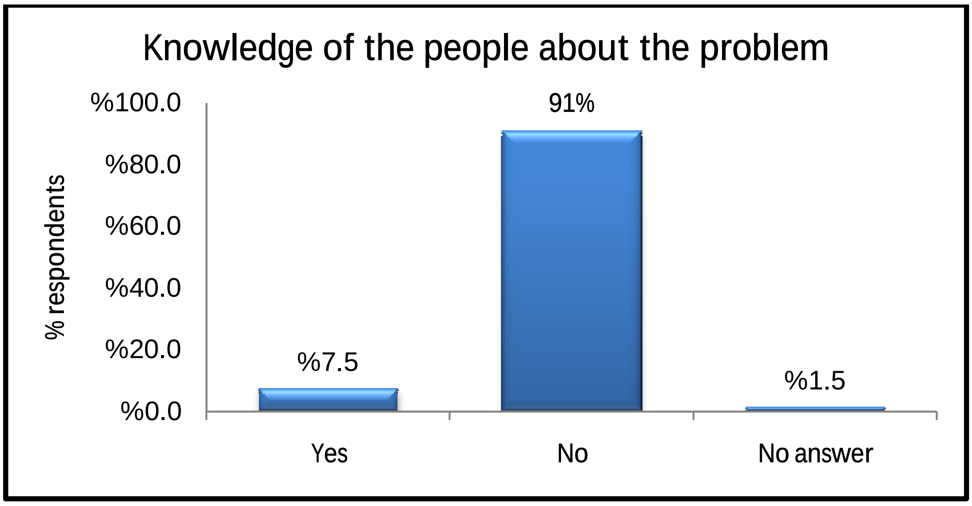


Figure 25: Knowledge of the people about the problem

About 9 % of the people also visit the dentists to have medical care to resolve the fluorosis problem while 91% do not visit the doctors.

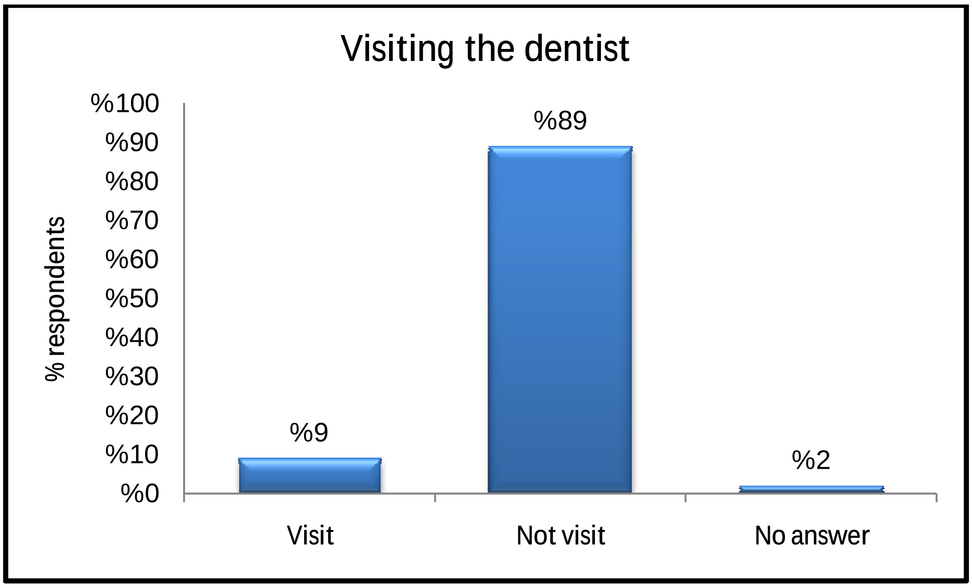


Figure 26: People Visiting the dentist

Most respondent (95%) who do not visit the dentists feel that the fluorosis is a normal thing, while 4% of them do not visit the dentists due to the high cost medication, and 1% gives other reasons.

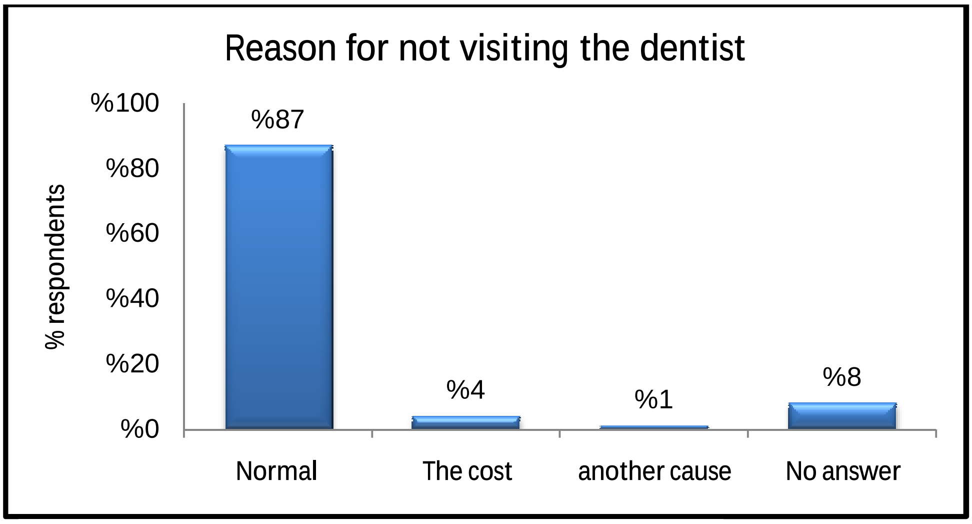


Figure 29 Reasons for not visiting the dentist

Most respondent (95%) feels unhappy about the color change of their teeth (fluorosis), 4% have no problem, and 1% has no answer.

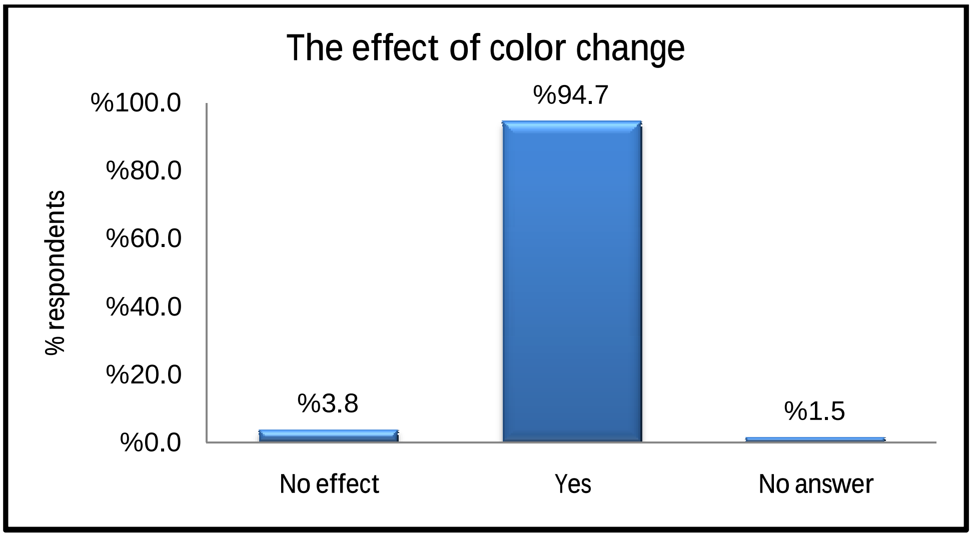


Figure 27 : The effect of teeth color change

According to the answer of the respondent 96% of them phase unacceptance from the others due to their teeth color (fluorosis), 2% does not have any problem, and 2% have no answer.

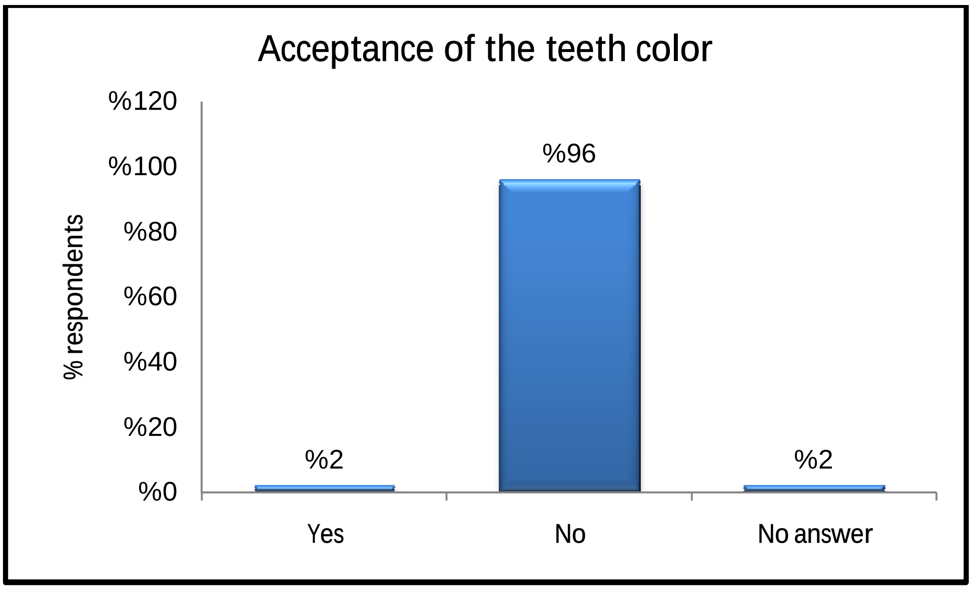


Figure 28 : Acceptance of the teeth color

Around 1% of the respondent faces problems with their marriage due to their teeth color, 97% have no problem, and 1% have no answer.

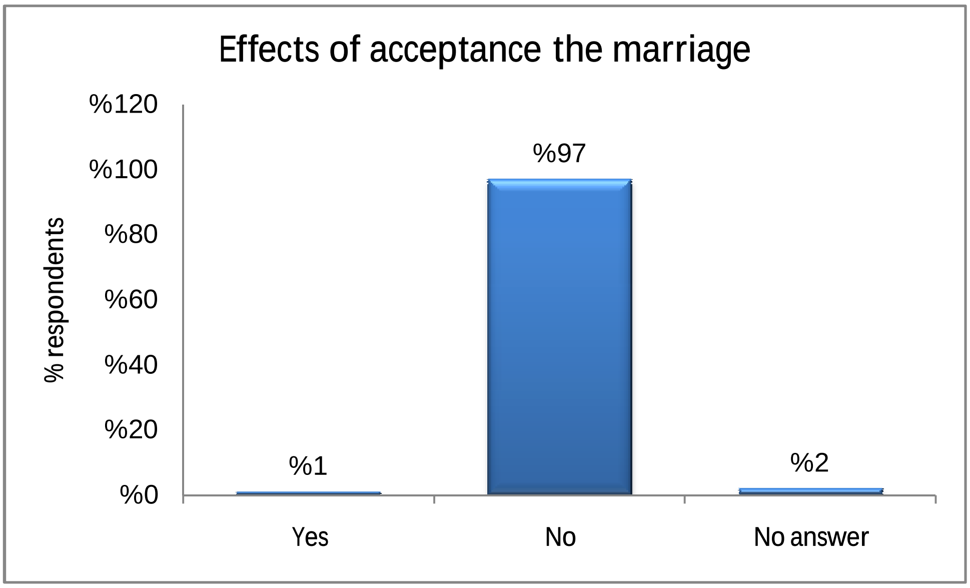


Figure 29 : Effects of acceptance the marriage

According to the result of the survey 97% of the respondent would like to remove their teeth color (fuorosis), 1% does not want, and 2 % have no answer.

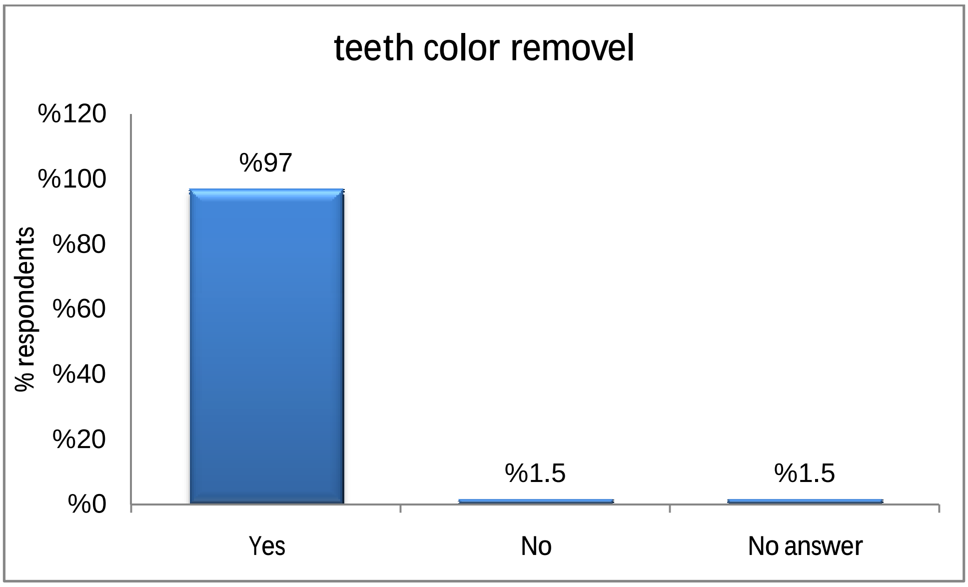


Figure 30: Desire to remove the color of the teeth

The survey also shows that 38% of the respondent tries different traditional and medical methods to remove the color of the teeth, 60 does not, and 2 have no answer.

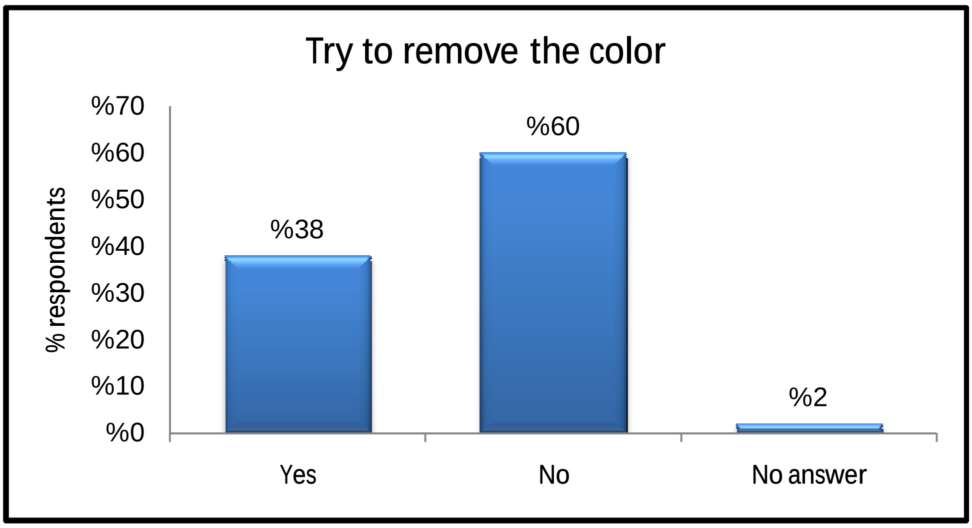


Figure 31 : Try to remove the color

About 62% of the respondent how tries different ways to remove the abnormal teeth color do it in a random way without mentioning any methods or tools, 18 used mainly tooth paste, 5% used abrasion, 5% used tooth cleanser, the rest 10 % used mixed methods. Deferent traditional substances also used to remove the abnormal teeth color.

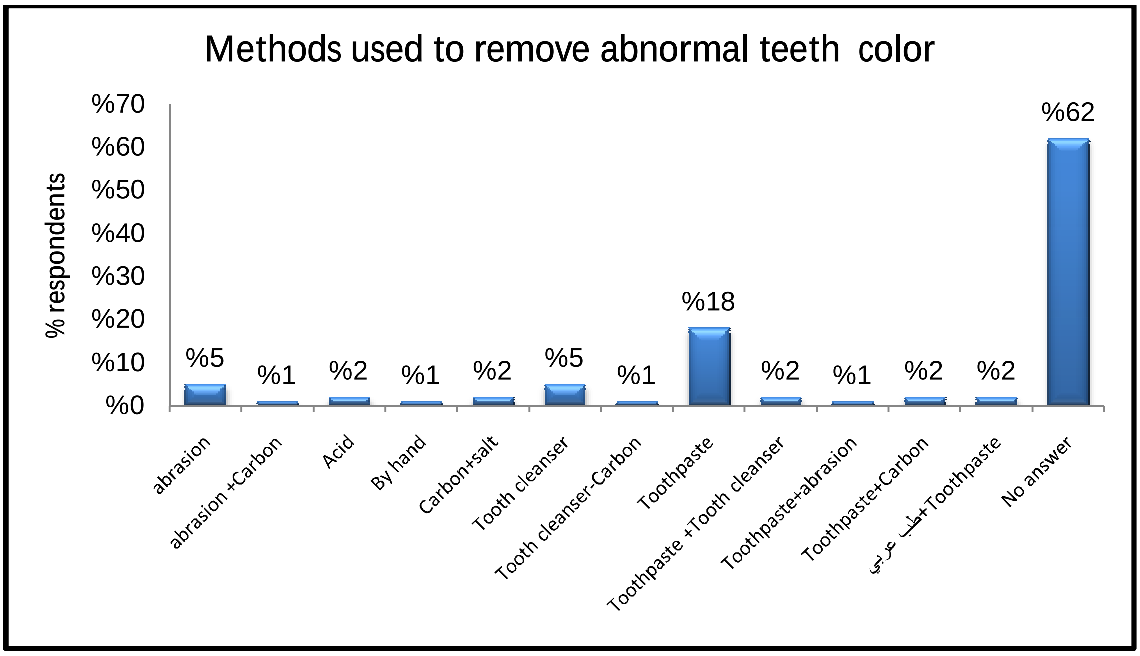


Figure 32: Ways of removing abnormal teeth color

Only few people less than 1% are satisfied with their teeth color subjected to medication, 38% are not satisfied, and the rest 62 % have no answer.

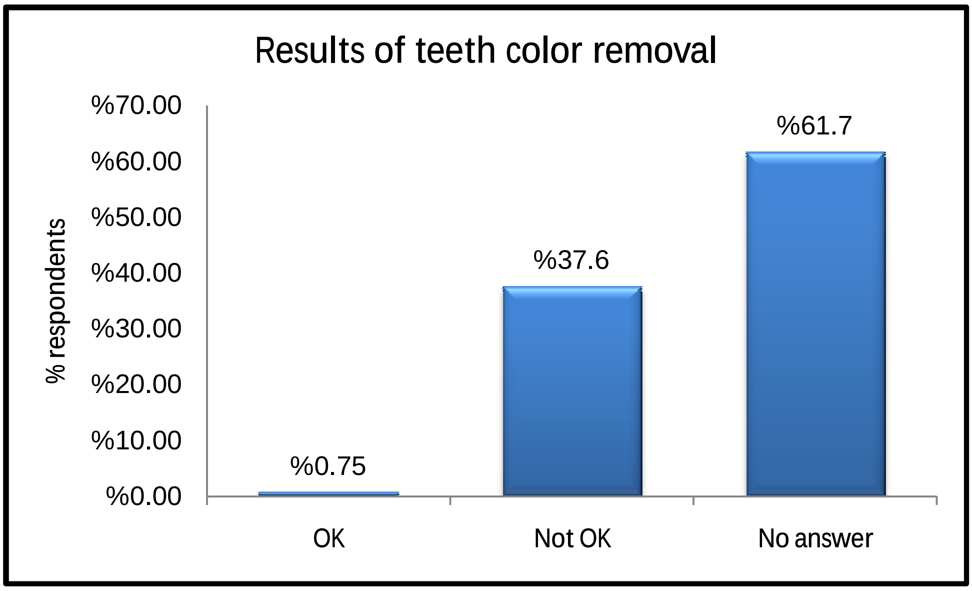


Figure 33: Results of teeth color removal

6.2 Interviews with decision makers

The survey examines the institutional activities in Taiz governorate, and MAwyah district in IWRM implementation. The results indicate that 21.4% of the institutions have only administrative activity, 14.3% have monitoring activity, 21.4% have technical activity, 28.7% have both technical and monitoring activities, 7.1% have all the activities, and 7.1% have no answer.

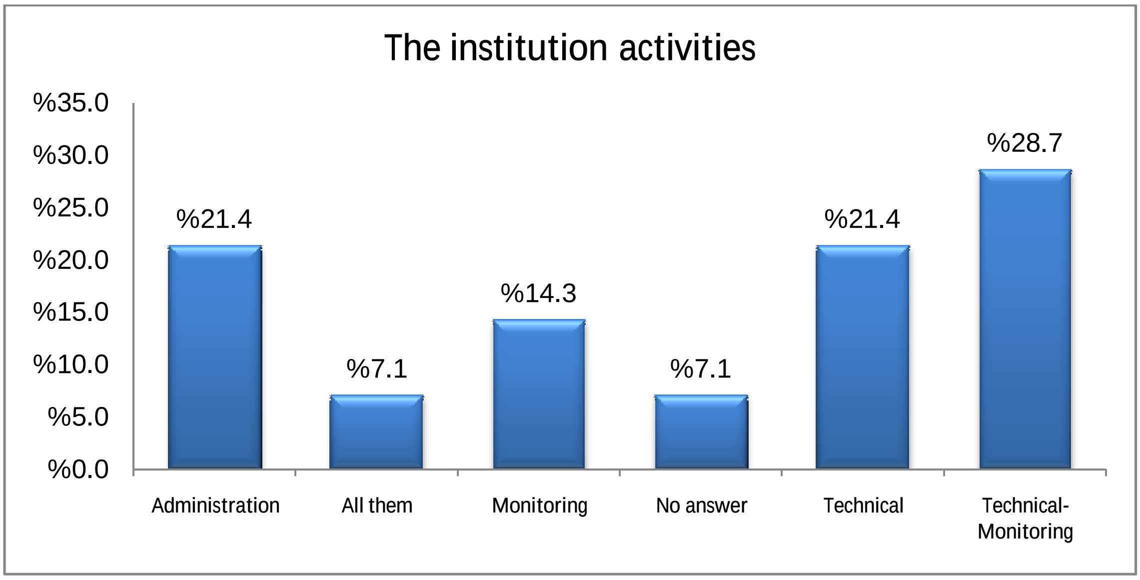


Figure 34: institutional activities in IWRM implementation

6.3 The Institutional Database

21% from the institution have a database about the fluoride concentration, 21%have a part database while 14% are not answered, and 43% answered haven't database.

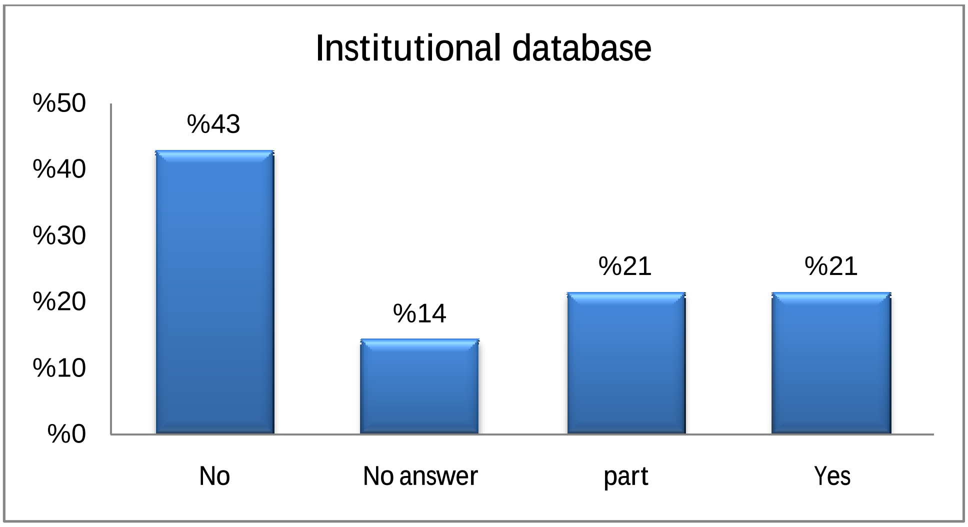


Figure 35: Institutional database

TWSLC and MLC have database in hard and soft copy format, while NWRA-Taiz, GARWSP-Taiz, Public Work office, and Al-Badiah association have hard copy only. Mawyah health office does not have database, while Social Fund Development project and Taiz health office do not answer.

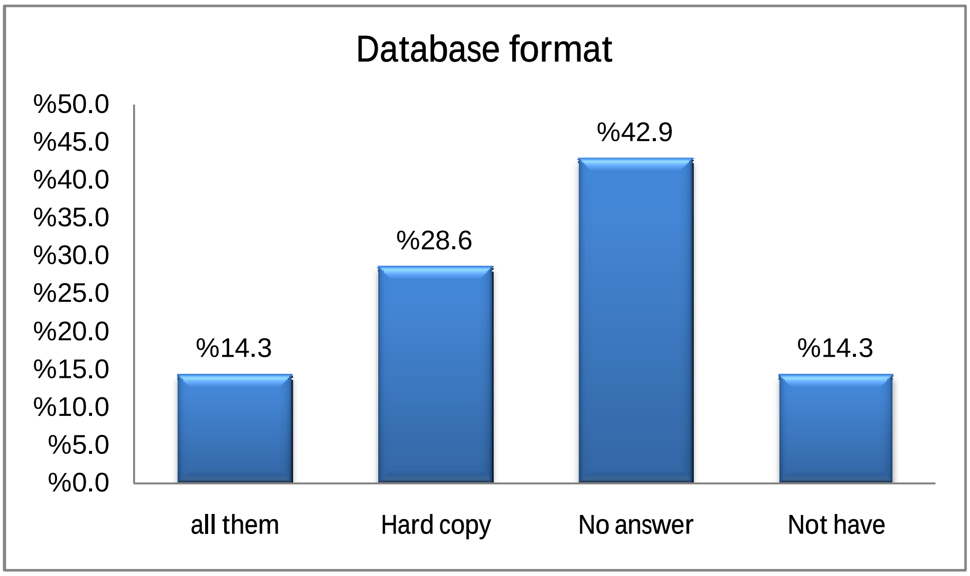


Figure 36: Database format

Table 5: Institutional activities in water sector

No	Institution Name	Institutional activities in water sector			Remarks
		Water analysis	Standards used	Action	
1	Depute manager of MLC	Yes	No answer	No answer	
2	Al-Badiah Association	No	Yemeni standard	Not use	
3	Akamt- Al-Massged Association	No	Yemeni standard	No answer	
4	Deputy manager of MLC- health office.	No	No answer	No answer	
5	Finance and planning manager of MLC	No	No answer	No answer	

No	Institution Name	Institutional activities in water sector			Remarks
		Water analysis	Standards used	Action	
6	Public Work Office	No	Yemeni standard	stop the source	
7	Social Fund Project	Yes	No answer	No answer	
8	Taiz Health Office	No	No answer	stop the source- treatment the water-awareness	
9	Taiz WSLC – Operating	Yes	Yemeni standard	stop the source - Mixing water	
10	Taiz WSLC– Laboratory	Yes	Yemeni standard	Not happened	
11	NWRA-Taiz	Yes	Yemeni standard	awareness	
12	Yemen Standard Authority	No	No answer	No answer	

No	Institution Name	Institutional activities in water sector			Remarks
		Water analysis	Standards used	Action	
13	Taiz- GARWSP	Yes	Yemeni standard - WHO	stop the source - awareness	
14	Al-Wedian Association	No	No answer	No answer	

Table (5) present that 43% of the institutions collected water chemistry data by chemical analysis using YS only, and 7% using both YS and WHO, while 57 % do not make chemical analyses. The proposed institutional interventions against high fluoride concentration varies between stop the source completely reflected by 7%, 8% make awareness only, 7% stop the source and make awareness, 7% stop the source, make awareness, and treat the water,7% stop the source and mix the water, while 50% from the decision markers do not answered.

Table 6 : Institutional intervention and future plans related to high fluoride concentration

No	Institution name	Fluoride effects			Implemented activities		Future institutional plan	
		Knowledge	nature	degree	Knowledge	degree	nature	Knowledge
2	Al-Badiah Association	No	change the color of teeth	No	No answer	No answer	No	No answer
3	Akamt- Al-Massged Association	Yes	change the color of teeth	Yes	No	No answer	No	No answer
4	M LC- Depute Manager	No	change the color of teeth	No answer	No	No	No	No answer
5	M LC(Finance& Planning)	Yes	change the color of teeth	Yes	No	No answer	Yes	awareness

No	Institution name	Fluoride effects			Implemented activities		Future institutional plan	
		Knowledge	nature	degree	Knowledge	degree	nature	Knowledge
6	Public Work Office	Yes	change the color of teeth	No	No	No answer	No	No answer
7	Social Fund Project	No answer	No answer	No answer	No answer	No answer	Yes	No answer
8	Taiz Health Office	Yes	change the color of teeth	Yes	No	No answer	Yes	awareness -journal
9	WSLC – Taiz- Operating	Yes	change the color of teeth	No	No answer	No answer	Yes	don't used this source
10	WSLC –Taiz- Laboratory	Yes	change the color of teeth	Yes	No	No answer	No answer	No answer

No	Institution name	Fluoride effects			Implemented activities		Future institutional plan	
		Knowledge	nature	degree	Knowledge	degree	nature	Knowledge
11	NWRA-Taiz	Yes	change the color of teeth	Yes	No	No answer	No answer	No answer
12	YSA	Yes	change the color of teeth	Yes	No answer	No answer	Yes	Analysis the flouride element - awareness
13	GARWSP - Taiz	Yes	change the color of teeth	Yes	Yes	audible	Yes	workshops
14	Al-Wedian Association	No	No answer	No	No	No answer	No	No answer

From table (6) 7% from the institution implement awareness program about fluoride hazardusing radio media, 50% from the institutions have general future plans to reduce the health effect hazards of high fluoride concentration,while 42% from the institution have identified the activities and interventions of the future action plans such as determine the fluoride concentration in water, reduce the high fluoride concentration, stop using the source for drinking, different awareness programs using different media.

Chapter 7: Conclusions&Recommendations

7.1 Conclusions

IWRM components are weakly implemented in Mawyah district. The technical, social, legal, and investment components are partially available and implemented in Mawyah district. The IWRM structure needs to be strengthened by capacity building of human resources. This is clearly seen from the results of the social and stakeholders studies.

The stakeholders study shows that most of the decision makers do not have good background about the IWRM and about the flouresis. The tools required to take decisions are not available. A limited inaccessible data is available in NWRA-Taiz while other organizations do not have any knowledge about flourosis.

The representative of the social components in the IWRM structure in Mawyah is mature. It is representative by water users associations. Most of those water users associations are new with very limited knowledge about IWRM. Their knowledge about IWQM is completely absent. Most of the interviewers from the society and their representative in water users associations do not know about the source of the flourosis. Some people who have flourosis visited the dentist to have solution but they do not get good results and still does not know the cause of the flourosis. Some people tries different natural medication but they fail to remove the flourosis. Some of them said that flourosis is a problem. Others do not feel it is a problem.

Water chemistry analysis present that floured with high concentration exceeding the WHO and Yemeni standards limits are found in some samples (areas). High fluoride concentration exceeding the standard limits was observed in 35% of the samples. The exceeding samples categorize to three groups. High fluoride concentration group with a fluoride concentration exceeding >4.5 mg/l, moderate concentration group with limits between 3 mg/l and 4.5mg/l, and low concentration group with limits between 1.5 mg/l and 3 mg/l.

The high exceeding limit group is located in Amamah sub district. The moderate group is located at the outer boundaries of Amamah, Gurane, Mariah, Qamahdah, and Al Dohrah sub districts. The low concentration group is found in KhadirAlburiahe, Al Duhrah, Mabar, Ahkrak, Mumaj, Al Mahta, Auman, and Asrar sub districts.

The social study performed in the areas are highly matched with the fluoride concentration analysis results of the water chemistry analysis of the samples. Moreover, the grouping of the concentration can easily recognized with the flourisis on the people.

7.2 Recommendations

To resolve or minimize the consequences of critical water resources quantity and quality effects on the life of Mawyahs population as social, agricultural, legal and economic aspectsan implementation of efficient IWRM is required soon. This can be achieved by the following:

- Preparing an Integrated Water Resources Management Plan (IWRMP).

This requires in depth studies as:

  - A socio-economic study.
  - An agricultural study.
  - Updating the hydrogeological and hydrological study.

- Complete building IWRM structure especially the social component through:
    - Creating water users associations for all stakeholders in the sub basin levels and basin level.
- Strengthening the capacity building of the IWRM components giving the social component priority.
    - Mobilizing the society to organize themselves in water user associations.
    - Public participation including WUAs in planning, decision making and implementing water projects.

- Capacity building for all stakeholders should include training programs towards the following aspects:
    - Random well drillings in Mawyah and its effects.
    - Random investment in groundwater.
    - Environmental problems related to water supply in Mawyah district.
    - Fluoride concentration in water supply of Mawyah.
    - Simple actions to resolve part of the flourosis problem in Mawyah.

- Formulate complete intensive package of awareness program towards IWRM components.
- Implement the awareness program for all IWRM components.
- Let the IWRM decision makers decide the priorities of the implementation of the MIWMP.

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Annex 1

- **Water Quality Sheet**
- **Questionnaire Sheet**
- **Interviews Sheet**

Water Quality Sheet

Report on Collected Sample of Water

Date and time: **Sample No.( )**

Governorate: Taiz **Distract: Mawyah**
Village:

The Location	
Type of the source	
Requested by	

Physical Parameters	Unit	Value	Remarks
Color	Co/Pt		
Electrical Conductivity at 25 °C	μs/cm		
Total Dissolved solid (EC × 0.65)	Mg/L		
PH at 25 °C			

Notes of the location and the source:-

____

____

____

____

____

استبيان خاص بمشكلة زيادة تركيز الفلوريد في الماء من منظور الادارة المتكاملة للموارد المائية

النوع / .... اسم المنطقة ....

مصدر ماء الشرب .... نوع الأكل ....

العمر ظهور اللون

<u>تأثيره على الصحة :</u>

شكل الأسنان			
الانتظام	نعم	لا	
القوة	قوية	هشة	
لونها	أبيض	صفراء	بني

العظام		
شكل الهيكل	مستوي	لا
القوة	قوية	هشة
الكسور(في حال الجواب ضعيفة)	كبيرة	صغيرة
الحركة	سهلة	صعبة

<u>التأثيرات الاجتماعية والاقتصادية :</u>

لون الأسنان هل له تأثير على نفسية الشخص ؟	نعم	لا	
هل الاخرين يتقبلون أصحاب الأسنان الملونة ؟	نعم	لا	
هل تعرف سبب المشكلة ؟	نعم	لا	
هل زرت دكتور أسنان لمعرفة سبب المشكلة؟	نعم	لا	
سبب عدم الزيارة ؟	اعتبار الأمر طبيعي	التكلفة المادية	أسباب أخرى
هل له تأثير على نسبة الزواج في المنطقة؟	نعم	لا	
هل لديك الرغبة بالتخلص من اللون ؟	نعم	لا	
هل جربت طرق لإزالة اللون؟	نعم	لا	
ماهي ؟؟	١.	٢.	٣.
هل كانت النتائج مقنعة ؟؟	نعم	لا	

استبيان لمتخذي القرار حول ظاهرة التراكيز العالية للفلوريد في محافظة تعز من منظور الإدارة المتكاملة للموارد المائية

١. اسم الجهة :..اسم المجيب..................................

رقم التلفون:...

٢. مسئولية الجهة في موضوع البحث.

- فني
- رقابي
- اداري
- كل ماسبق

٣. الجهة تعتبر التراكيز العالية للفلوريد في مصادر المياه ظاهرة واسعة الانتشار.

- نعم
- لا
- جزئيا

٤. التراكيز العالية للفلوريد في مصادر المياه من منظور الجهة مشكلة خطيرة.

- نعم
- لا

٥. تتوفر لدى الجهة بيانات شاملة عن تراكيز الفلوريد وانتشاره الجغرافي في نظام عملها.

- نعم
- لا
- جزئيا

٦. البيانات المتاحة لدى الجهة متوفرة في نسق:

- قاعدة بيانات حاسوبية
- ارشفة يدوية
- كليهما

٧. تستخلص الجهة بياناتها وفق تحليل كيميائي شامل لعينة المصدر المائي المستهدف

- نعم
- لا
- وفقا لاخرى (تذكر).

٨. عند ظهور ارتفاع ملحوظ لتراكيز الفلوريد في المياه تبادر الجهة فورا لاتخاذ الإجراءات المناسبة.

- نعم
- لا
- احيانا

٩. الحدود القصوى المسموح لتراكيز الفلوريد التي تعمل بها الجهة وفقا لـــ

- المواصفات اليمنية
- منظمة الصحة العالمية
- اخرى بحسب الجهة (تذكر)

١٠. ابرز تدخلات الجهة عند ظهور عند ظهور تراكيز عالية للفلوريد هي:

- ايقاف المصدر المائي
- معالجة المياه
- توعية المستهلك
- اخرى (تذكر)

١١. الانتشار الجغرافي (الاداري) لظاهرة التراكيز العالية للفلوريد في مصادر المياه وفقا لمعلومات الجهة هي بحسب الارتفاع الملحوظ

١. ....
٢. ....
٣. ....

١٢. المصدر المائي ذو التراكيز العالية للفلوريد وفقا لمعلومات الجهة عادة يكون

- مياه جوفية ضحلة
- مياه جوفية عميقة
- مياه عيون
- اخرى (تذكر)

١٣. التكوين الصخري الحامل للمياه اعتمادا على الارتفاع الملحوظ و وفقا لبيانات الجهة عادة يكون

١. ....
٢. ....
٣. ....
٤. ....

١٤. الجهة على معرفة بظهور اثار صحية على الانسان

- o نعم
- o لا

١٥. في حالة الاجابة بـ نعم :

A. التأثيرات الصحية على الانسان كانت بشكل حاد

- o نعم
- o لا

B. طبيعة الاثار الصحية الناجمة بحسب درجة خطورتها هي

١) ....

٢) ....

٣) ....

١٦. نظمت الجهة توعية للمواطنين بخطورة الفلوريد على الصحة وسبل الوقاية

- o نعم
- o لا

١٧. الوسائل للاعلامية المستخدمة لايصال رسالة التوعية

- o مرئية
- o مسموعة
- o مقروءة
- o كل ما ورد

١٨. لدى الجهة رؤية مستقبلية (وفقا لمسئوليتها)للتخفيف من الاثار الصحية الخطيرة على الانسان الناجمة عن هذه الظاهرة:

- o نعم
- o لا

١٩. في حالة الاجابة بـ نعم

٢٠. ابرز الخطوات / الانشطة/ البرامج / الوسائل لهذة الرؤية.

١. ....

٢. ....

٣. ....

Standards for the composition of drinking water and contribution of drinking water to the intake of elements in nutrition (Appelo et al, 1993).

Constituent	**Contribution to mineral nutrition (%)**	**Highest admissible concentration (mg/l)**	**Comment**
Mg^{2+}	3-10	50	Mg/SO4 diarrhea
Na^{+}	1-4	175	
Cl^{-}	2-15	300	Test; safe<600mg/l
SO_4^{-2}		250	Diarrhea
NO_3^{-}		50	Blue baby disease
NO_2^{-}		0.1	
F^{-}	10-50	1.7	Lower at high water consumption
As	Ca.30	0.05	Black-foot disease
Al	..	0.2	Acidification/Al-flocculation
Cu	6-10	0.1	3mg/l in new piping systems
Zn	Negligible	0.1	3mg/l in new piping systems
Cd	..	0.005	
Pb	..	0.05	
Cr	20-30	0.05	

Annex 2

- **Classification of water samples**
- **Piper Diagram**
- **Classification of water samples by Piper Diagram**
- **Durov Diagram**
- **Stiff Diagram**

Table 4 Classification of water samples:

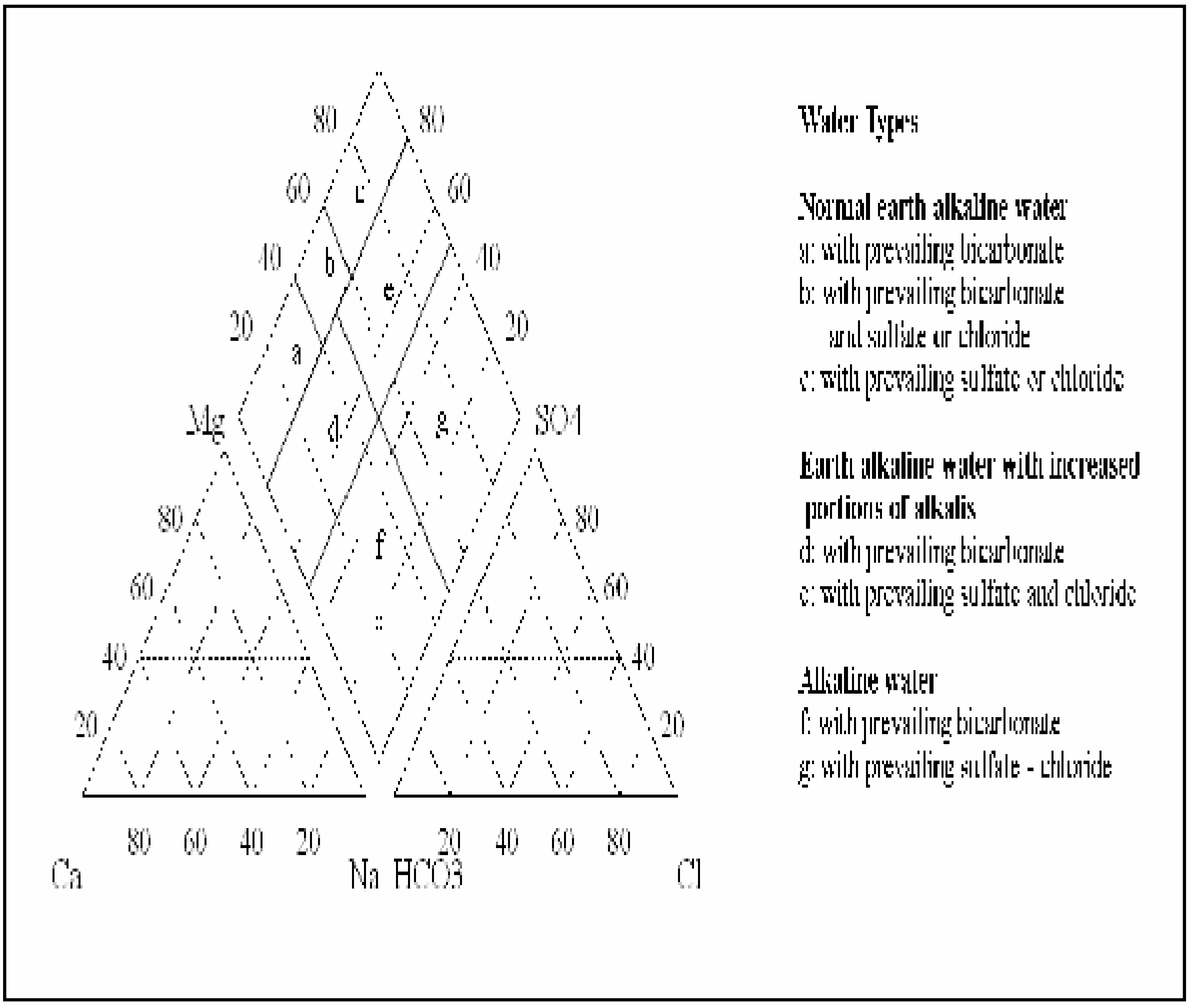
Elements	Total Dissolved solids (mg/l)					Total Hardness (mg/l)			PH		
Range	0-500	500-1000	1000-1500	1500-2000	2000-10000	30-150	150-300	300>	6.5	7	8.5
Classification	Very Fresh	Fresh	View Salt	Medium Salt	high Salt	Soft Water	Hard water	Very Hard water	Acidic water	Moderate water	Basic water
1		804.72						365		7.66	
2			1462.5					700		7.53	
3		503.44					298			7.52	
4				1590.4				366			8.34
5			1016.6					480		7.63	
6					2554.5			1079		7.38	
7					2060.5			564			8.27
8			1069.9					426		7.26	
9					3224			930		7.24	
10		641.76						333			8.12
11			1410.5					625		7.61	
12			1422.4					518			8.07
13			1201.2					598		7.54	

Elements	Total Dissolved solids (mg/l)					Total Hardness (mg/l)			PH		
Range	0-500	500 1000	1000 1500	1500-2000	2000 10000	30-150	150-300	300>	6.5	7	8.5
Classification	Very Fresh	Fresh	View Salt	Medium Salt	high Salt	Soft Water	Hard water	Very Hard water	Acidic water	Moderate water	Basic water
14					2223			450		7.8	
15				1735.5				359			8.13
16	403.76							335		7.56	
17			1209.6					682		7.29	
18			1226.4					407		7.75	
19			1220.8					501		7.61	
20			1193.4					520		7.29	
21	433.44							318		7.29	
22		942.48						502		7.88	
23			1102.00					595		7.19	
24		806.96						320		7.27	
25			1196					519		7.88	

Elements	Total Dissolved solids (mg/l)					Total Hardness (mg/l)			PH		
Range	0-500	500-1000	1000-1500	1500-2000	2000-10000	30-150	150-300	300>	6.5	7	8.5
Classification	Very Fresh	Fresh	View Salt	Medium Salt	high Salt	Soft Water	Hard water	Very Hard water	Acidic water	Moderate water	Basic water
26	396.48							316		7.56	
27				1747.2				1006			8.04
28			1282.4					706		7.55	
29				1506.4				349			8.23
30					2177.5			753		7.49	
31			1047.76					608		7.59	
32	375.2							314		7.53	
33				1651				744		7.6	
34			1104.35					438		7.36	
35			1215.2					454		7.87	
36		872.95						351		7.83	
37		514.08					261				8.28

Elements	Total Dissolved solids (mg/l)					Total Hardness (mg/l)			PH		
Range	0-500	500-1000	1000-1500	1500-2000	2000-10000	30-150	150-300	300>	6.5	7	8.5
Classification	Very Fresh	Fresh	View Salt	Medium Salt	high Salt	Soft Water	Hard water	Very Hard water	Acidic water	Moderate water	Basic water
38		643.5						451			8.1
39		545.44						391		7.36	
40		694.96						416		7.59	
41					2164.5			1017		7.4	
42	374.64							306		7.46	
43		562.24						411			8.08
44		912.24						533		7.71	
45		736.96						461		7.67	
46					2333.5			1133		7.34	
47				1937				860		7.33	
48	349.7						210			7.46	
49					3048.5		252				8.05

Elements	Total Dissolved solids (mg/l)					Total Hardness (mg/l)			PH		
Range	0-500	500-1000	1000-1500	1500-2000	2000-10000	30-150	150-300	300>	6.5	7	8.5
Classification	Very Fresh	Fresh	View Salt	Medium Salt	high Salt	Soft Water	Hard water	Very Hard water	Acidic water	Moderate water	Basic water
50				1644.5				756		7.39	
51		747.04						349		7.34	
52					2374.4		219			7.73	
53				1668.8				912	6.85		
54		570.64						390	6.87		
55			1478.4					429		7.42	
56					2320.5			1257		7.38	
57				1624				737			8.17



Piper diagram showing the different water types (Langguth. 1966).

Classification of water samples by piper Diagram in Mawyah district

No.of Well	Water Type	Dissolved minerals	Classification of water
W-10	Na-Mg-HCO3	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing bicarbonate
W-18	Na-Ca-HCO3-Cl	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing bicarbonate
W-19	Na-Mg-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing bicarbonate
W-33	Na-Mg-Ca-HCO3-Cl	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing bicarbonate
W-34	Na-Ca-Mg-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing bicarbonate

1

W-51	Na-Ca-HCO3-Cl	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing bicarbonate
W-1	Na-Mg-HCO3	Halite (NaCl)+ Anhydrite (CaSO4)	Alkaline water with prevailing bicarbonate.
W-7	Na-Mg-SO4-HCO3-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-8	Na-Ca-Mg-HCO3-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-9	Na-Mg-Cl-So4-HCO3	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-11	Na-Mg-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-12	Na-Mg-SO4-HCO3-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-14	Na-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-15	Na-Mg-Cl-HCO3	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride

W-17	Na-Mg-Ca-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-20	Na-Ca-Mg-SO4-HCO3	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-21	Ca-Mg-Na-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-22	Na-Mg-Ca-SO4-Cl-HCO3	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-26	Ca-Mg-HCO3-Cl	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-27	Mg-Na-Ca-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-31	Mg-Na-Ca-Cl-SO4-	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride

	HCO3		
W-32	Ca-Mg-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-44	Na-Mg-Ca-HCO3-SO4-Cl	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-47	Na-Mg-Ca-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-49	Na-Mg-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-50	Na-Mg-Ca-Cl-HCO3-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-52	Na-HCO3-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-53	Na-Mg-Ca-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride

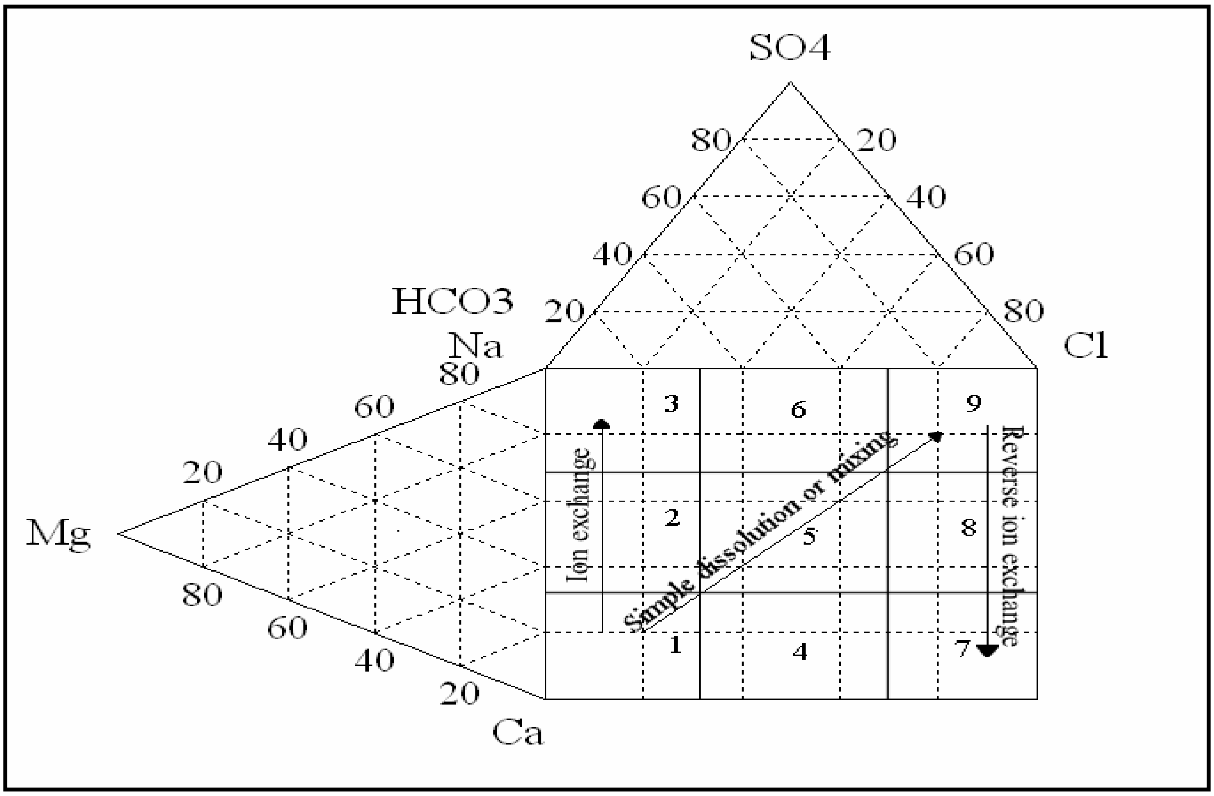
W-55	Na-Ca-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-57	Na-Mg-Ca-SO4-Cl-HCO3	Halite (NaCl)+Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-4	Na-HCO3-Cl	Halite (NaCl)+Dolomite(CaMg(CO3)2)+ Anhydrite (CaSO4)	Alkaline water with prevailing sulfate or chloride
W-3	Ca-Na-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-23	Na-Ca-Mg-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-29	Na-Ca-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-36	Na-Mg-HCO3-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate

W-39	Ca-Mg-Na-HCO3-Cl	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-40	Ca-Na-HCO3-Cl-SO4	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-42	Ca-Mg-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-43	Ca-Mg-Na-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-48	Ca-Na-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-54	Ca-Na-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing bicarbonate
W-2	Na-Mg-Ca-HCO3-Cl-	Halite (NaCl +Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with

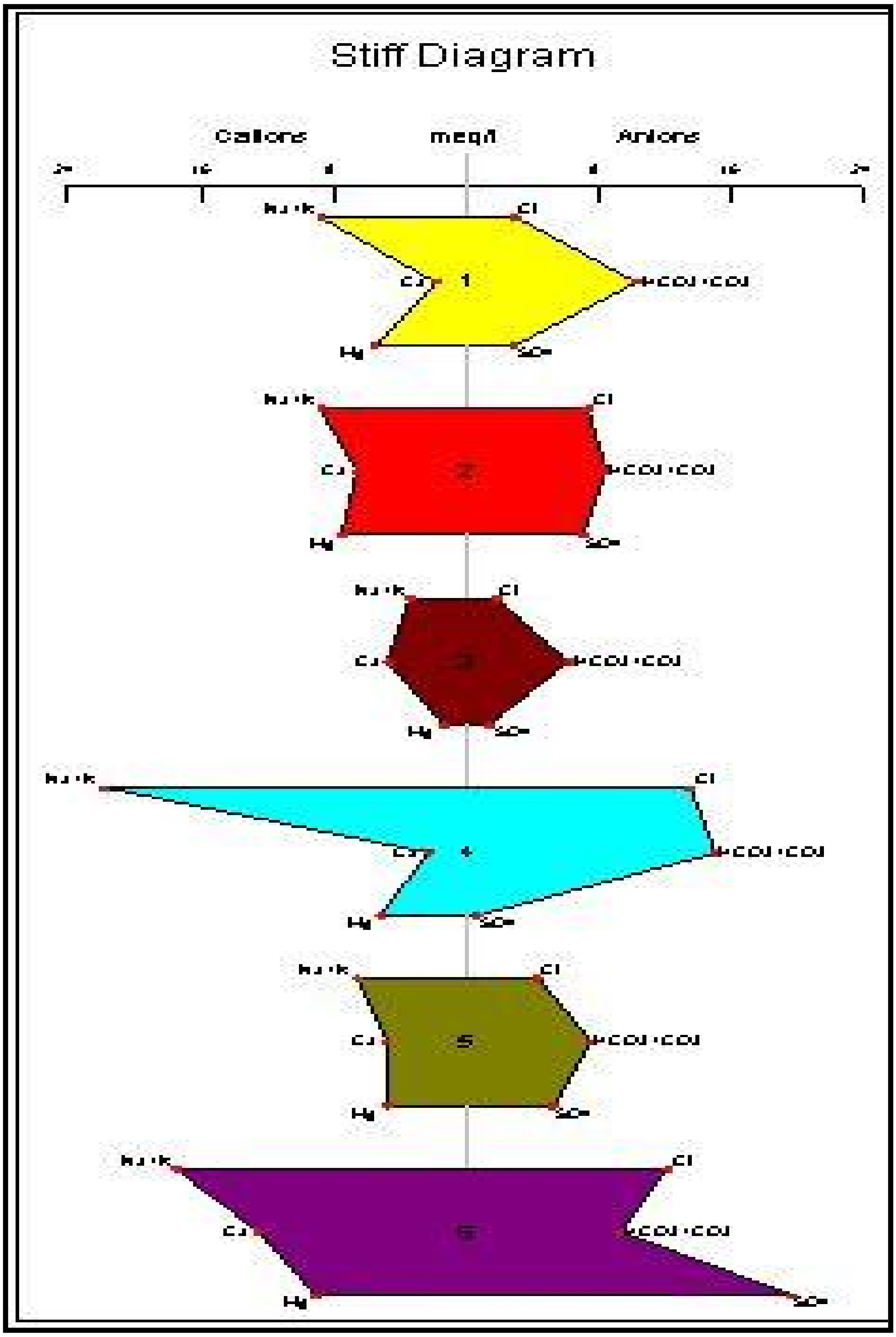
	SO4		prevailing sulfate or chloride
W-5	Na-Ca-Mg-HCO3-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-6	Na-Ca-Mg-SO4-Cl-HCO3	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-13	Mg-Na-HCO3-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-24	Na-Ca-HCO3-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-25	Na-Mg-Ca-Cl-HCO3-SO4	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-28	Na-Mg-Ca-HCO3-Cl-SO4	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride

W-30	Na-Mg-Cl-So4-HCO3	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-35	Na-Mg-HCO3-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-37	Na-Mg-Ca-HCO3-SO4	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-38	Ca-Mg-HCO3	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-41	Na-Mg-Ca-HCO3-Cl-SO4	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-45	Ca-Mg-Na-HCO3-Cl-SO4	Halite (NaCl)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-46	Na-Mg-Ca-Cl-SO4-Cl	Halite (NaCl)+Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with

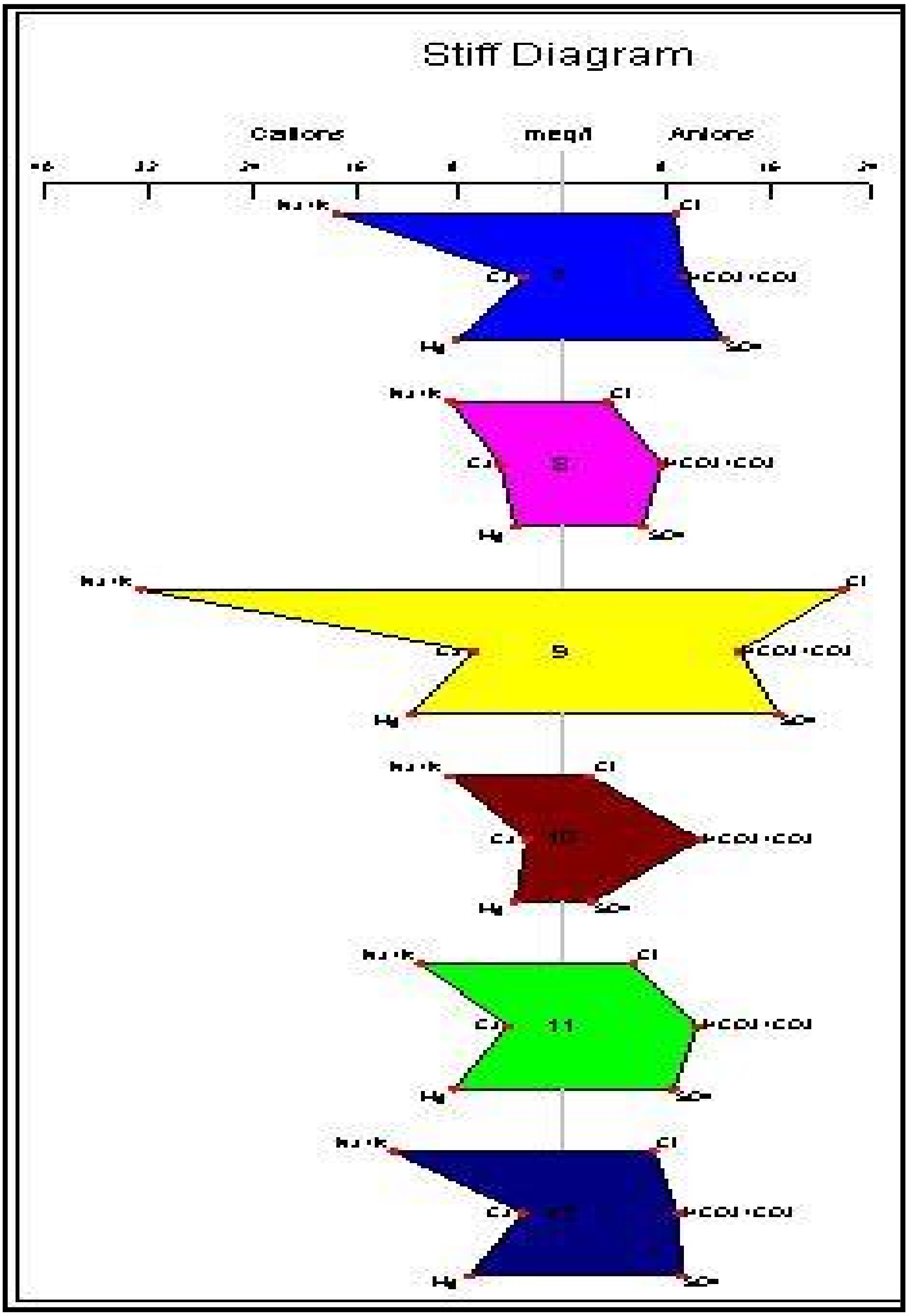
			prevailing sulfate or chloride
W-56	Ca-Na-Cl-SO4	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Earth alkaline water with increased portions of alkalis with prevailing sulfate or chloride
W-16	Ca-Mg-HCO3-Cl	Halite (NaCl)+Carbonate (CaCo3)+Dolomite (CaMg(CO3)2)+ Anhydrite (CaSO4)	Normal earth alkaline water with prevailing bicarbonate and sulfate or chloride



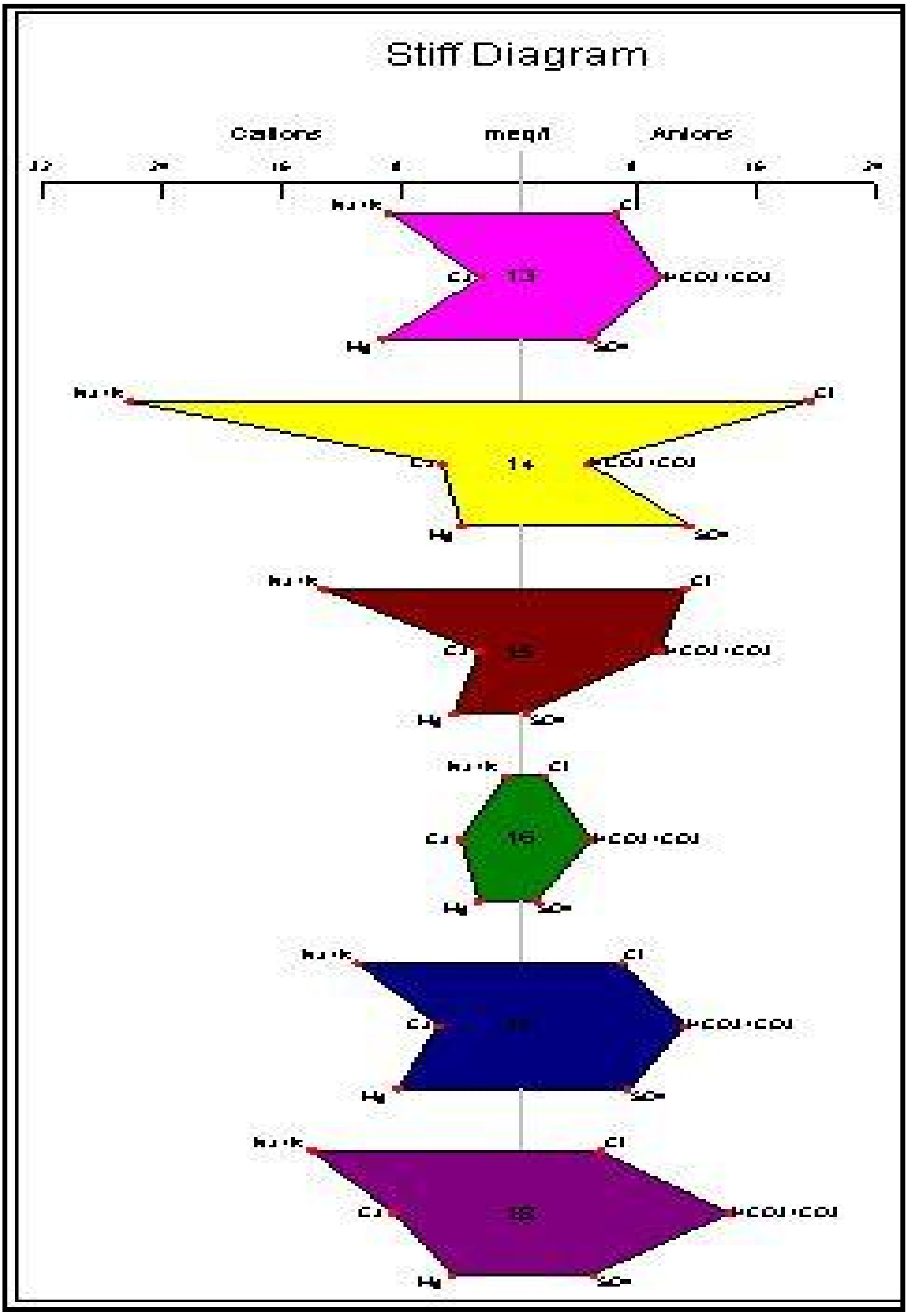
Durov diagram divisions for the major ions (Lloyd and Heathcoat (1985).



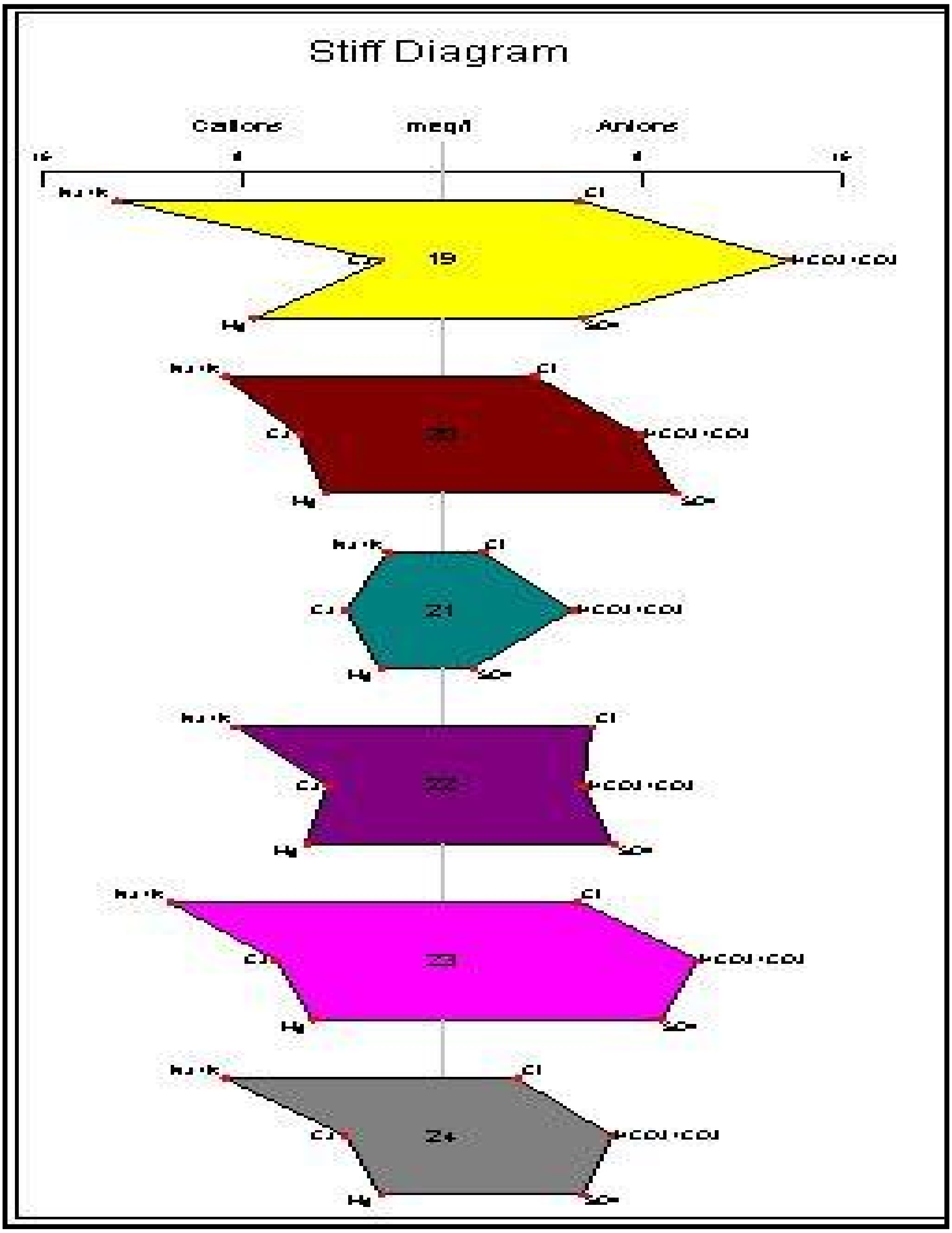
Stiff diagram for water samples (1-6)



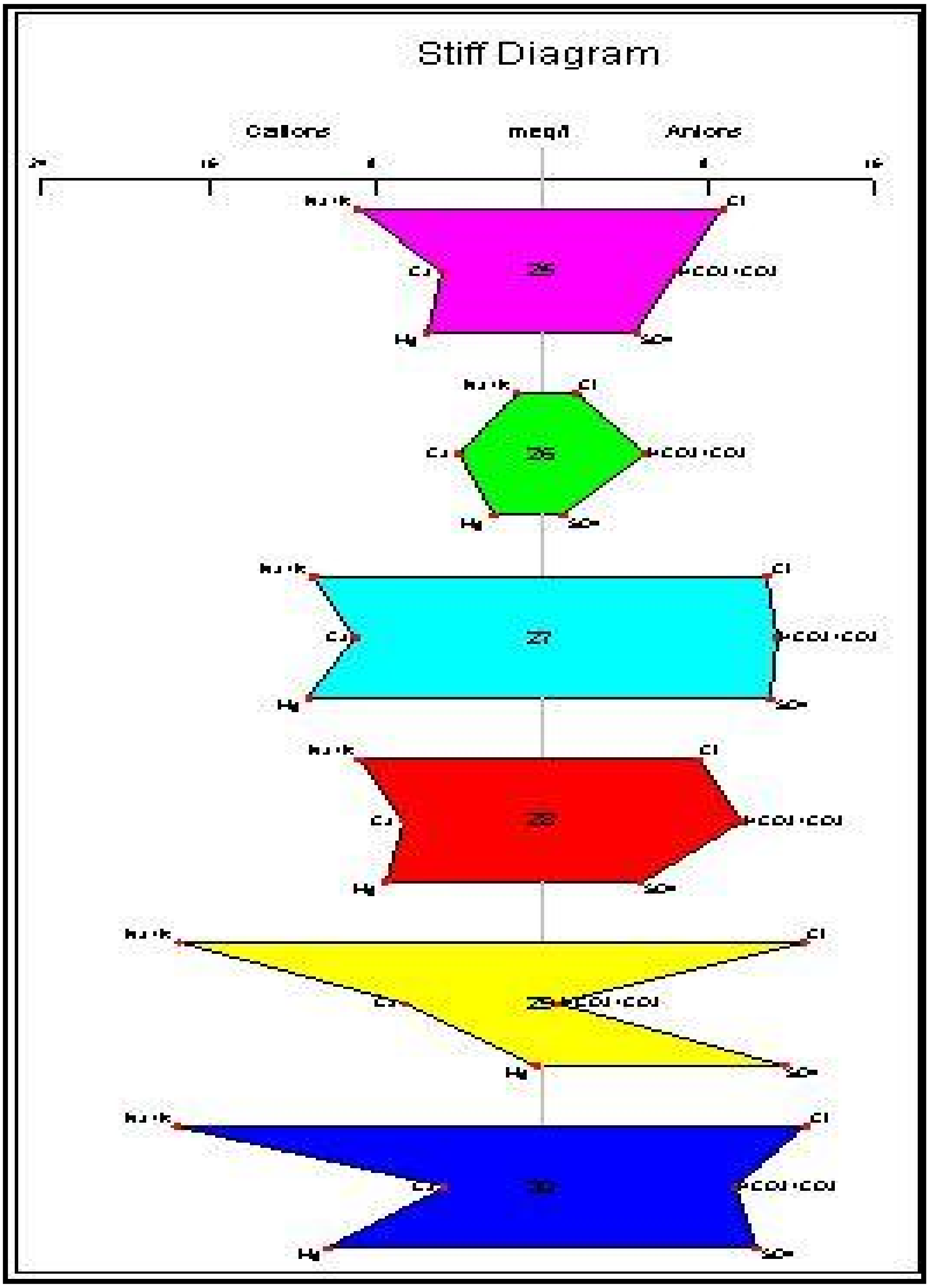
Stiff diagram for water samples(7-12)



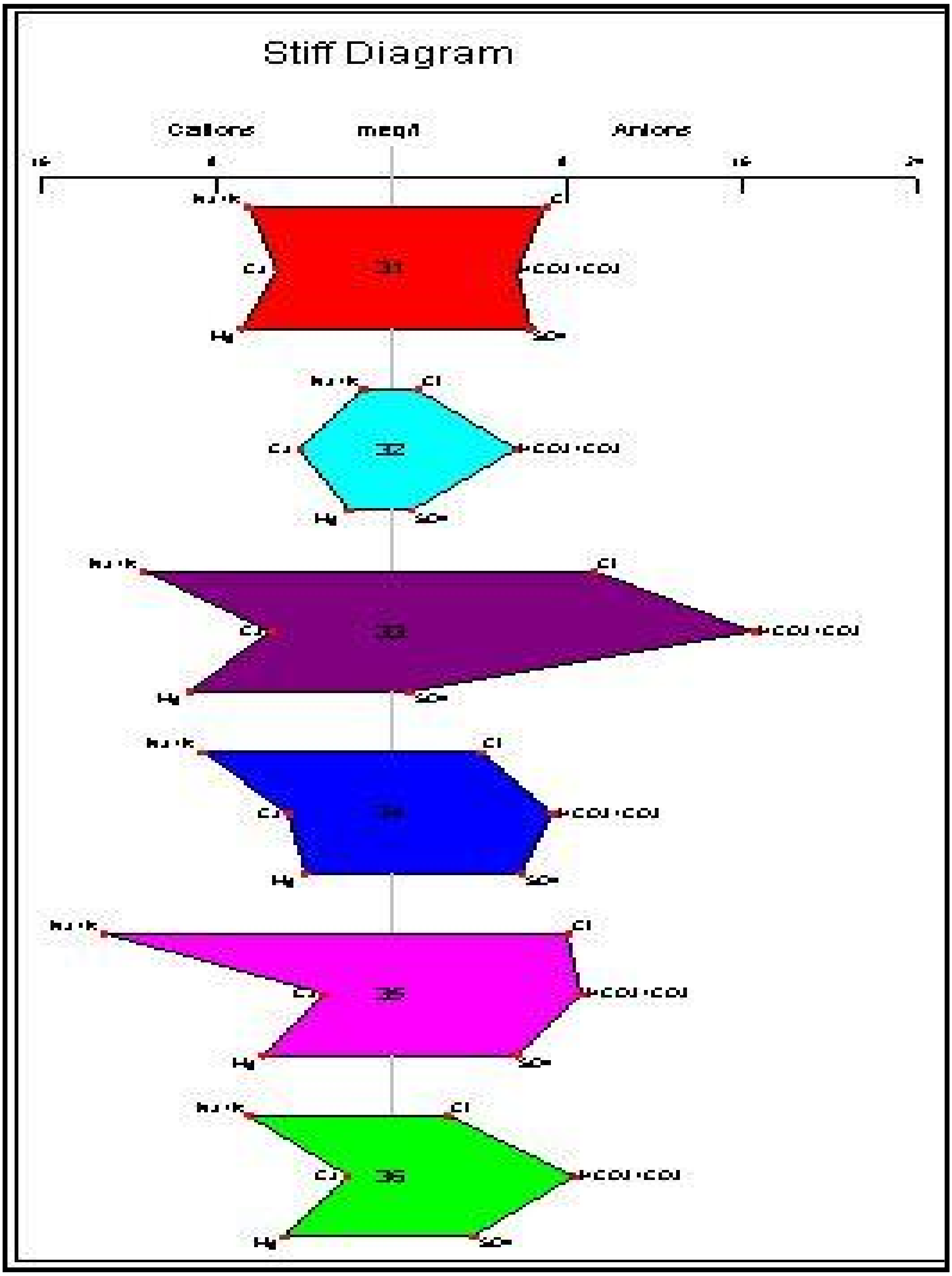
Stiff diagram for water samples(13-18)



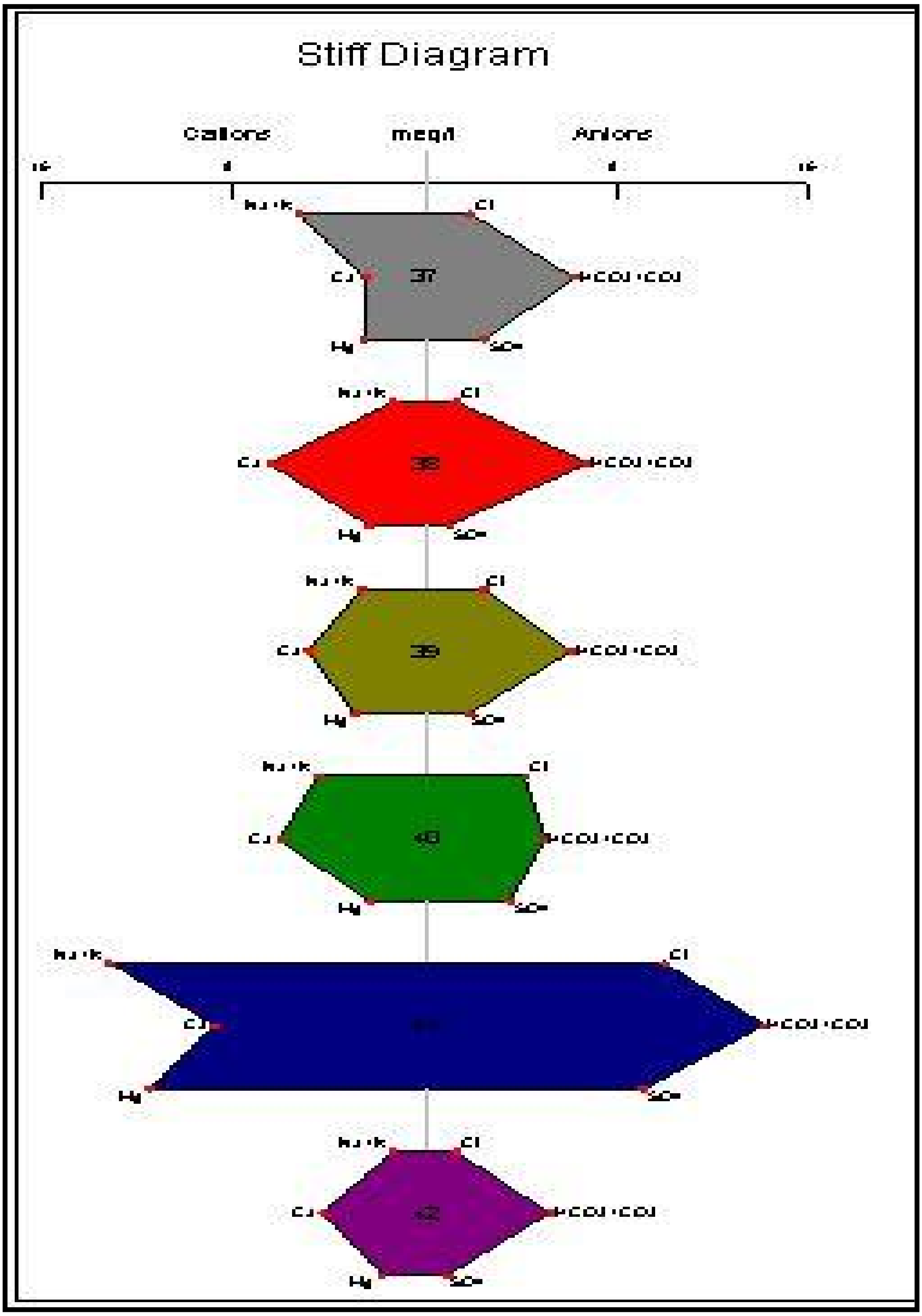
Stiff diagram for water samples (19-24)



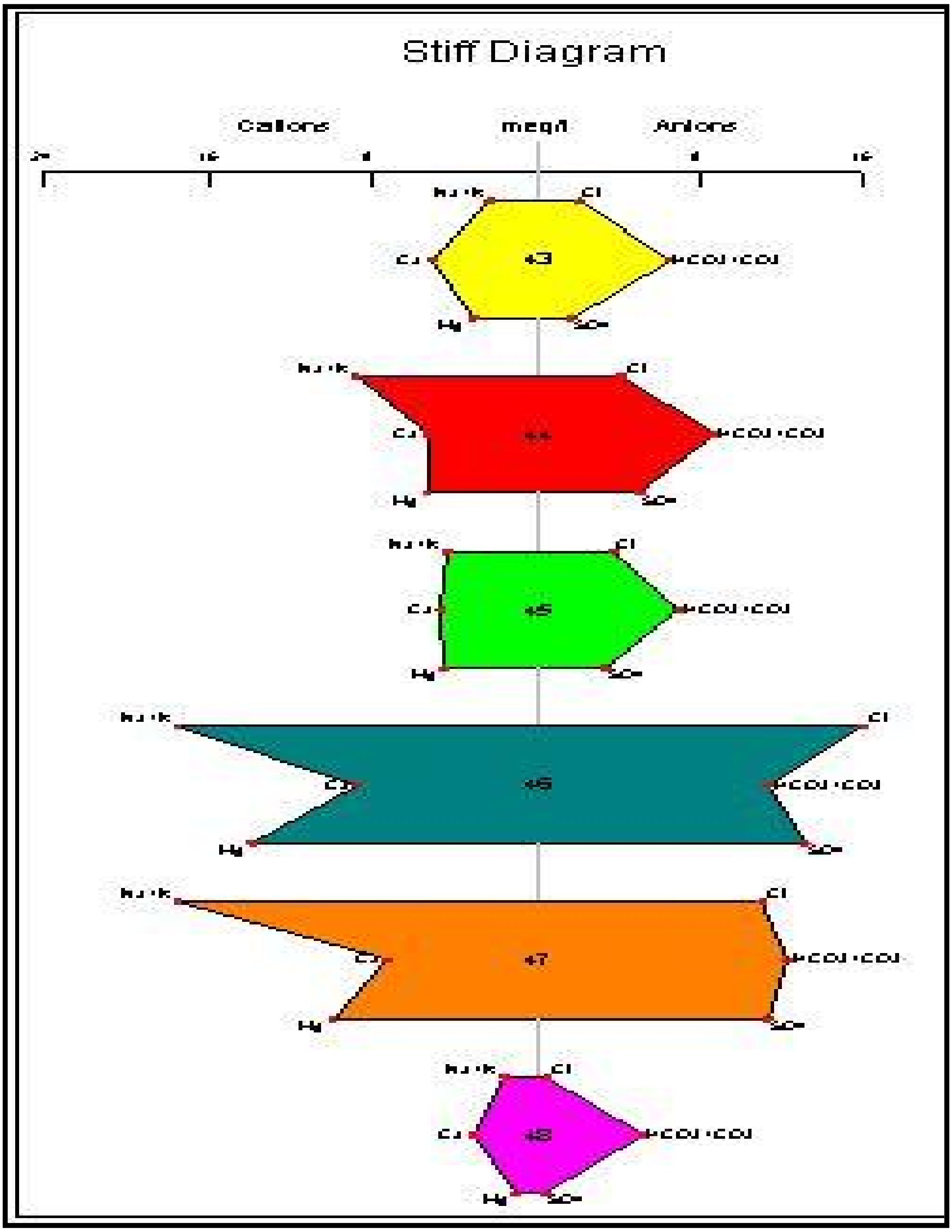
Stiff diagram for water samples (25-30)



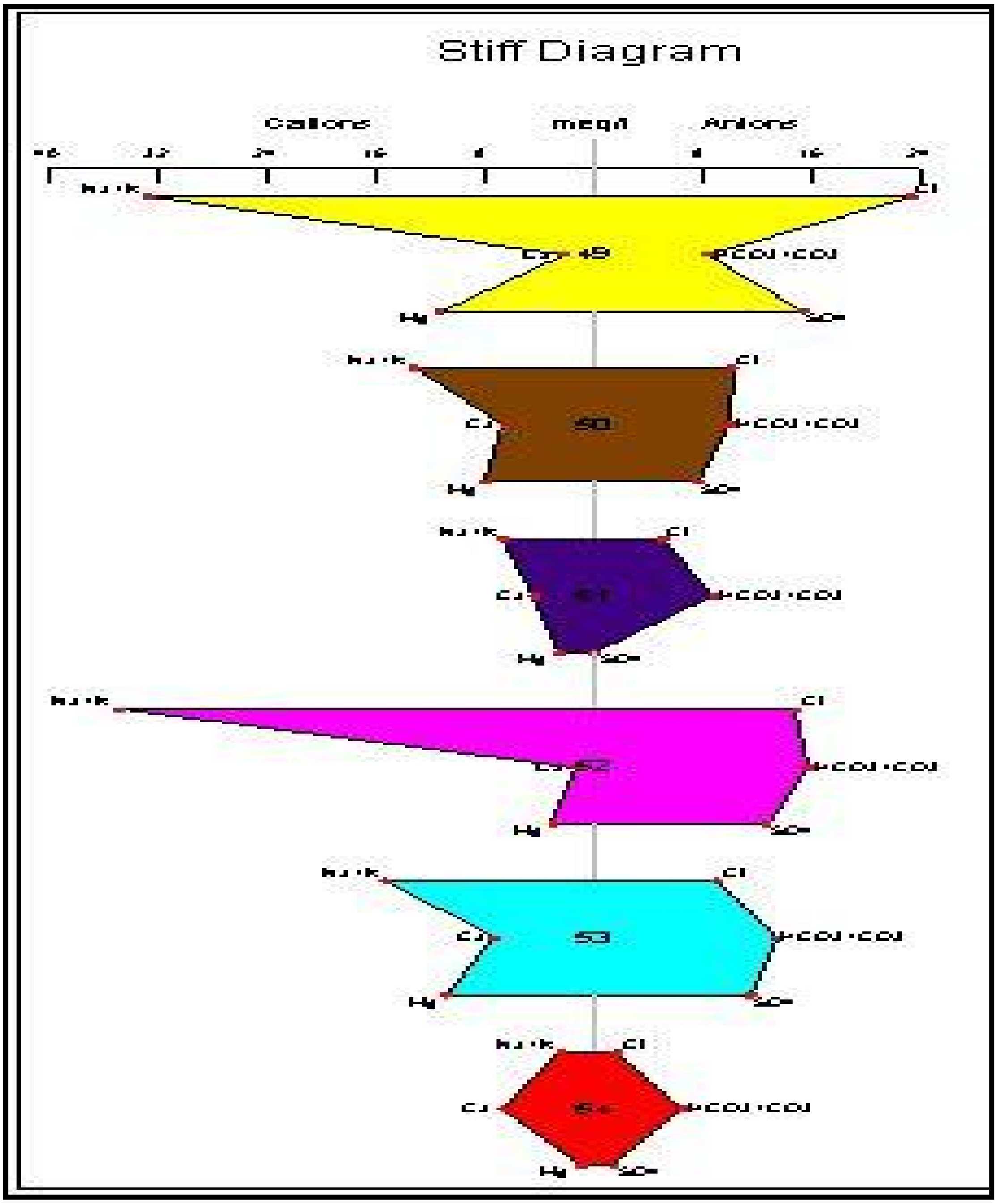
Stiff diagram for water samples (31-36)



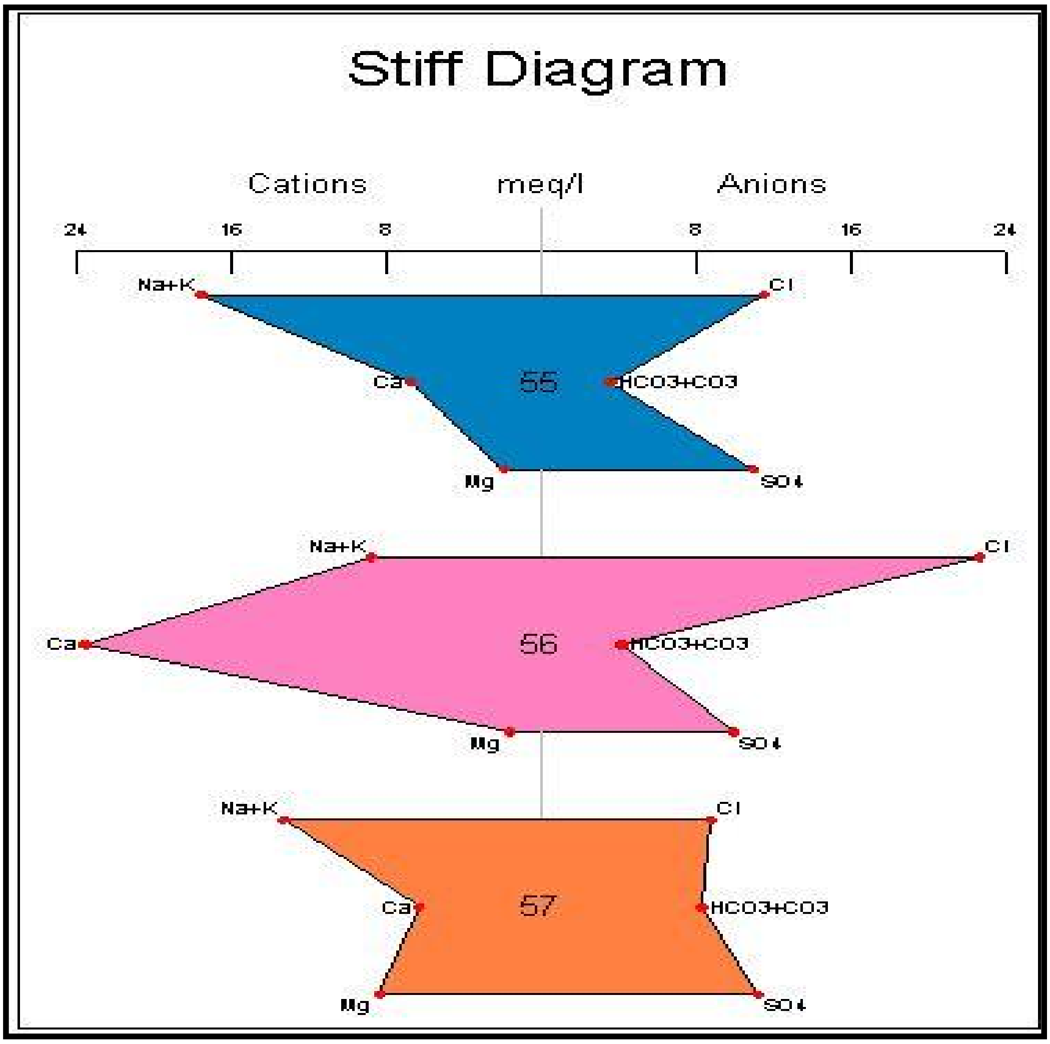
Stiff diagram for water samples (37-42)



Stiff diagram for water samples (43 – 48)



Stiff diagram for water samples(49-54)



Stiff diagram for water samples (55-57)

Annex 3

- **The interviews with Decision markers**

The interviews by Decision markers

NO	What are the responsibility/ies of the organization in the research subject?	Does the organization think that the high fluoride concentration in water resources is wide spread?	Does the organization Think that high fluoride concentration in the water resources is a huge dangerous hsiue.	Does the organization has detail data about the fluoride concentration distribution in the area?	How does the data organize in the organization?	Does the organization collect its data according to detail chemical analysis for water samples collection from the source?	Does the organization take any action if the fluoride concentration is high?	What type of standards does the organization use?	What is the most critical interference does the organization use if the fluoride concentration high?	What is the name of the areas with high fluoride concentration?	In what type of water source does fluoride concentration appears in the area?	In what type of rock formation does fluoride concentration appears in the area?	Doe the organization knows if there is fluoride effects in the people of the area?	Is the effect clear?	In what type of fluoride effects appear in the area?	Does the organization implement any awareness program about the fluoride effects?	What type of media used to implement the awarenesss program?	Does the organization have any vision (according to its responsibility) for future interference to reduce the effects of fluoride concentration?	What are the mean plans, activities, programs, and tools to implement such vision?
1	Technical-Monitoring	part	Yes	part	Hard copy	Yes	occasionally	Yemeni standard	awareness	Taiz city - Mawyah	shallow water - springs	Base rocks	Yes	Yes	change the color of teeth	No	No answer	No answer	No answer
2	Technical	Yes	Yes	No	No answer	No	Yes	No answer	stop the source-treatment the water-awareness	Taiz city	shallow water	No answer	Yes	Yes	change the color of teeth	No	No answer	Yes	awareness - journal
3	Technical-Monitoring	Yes	Yes	No	No answer	No	No answer	No answer	No answer	No answer	Deep water	No answer	Yes	Yes	change the color of teeth	No answer	No answer	Yes	Analysis the fluoride element - awareness
4	Technical-Monitoring	No	Yes	Yes	Hard copy	Yes	Yes	Yemeni standard - WHO	stop the source - awareness	Mawyah - Jabal Saber	Deep water	Volcanic rocks	Yes	Yes	change the color of teeth	Yes	audible	Yes	workshops
5	No answer	No answer	No answer	No answer	No answer	Yes	No answer	No answer	No answer	No answer	No answer	No answer	No answer	No answer	No answer	No answer	No answer	Yes	No answer
6	Administration	part	medial	Yes	all them	Yes	Yes	No answer	No answer	Mawyah	shallow water - springs	No answer	Yes	Yes	change the color of teeth	No	No answer	Yes	awareness - treatment the drinking water
7	All them	Yes	Yes	No	Not have	No	No	No answer	No answer	Mawyah	No answer	No answer	No	No answer	change the color of teeth	No	No	No	No answer
8	Monitoring	part	Yes	Yes	Not have	No	No answer	No answer	No answer	Mawyah	springs	Volcanic rocks	Yes	Yes	change the color of teeth	No	No answer	Yes	awareness
9	Technical	No answer	No answer	No answer	No answer	Yes	Yes	Yemeni standard	stop the source - Mixing water	Jabal Saber	springs	igneous rocks	Yes	No	change the color of teeth	No answer	No answer	Yes	don't used this source
10	Monitoring	part	Yes	part	Hard copy	No	No	Yemeni standard	stop the source	Jabal Saber	springs	No answer	Yes	No	change the color of teeth	No	No answer	No	No answer
11	Technical	part	No	part	all them	Yes	Not found	Yemeni standard	Not happened	Jabal Saber	No answer	sedimentary and volcanic rocks	Yes	Yes	change the color of teeth	No	No answer	No answer	No answer
12	Administration	Yes	Yes	No	Hard copy	No	No	Yemeni standard	Not use	No answer	Deep water	igneous rocks	No	No	change the color of teeth	No answer	No answer	No	No answer
13	Technical-Monitoring	Yes	Yes	No	No answer	No	No	No answer	No answer	Mawyah	Deep water	Volcanic rocks	No	No	No answer	No	No answer	No	No answer
14	Administration	Yes	Yes	No	No answer	No	No	Yemeni standard	No answer	Mawyah	Deep water	Volcanic rocks	Yes	Yes	change the color of teeth	No	No answer	No	No answer

المقدمة:

ماوية مديرية ضمن مديريات محافظة تعز اظهرت مشكلة محدودية المصادر المائية مع الاستخدام المكثف للمياه الجوفية خاصة في ري القات.

ندرة المياه و الاستخدام العشوائي لها ادى الى ظهور مشاكل في الكمية والنوعية واجتماعية واقتصادية.

ظاهرة التفلور واحدة من هذة المشاكل في مديرية ماوية.

الادارة المتكاملة للموارد المائية هي وسيلة تستخدم لتحديد وتقييم واقتراح الحلول للمشاكل.وهذة الدراسة ركزت على الارة المتكاملة لنوعية مصادر المياه للابار الخاصة بالشرب وامدادات المياه وذلك لتقدير الاثار الصحية والاجتماعية والاقتصادية لزيادة تركيز الفلوريد وايضا مقابلة متحذي القرار في المديرية.

الابار الخاصة بالشرب و امداد المياه حددت وجمعت العينات تبعا للشروط المحددة , تحليل العينات وتقييمها وفق مبادئ الادارة المتكاملة للموارد المائية.

باستخدام عدة خرائط مختلفة مثل خريطة الاساس وخريطة النقاط المائية , خريطة العزل والخريطة الجيولوجية والطبوغرافية وايضا من البيانات الخاصة بالعمل الحقلي رسمت خريطة نوعية المياه الخاصة بالمديرية.

نتائج التحليل الكيميائي للعينات اوضحت ارتفاع التوصيلية الكهربية في 37% من العينات. ارتفاع العسرة الكلية في 46%من العينات. ارتفاعالاملاح الذائبة (حسابيا) في 33% من العينات ,وارتفاع تركيز الايونات في كل العينات 31%, 7%, 35%, و7% . ارتفاع تركيز الكاتيونات في كل من الكالسيوم والماغنسيوم و الصوديوم على التوالي 4%, 2, و 9% . ارتفاع تركيز الفلوريد في 35% من العينات من 1.6 – 16.1مليجرام/لتر وهذة النتائج تجاوزت المواصفات اليمنية ومواصفات منظمة الصحة العامة.

نتائج الدراسة الاجتماعية والصحية والاقتصادية اظهرت ان 74% من السكان يعانون من التفلور في اسنانهم, 94% من الناس لايعلمون سبب المشكلة بخجل من تغيير لون اسنانهم, 96% من الاخرين

لايتقبلون اصحاب الاسنان الملونة, 97% من يرغبون بازالة اللون من اسنانهم, 9%من السكان زاروا طبيب الاسنان للتخلص من اللون , 95%من السكان يشعرون بان هذا اللون طبيعي ,4% من السكان لم يتمكنوا من زيارة طبيب الاسنان بسبب ارتفاع التكلفة.

الدراسة شملت 14 مقابلة مع متخذي القرار لتفسير الادارة المتكاملة للموارد المائية. 79% من متخذي القرار اجابوا ان زيادة تركيز الفلوريد يسبب مشكلة , 21% من الجهات لديها بيانات عن تركيز الفلوريد, 43% من الجهات تستخلص بياناتها حول تركيز الفلوريد من التحليل الكيميائي وتستخدم المواصفات اليمنية كمرجعية.72% من متخذي القرار يعرفون الاثار المترتبة من زيادة تركيز الفلوريد في مياه الشرب, 57% من متخذي القرارلاحظوا الاثار على الانسان,50% من الجهات فكرة في اعداد خطة مستقبلية لحل مشكلة الاثار الصحية للفلوريد. 42% من هذة الجهات لديها هذةالخطةللعمل بها في المستقبل.

أظهرت الدراسهالمتكامله لنوعية المياه بان المياه المتواجده في الخزان الرسوب الذي يمثل المصدر الرئيسي لمياه الشرب في ماويه هي مياه حديثه ناتجه من مياه التغذيهالناتجه من الامطار والسيول.

الضغط الجائر للخزان الناتج عن ري القات والجفاف يعملان على تركيز بعض العناصر الكيميائيه التي توثر في بعض المعاملات مثل التوصيلية الكهربية , العسرة الكلية والاملاح الذائبة الكلية.

الادارة المتكاملة لمصادرالمياه في مديرية ماوية لاتزال في مرحلتها الاولى الى الان و لاتوجد خطة متكاملة لادارتها .تمثيل الادارة المتكاملة لمصادر المياه للجهات الحكومية في المديرية ضعيفة جدا من ناحية الوضع المؤسسي وبناء القدرات.

الإدارة المتكاملة لإدارة نوعية المياه و اثرها على سكان مديرية ماوية

بحث مقدم إلى مركز المياه و البيئة – جامعة صنعاء لاستيفاء متطلبات درجة الماجستير في الإدارة المتكاملة للموارد المائية

رندا علي احمد علي الذابل

بكالوريوس كيمياء/ علوم حياة

المشرف الرئيسي

د. عبد الله عبد القادر نعمان

استاذ الهيدرولوجيا وإدارة المصادر المائية المشارك

المشرف المشارك

د. بلقيس زباره

استاذ الكيمياء الفيزيائية المساعد

2012