بسم الله الرحمن الرحيم

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Assessment of Ground Water Quality in Omdurman City

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A thesis

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بسم الله الر حمن الرحيم

قال تعالى:-

(أولم يروا انا نسوق الماء الي الارض الجرز فنخرج به زرعا تاكل منه انعامهم وانفسهم افلا يبصرون).

سورة السجده
الايه(27)

(الله الذي يرسل الرياح فتثير سحابا فيبسطه في السماء كيف يشاء ويجعله كسفا فتري الودق يخرج من خلاله فاذا اصاب به من يشاء من عباده اذا هم يستبشرون).

سورةالروم
الايه (48)

Dedication

To the soul of my father

my mother

my brothers and sisters

my friends

those who encouraged me to complete this work.

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My thanks due to all those who participated in bringing this study to life. It is a great pleasure to be able to express my appreciation and gratitude to all of them.

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Contents

List of Tables

List of Figures

List of Appendices

Abstract

Over much of omdurman area groundwater represents the main source for the domestic water supply as well as for the limited agricultural and industrial activities.

This study was conducted in Omdurman city, which include, Omdurman, Karrari and Ombada localties, during the period from Augest 2006 to March 2007.

15 Boreholes were selected in the study area. These are distributed according to localities.

The target samples were distributed in Omdurman, Karrari and Ombada localties, and were collected from Boreholes, Storage facilities, houses and Vendors, which are feeding the houses not connected to the network, samples were taken for laboratory analysis, which included chemical, physical and bacteriological examinations.

The results of the study showed that, the majority of boreholes in study area were safe regarding chemical quality aspects. This included (F- NO_2- NO_3- CL – pH - TDS);the concentration of these parameters were within the allowable limits set by (WHO) and (SSMO).The samples taken from Elshab factory boreholes recorded high level of chlorides 7250mg/l, exceeding the maximum permissible level of 250mg/l, and TDS values, equaling 1023mg/l, were also more than the maximum permissible level of 1000mg/l in drinking water.

The results of physical quality of water samples, taken from the study area, were acceptable.

The bacteriological analysis of the water samples taken from the boreholes in the study area recorded higher level of *thermotolerant* and *Ecoli,* (46%) were more than the permissible levels set by (WHO) and (SSMO) standards.

The results of samples taken from the Storage facilities showed that (66.7%) of these facilities were safe (not polluted).

As for the Bacteriological quality of water samples taken from Houses, samples were found to be polluted by Ecoli and thermotolerant *coliforms.*

It was observed that the contamination rate of water in houses which are not connected to the net work was (62.3%) higher in comparison with those directly connected to the net work. This demonstrates the importance of distribution system in alimentally the contamination rate.

This study comes out with many suggested recommendations, the important of which are that the pollution sources should be sited away from boreholes, Septic tank and latrines should be of proper designs to eliminate infiltration to boreholes through soil layers. Also disinfection of wells is important. On the other hand legislative acts and regulation for well drilling and proper disposal of effluent is of high importance.

- Health education and awareness to consumers should be provided regarding protecting and conservation of water in houses.
- Connect all houses in the study area to the public net work of drinking water.
- Encourage research in groundwater quality in order to protect, monitor and control pollution.
- Establish ground water conservation programme.

ملخص الدراسة:-

لقد أصبحت المياه الجوفية مصدر رئيسي يعتمد عليها لتوفير ميـاه الـشرب لمجموعة مقدرة من سكان مدينة امدرمان لاستعمالها في أغـراض مـشاريع التنميـة المحدودة في الزراعة والصناعة.

أجريت هذه الدراسة في مدينة امدرمان التي تضم محليات (امدرمان وكرري وامبـدة) في الفترة ما بين أغسطس 2006 الى مارس 2007 ,بهدف تقييم نوعية المياه الجوفية.

تم اختيار 15 بئر من منطقة الدراسة وزعت حسب المحليات.

العينات المختارة تم توزيعها على محليات امدرمان وكرري وامبدة حيـث تـم جمع هذه العينات من الآبار و الخزانات و المنازل والكاورو التي تغذى المنازل غيـر المرتبطة بشبكة المياه, من اجل التحليل المعملي الـذي يـشمل الفحـص الكيميـائي و الفيزيائى والبكتريولوجى.

أوضحت نتائج الدراسة أن غالبية الآبار في منطقة الدراسة سليمة من النـواحي الكيميائية التي تضمنت (F^- NO_2^- NO_3 – CL – PH- TDS) حيث أن تركيز هـذه المواد وفق الحد المسموح به من قبـل "مواصـفات" (WHO) و (SSMO) بينمـا العينات الماخوذه من بئر مصنع سحاب سجلت تركيز عالي للكلورايد (7250 ملجرام / لتر) اعلي من الحد المسموح به وهو (250 ملجرام / لتر) كذالك تركيز المواد الصلبة الذائبة في هذه البئر بلغ (1023 ملجرام / لتر) أعلى من الحد المسموح به فـي ميـاه الشرب (1000 ملجرام / لتر).

أوضحت الدراسة أن نوعية المياه من النواحي الفيزيائية مقبولة.

أوضحت الدراسة أن النوعية البكترلوجية لعينات المياه المأخوذة مـن الابـار سـجلت مستويات عالية من التلـوث بلغـت (46.6%) بالبكتريـا القولونيـة *E. Coli* and *thermotolerant* اعلئ من الحد المسموح بـه مـن قبـل مواصـفات(WHO) و (SSMO)

أوضحت الدراسة أن النوعية البكترلوجية لعينات المياه المـأخوذة مـن الخزانـات أن (66.7%) من العينات سليمة من الناحية البكترلوجية.

كذلك النوعية الجرثومية لعينات المياه المأخوذة من المنازل في منطقة الدراسة أوضحت أن (49.6%) ملوثه بالبكتريا القولونية *E. coli* and *thermotolerant*.

من الملاحظ أن النسبة المئوية لمعدل التلوث في المنازل غير المرتبطة بشبكة المياه (62.3%) عالية مقارنة مع المنازل الأخرى المرتبطة مباشرة بالشبكة(38.3%) هذا يدل على أهمية نظام التوزيع في الحد من التلوث.

خرجت الدراسة بعدة توصيات أهمها:-

- موقع الآبار يجب ان يكون بعيدا عن مصادر التلوث.
- يجب أن يكون تصميم المراحيض وأحواض التحليل بطريقة جيدة تمنع تسرب محتوياتها للآبار من خلال طبقات التربة.
- تطبيق القوانين واللوائح في حفر الآبار وطرق التخلص من المخلفات السائلة.
- التثقيف الصحي والتوعية للمواطن بكيفية حفظ وحماية المياه على مستوى المنازل من التلوث.
- ربط جميع المنازل بمدينة امدرمان بالشبكة العامة لمياه الشرب.
- تشجيع البحث في مجال التقصي عن المياه الجوفية من اجل الحماية والرقابة والتحكم في التلوث.
- تأسيس برنامج الحفاظ على المياه الجوفية.

CHAPTER 1

Introduction

1-1 General

Groundwater is one of the most important sources of water for human life and for flora and fauna. It is generally considered to be a safer source of drinking water than surface water but can also be contaminated by bacteria. It has been a frequent cause of epidemics, sometimes with high death toll, chemical pollution, although not directly identified as such has become equally serious (Jousma and etal, 1987).Every effort should be made to achieve a drinking water quality as high practicable. Protection of water supplies from contamination is the first line of defense. Source protection is almost invariably the best method of ensuring safe drinking water supply to render it suitable for consumption .Once a potentially hazardous situation has been recognized, however, the risk to health, the availability of alternative source and the availability of suitable remedial measures must be considered so that decision can be made about the acceptability of the supply (WHO, 1993).

The world's total water resources are estimated at 1.37×10^8 million ha-m, of this global water resource about 97.2% is salty water, mainly in oceans, and only 2.8% is available as fresh water at any time on the planet earth. Out of this 2.8%, about 2.2% is available as surface water and 0.6% as ground water. Even out of this 2.2% of surface water, 2.15% is the fresh water in glaciers ice cap and only of the order of 0.01%(1.36×10^4 M ha-m) is available in lakes and reservoirs, and 0.0001% in streams the remaining being in other forms – 0.0001% as water vapour in atmosphere, and 0.002% as soil moisture in the top 0.6m out of 0.6% of stored ground water, only about 0.3% (41.1 x 10^4 M ha-m) can be economically extracted with the present drilling technology, the remaining being unavailable as it is situated below a depth of 800 m.

Thus ground water is the largest source of fresh water on the planet excluding the polar ices caps and glaciers.

At present nearly one fifth of all the water used in the world is obtained from ground water resources (Raghunath, 1987).

Within the next 50 years the world could be facing critical water shortages.

The current water crisis has two dimensions:

- Water supply, sanitation and irrigation are often inadequate.
- The development and management of water sources are not sustainable.

One billion people still lack access to safe water and 2.8 billion are without sanitation. In 2025 the World Bank foresees a general shortage of safe drinking water in third world countries. Despite major investment, the quality and reliability of services are often unacceptable. Water supply, sanitation and irrigation policies are frequently outdated inappropriate and financial mechanism is ineffective. As a result four million children die each year from causes related to lack of safe water and sanitation (WMO, 1997).

Water source is becoming increasingly scare due to over exploitation, wastage and pollution .Although readily accessible fresh water supplies comprise less than one percent of all the water on earth, even this quantity is considered sufficient to meet all the human needs. Unfortunately, it is not distributed evenly over the globe, either temporally or spatially, thereby providing the basis for water conflicts use in countries and between countries sharing Trans-boundary waters. Thus water remains a major global survival issue, though this reality continues to be ignored in many political arenas (UNEP, 1997).

Water is by far the most important liquid found on earth and is the substance most familiar to man.

1-3 Objectives

General Objective:

To Assess the Ground Water Quality in Omdurman City.

Specific Objectives: To assess**:-**

1- The chemical parameters of ground water (fluorid, chloride, nitrite, nitrate, pH and total dissolved solid).

2- The physical parameters of ground water (taste, odour and conductivity).

3- The Bacteriological parameters of ground water (*E.coli, thermo-tolerant coli form and Coli form*.).

1-2 Justification

A survey conducted by WHO in 1972 with participation of most members state, showed that more than a half of urban population and 88% of rural population are still without satisfactory water supply and environmental sanitation.

Water is inevitably associated with many problems, but serious health problems are raised due to the nature of the inputs in these source.

In an unpublished study conducted by Izzeldin and others (1999) for UNDP, they found serious background bacteriological contamination in many wells in Khartoum State .This supported by complains from consumers of water quality degradation as well as outbreak of diarrhea in some areas.

Therefore this study has come out to investigate those problems and to identify their magnitudes.

CHAPTER 2

Literature Review

2- Literature Review

2-1 Introduction

Much of the ill-health which affects humanity especially in the developing countries can be traced to lack of safe and wholesome water supply. Water that easily accessibly adequate in quantity, free from contamination, safe readily available throughout the year. There can be no state of positive health and well being without safe water. Water is not only a vital environment factor to all forms of life, but it has also a great role to play in socio-economic development of human population **(**Park, 2002)**.**

2-2 Importance of water:

Water is considered an economic good, therefore each unit of it should be used efficiently, equitably and soundly (UNESCO, 1997).

2-3 Water Safe and Wholesome:

Water intended for human consumption should be both safe and wholesome. This has been defined as water that is:

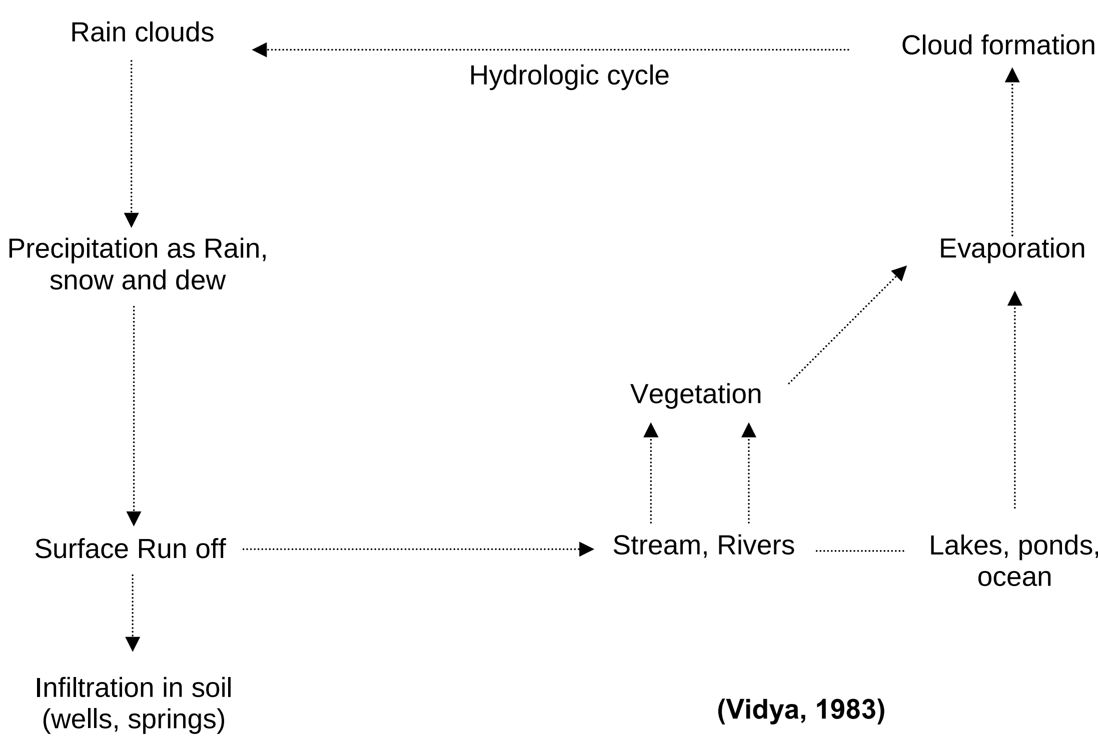
- Free from pathogenic agents.
- Free from harmful chemical substances.
- Pleasant to the taste, free from odour and colour.
- Usable for domestic purposes.

Water is said to be polluted or contaminated when it does not fulfill the above criteria. Water pollution is a growing hazard in many developing countries owing to human activity without ample and safe drinking water; we can not provide health care to the community (park, 2002).

2-4 Water Requirements:

The basic physiological requirements for drinking water have been estimated at about 2 liters per head per day.

This is just for survival. But from the standpoint of public health and improvement of the quality of life, water should be provided in an adequate volume. It will help to reduce the incidence of many water-related diseases among the people most at risk. The consumption of water, however, depends upon climatic conditions, standard of living and habits of the people. A daily supply of 150 - 200 liters per captia is considered an adequate supply to meet the needs for all domestic purposes (park, 2002).



(Vidya, 1983)

FIG2: Hydrologic Cycle

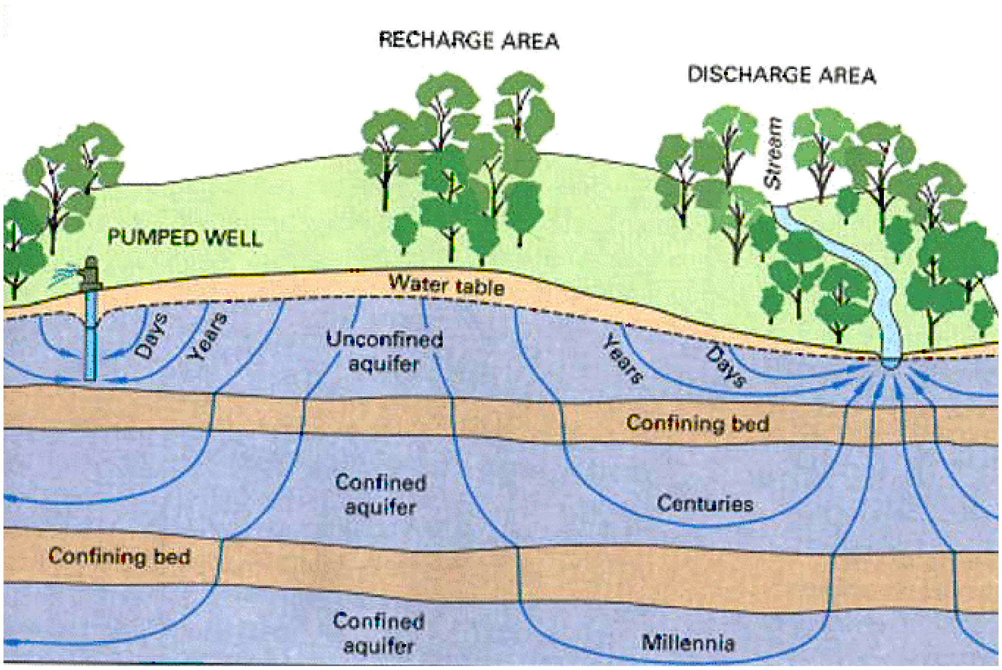


FIG2:

Groundwater in the water cycle

htt:// en. Wikipedia.org/ wiki/ Groundwater

No higher resolution available.

A cross sectional diagram showing qualitative flow times for various pathways through a typical aquifer system, from USGS circular 1139.

2-5 Uses of water:

The uses of water in a community are many, and the requirements in quantity are varied, conventionally it has been convenient in quantity to serve all uses and suitable in quantity to meet drinking requirement, even though only a small fraction of total water supply, is actually used for drinking.

The uses of water include:

- **Domestic uses**: on domestic front, water is required for drinking, cooking, washing and bathing, flushing of toilets gardening etc.

- **Public purposes**: cleaning streets, recreational purposes like swimming pools, public fountains and ornamental ponds, fire protection and public parks.
- **Industrial purposes**: for processing and cooling.
- **Agricultural purposes**: irrigation.
- Power production from hydropower and steam power.
- Carrying away waste from all manner of establishments and institutions.

Water is therefore an essential factor in the economic, social and cultural development of a community; it can eliminate diseases, promote rural development and improve quality of life (Park, 2002).

2-6 Source of water:

The source of water commonly determines the nature of the collection, purification, transmission, and distribution works. Common sources of fresh water and their development are:

2-6-1 Rain water:

- From roofs, stored in cisterns, for small individual supplies.
- From larger, prepared watersheds, or stored in reservoirs, for large communal supplies.

2-6-2Surface water:

- From streams, natural ponds and lakes of sufficient size, by continuous draft.
- From streams with adequate flood flows, by intermittent seasonal, or selective draft of clean flood waters, and their storage in reservoirs adjacent to the streams, or otherwise readily accessible from them.
- From streams with low dry-weather flows but with sufficient annual discharge by continuous draft through storage of necessary flow in excess of daily use in one or more reservoirs impounded by dams thrown across the stream valleys (Gordon and etal, 1966).

2-6-3Ground water:

Ground water is underground water that occurs in the saturated zone of variable thickness depth, below the earth, surface, cracks and pore in existing rocks and un consolidated crystal layers, make up a large underground reservoir, where part of precipitation is stored (Santosh, 2005)

2-6-3-1 Utilization of ground water:

Ground water is an important source of water supply throughout the world. Its use in irrigation, industries, municipalities, and rural homes continues to increase (David, 1995)

2-6-3-2 Occurrence of ground water:

The rainfall that percolates below the ground surface passes through the voids of rocks and joins the water table, voids are generally inter connected, permitting the movement of the ground water. But in some rocks, they may be isolated and thus, preventing the movement of water interstices. Hence, it is evident that the mode of occurrence of ground water depends largely upon the type of formation, and hence upon the geology (Santosh, 2005).

Conditions affecting the amount of rainfall that may percolate into the ground water include:

- Amount and intensity of rainfall.
- The distribution of rainfall.
- The topography and permeability of ground surface.
- The water capacity of the ground.

2-6-3-3 Location of ground water supplies:

Because of the cost of well drilling, it is desirable to have some assurance that a well will reach a satisfactory aquifer. It may be possible to predict the depth and productivity of an aquifer from conditions in other wells in the vicinity. Large projects will justify exploration by a competent geologist. Sub surface exploration is often done with small-diameter best holes from which sample of the soil and rock may be obtained and tested for permeability and specific yield. Pumping test may also be conducted on these test wells to determine the transmissibility and storage constant for the aquifer.

Seismic surveys are conducted by firing a charge of explosive near the ground surface and timing the travel of resulting shock waves to a series of geophones remote from the shot point. The velocity of the shock wave depends on type of formation and the presence of water. From the differences in indicated velocity's to the several geophones it may be possible to estimate the depth to the water table or to the interface between formations. Resistivity surveys make use of the fact that the depth of penetration of current between two electrodes in the soil surface increases as the electrodes spacing increases.

It is possible to estimate the relative Resistivity of formation at different depth by measuring the current flow with various electrode spacing. Since water the increases the conductivity of soil or rock, the presence of ground water may be indicated by a decrease in Resistivity. Both seismic and Resistivity surveys should be made and interpreted by persons trained in the work. Neither method specifically locates groundwater but merely indicates discontinuities which may bound and aquifer. With a few test holes as control points, large areas may be surveyed rapid by seismic or Resistivity methods (Ray and et al, 1979).

2-6-3-4 The main sub-surface sources are:

1- Springs: ground water reappears at the ground in the form of springs. Springs are brought about under the following condition:

- When the surface of the earth drops sharply below the normal ground water table, the water bearing stratum (aquifer) is exposed to the atmosphere and springs are created. The formation of such springs results from an overflow of the ground water table. This type of springs is also called as (Gravity) or shallow springs and water table in such springs varies with the rainfall.

- When due to an obstruction ground water is stored in the form of a reservoir and this water is forced to overflow at surface. Springs of this type are most common. These are formed when an imperious stratum, which is supporting the ground water reservoir, becomes out crops. The storage capacity of these springs is very small which ceases after a drought. They can be developed by the construction of cut off trench.
- When a fissure in an impervious stratum allows artesian water to flow in the form springs.

Such types of springs come across when ground water arise though a fissure in the upper impervious stratum. These are also known as "artesian" springs in these the water appears at the ground surface under pressure. The amount of water available is large and the rate of flow of water is constant because water comes out by a constant pressure.

Deep-seated spring: a deep seated spring is one which is formed exposing of a pervious stratum enclosed between two impervious strata i.e. which has impervious strata both above and below it. These springs usually have a large length of watershed and their out crop is too for away from spring.

The water come out in the from spring under pressure. The first three springs detailed above are called surface springs and the last called deep-steated spring (Lai, & etal, 2006).

Some springs contain minerals like sulphur, iron, manganese etc. and are called mineral springs these at some place are used for therapeutic purposes. The springs usually hard and unfit for washing-source pollution of springs are leaking cesspool, privies, stables situated near and above them (Richard and etal, 1982).

2- Infiltration galleries:

A gallery is a horizontal or approximately horizontal tunnel or open ditch constructed through water bearing material in a direction approximately normal to direction of flow at the underground water.

As we have seen earlier that sub-surface water always tries to travel towards lakes, rivers or streams. This traveling water can be intercepted by digging a trench or constructing a tunnel with holes on sides or right angle to the direction of follow of underground water. These underground tunnels used for tapping underground water near lakes, river, are called infiltration galleries.

The yield from these galleries may be as much as 1.5×10^4 liters/day/meter length of the infiltration gallery. For maximum yield, the galleries are placed at the full depth of aquifer. These are constructed with bricks or concrete with weep holes of 5cm x 10 cm.

Infiltration galleries are surrounded on sides and top with gravel or crushed stones to increase their intake capacity.

3- Porous pipe galleries:

If there is a much greater amount of water (ground water) available over a wide area, it can be cheaply collected by laying porous pipes or pipe with open joints in the full area at some distances. These longitudinal and cross pipes will be given a slope such that water should be brought towards appoint.

There intake capacity can be increased by surrounding them with rubble, gravel and sand (Lai, and etal, 2006).

4- Wells:

Wells are dug or driven holes to reach the under ground water.

Types of well:

- **Shallow well**: This is a dug well up to ground water lying between surface and first impermeable layer. It is an unsafe source of water as it gets easily polluted from surface with sewage, and other impurities from surrounding cesspools leaking drains, privies, droppings of animal and plant leaves.
- **Deep well**: This is a dug well, which goes beyond the first impervious layer to reach the water strata below. This water is and free from surface contamination, though it may be hard due to nitrites and nitrates.
- **Artesian well:** This is a variety of deep wells. In this, water strata lies between to impermeable layers. The strata are cup-shaped and surface of well is much lower than the upper level of water stratum tapped.

- **Tube-well:** consists of iron-tubing (8-15 cm) driven into ground up to required depth. These are more sanitary than dug wells. Deep tube wells can serve as one of the ideal source of water supply.
- **Ideal well**: an ideal well is deep well with the following characteristics:-
  - Soil should be good and well away (60 meters) from sources of pollution.
  - Site should be at a higher level to prevent draining of surface water into well.
  - Site should have water roof wall from within out side consisting of clay, bricks and cement respectively.
  - A parapet about 3/4 meters high should be here with top sloping outwards.
  - The mouth of the well should be covered to prevent leaves and other droppings from falling into the well.
  - Water should be drawn by a hand pump or by a single bucket and rope only.
  - Washing clothes, cleaning utensils and bathing should be prohibited near the well. Such a provision may, however, be made through a short distance away from the well.
  - Proper drainage of water to a safe distance should be provided.

- **Well Cleaning:**

This is usually carried out at the end of summer, when water in the well is at its lowest. All water, mud, stones etc, are removed from the bottom, and the well is disinfected with slaked time (1 part to 4 parts water) or pot. Permanganate (just enough to make water pinkish). Periodic disinfection of well is carried out at night with 102mg bleaching power per 1000 gallons of water. This esures at least 6hours contact needed for proper disinfection.

- **Well Inspection:**
  - Depth of well and depth of water level.
  - Nature of soil condition wall of the well, and whether mouth is covered or open.
  - Parapet, its construction, height and slopes.
  - Any location of cesspools and privies, area of cone of filtration.
  - Depression of water by pumping and time taken for its restoration.
  - Water sample testing: water sample is collected from surface and bottom preferably at days end (Richard and etal, 1982).

2-6-3-5 Ground water in Sudan:

Ground water is potentially available in large areas away from Nile, major water aquifers cover about 50% of the surface of the country, and it occurs either in shallow aquifer along the major seasonal streams or in deep aquifer of Nubian sand stone formation (SNCESCO, 2000).

The main Aquifers fall under three categories:-

i- The Nubian sand stone aquifers

ii- The Detrital quaternary .Tertiary aquifers.

iii- The recent alluvial wadi- fill aquifers (Izzeldin et al ,2000).

2-6-3-6 Quality of ground water:

Generally recognized that the quality of ground water is just as important as its quantity. All ground water contain salts in solution that are derived from location and past movement of the water. The quality of ground water supply depends on it is purpose. Thus need for drinking water, industrial and irrigation water vary widely. To establish quality criteria, measures of chemical, physical, biological and radiological constituents must be specified, as well as standard methods for reporting and comparing results of water analysis, dissolved gases in ground water can pose hazards if their presence goes under unrecognized. The uniformity of ground water temperature is advantageous for water supply and industrial purposes, and underlying saline ground water are important because they puffer potential benefits (David,1995).

2-7 Water quality:

The quality of the aquatic environment can be defined by :(i) a set of concentrations, speciation and physical partition of inorganic or organic substance, and (ii) the composition and state of aquatic biota found in water body. The quality of aquatic environment shows temporal and spatial variations due to factors internal and external to the body (Deborah, 1992).

2-7-1 Physical characteristic:

Physical parameters are usually used to determine water quality; they depend on condition of water bodies:

1- Transparency:-

Transparency is determined by the color and turbidity i.e. it is affected by various colored leaves and suspended organic and inorganic materials. Using white colored paper of know dimension and lowing it in the water column the depth at with it is distinguished is used as measure of transparency.

2- Temperature:-

Temperature: the tendency of changes in water quality. All reaction, chemicals and biological, in water are affected by temperature, the amount of gases in water and the process of chemical and biochemical self-purification and the formation of secondary pollutants are affected by temperature variation. Degree of saturation is highly influenced by temperature.

3- Electrical conductivity:-

Electrical conductivity dissociated cations and anions in water determine its electrical conductivity, the electrical conductivity is measured by finding the inverse of electrical Resistivity between two electrodes (each having an area of km2) one centimeter apart. The unit used is micro siemens per centimeter. The electrical conductivity reflects the amount or concentration of dissolved substances in water (INWRDAM, 1997).

4- Taste and odour:-

Objection to taste and small is to some extant subjective for example, the concentration of iron which makes water unacceptable varies from 0.04 mg/l to over 200 mg/l-water chloride in excess 250 mg/l is sometime considered as unpalatable.

Odours is stronger at higher temperature. They may be due to the release of dissolved gases such as hydrogen sulphide, to the growth of microorganisms which release taste and odour producing substances, or to the decomposition of dead microorganisms, leaves, grass and aquatic vegetation, even if taste and odour are harmless in themselves, consumer often interpret them as evidence of pollution and consequently use other sources which are inferior from a health point of view (Richard and etal, 1982).

5- Colour:

Drinking water should be free colour which may be due to the presence of colored organic matter (primarily humic substance) metals such as iron and manganese or highly colored industrial waste, consumers may turn to alternative, perhaps unsafe, source when their water is colored to an aesthetically displeasing degree. The guideline value is up to 15 true color units (TCU) although level of color above 15 TCU can be detected in a glass of water.

6- Turbidity:

On aesthetic grounds, drinking water should be free from turbidity. Turbidity in drinking water is caused by particulate matter that may be present as a consequence of inadequate treatment or from resuspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some ground water. Turbidity interferes with disinfection and microbiological determinations. Water with turbidity of less than 5 nephelometric turbidity units (NTU) is usually acceptable to consumer (Park, 2002).

2-7-2 Chemical characteristic:

Chemical parameters enable us to classify the water and find degree of pollution and cause of sharp increase of polluting substances. The main parameters can be stated as:-

1- PH:-

PH one of the main objectives in controlling the PH is to minimize corrosion and incrustation in the distribution system. PH level of less than 7 may cause severe corrosion of metals in the distribution pipes and elevated concentrations of certain chemical substances such as lead, may result. At PH levels above 8 there is a progressive decrease in the efficiency of the chlorine disinfection process. An acceptable PH for drinking water is between 6.5 - 8.5.

2- Hydrogen sulphide:

In water are estimated to be between 0.05 and 0.1 mg/l. the hydrogen sulphide is particularly noticeable in some ground waters and stagnant drinking water in distribution system as the result of oxygen depletion and the subsequent reduction of sulphate by bacterial activity, sulphide is oxidized rapidly to sulphade in well.

3- Iron:

Iron anoreobic ground water may contain ferrous at concentrations of up to several mg/liter without discoloration turbidity in water when directly pumped from the well. At level above 0.3 mg/liter, iron stains laundry and plumbing fixture.

4- Sodium:

The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature the average taste threshold for sodium is about 200 mg/l.

5- Sulphate:

The presence of Sulphate in drinking water can cause noticeable taste. It is generally considered that taste impairment is minimal at levels below 250 mg/liter.

6- Total dissolved solids:

(TDS) can have an important effect an the taste of drinking water. The palatability of water with a TDS level of less than 600 mg/liter is generally considered to be good. Drinking water become increasingly unpalatable at TDS levels greater than 1200 mg/l. water with extremely low concentration of TDS may be unacceptable because of it is flat, insipid taste. The presence of high levels of TDS may also be objectionable to consumer owing to excessive scaling in water pipes, heaters, boilers..etc Water with concentrations of TDS below1000mg/l is usually acceptable to consumers.

7- Manganese:

Manganese concentrations below 0.1 mg/l are usually acceptable to consumers. At level above 0.1 mg/l manganese in water supplies stains sanitary ware and laundry, and causes an undesirable taste in beverages. It may lead to accumulation of deposits in the distribution system. Even at concentration of 0.02 mg/liter manganese will often form a coating on pipes, which may slough off as a black precipitate.

8- Nitrate and nitrite:

Nitrate and nitrite are naturally occurring ions that are part of nitrogen cycle. Naturally occurring levels in surface and ground water are generally a few milligrams per liter. In many ground waters, an increase of nitrate level has been observed owing to the intensification of farming practice.

In some countries, up to 10 percent of the population may be exposed to nitrate level in drinking water of above 50 mg/liter. The guideline value for nitrate in drinking water is solely to prevent methamoglobinaemia, which depends upon the conversion of nitrate into nitrite.

As a result of recent evidence of the presence of nitrite in some water supplies, it was concluded that a guideline value of 3 mg/liter for nitrite should be proposed (Park, 2002).

9- Fluoride:

The concentration of fluoride is critical for dental health in children. Too high a concentration can result in dental flourosis, in some children, but small amount is essential for the prevention of dental caries. The desirable concentration varies with average ambient temperature; it should be 0.9-1.7 mg/l at 10°c, 0.7-1.2 mg/l at 20°c and 0.6-0.8 mg/l at 30°c (Richard et al 1982).

Ground water may contain about 10 mg/l in areas rich in fluoride – containing minerals. The guideline value suggested is 1.5 mg/l (Park, 2002).

10- Chloride:

Large quantities of chlorides are usually present in surface and ground waters, Pollution of water by industrial activities might be the cause for further increase in chloride concentration (INWRDAM, 1997).

11- Free Ammonia:

Free ammonia represents the first product of decomposition of organic matter, thus appreciable concentration of free ammonia usually indicate "fresh pollution" of sanitary significance. Ammonia in the range of 0.2 to 2.0 mg/l is toxic to many fish.

12- Alkalinity:

The alkalinity of water passing through iron distribution system should be in the range of 30 to 100 mg/L as ca co_3, to present serious corrosion, up to 200 mg/l is standpoint of PH, hardness, carbon dioxide and dissolved oxygen content – corrosion of iron pipe is prevented by the maintenance of calcium – carbonate stability – sufficient alkalinity is needed to water to react with added alum to form a floc in water coagulation. Insufficient alkalinity will cause alum to remain in solution. Bathing or washing in water of excessive alkalinity can change the PH of the lacrimal fluid around the eye, causing eye irritation.

13- Hardness:

Hardness results from the presence of divalent metallic cations, of which calcium and magnesium are the most abundant in ground water. These ions react with soap to form precipitates and with certain anions present in the water to form scale. Because of their adverse action with soap, hard waters are unsatisfactory for household cleaning purposes. Hence water softening processes for removal of hardness are needed (Santosh, 2005)

Hardness may be classified as:

(1) Temporary hardness: the presence of bicarbonates of calcium and magnesium in water known as temporary hardness.

(2) Permanent hardness: the presence of sulphates, chloride and nitrates of calcium and magnesium in water known as permanent hardness (Basak, 2004).

The degree of hardness in water commly based on classification listed in table:

Table (2-1) Hardness Classification of Water

H mg/l as caco$_3$	Water class
0 – 75	Soft
75 – 150	Moderately hard
150 – 200	Hard
Over 300	Very hard

(Santosh,2005)

2-7-3 Bacteriological characteristic:

From the health point of view the most important characteristic of good water obviously an absence of pathogenic organism, most microorganisms are actually harmless, however, some of the people who pollute a water source may have diseases and there for all faecal organisms should ideally be absence. Faeces of healthy as well as ill people contain millions of *Echerchia cloi* and these are generally taken as a measure of faecal pollution although faecal streptococci and clostridium perfingers are also used (Richard and etal, 1982).

1- Escherichia coli:

E-coli is a member of the family *enterobacteriaceae*, and characterized by possession of the enzymes *B-galactosidase* and *B-glucuronidase*. It grows at 44-45°c on complex media, ferments lactose and manitol with the production of acid and gas, and produces indol from tryptophan. Some strains can grow at 37°c and some do not produce gas. *E-coli* dose not produce oxidase or hydrolyse urea. The WHO international standard lay down that in piped supplies there should be no *E.coli.* This high level of purity is attainable.

2***- Thermo tolerant coli form*** **bacteria**:

These are defined as the group of coliform organism that are able to ferment lactose at 44-45°c. They comprise the genus *E-coli, thermo tolerant coli forms* other that *E.coli* may also originate from organically enriched water such as industrial effluents or from decaying plant materials and soils.

Re-growth *thermotolerant coliforms* organisms in the distribution system is unlikely unless sufficient bacterial nutrients are present or unsuitable materials are in contact with treated water, water temperature is above 13°c, and there is no free residual chlorine.

The concentration of *thermo tolerant coli forms* are under most circumstances, directly related to that of E coli. Hence, their use in assessing water quality is considered acceptable for routine purposes.

3- *Coliform* organisms (total coliforms):-

Coliform organisms have long been recognized as a suitable microbial indicator of drinking water quality, largely because they are easy to detect in water. The term coliform organism refers to gram-negative, rod-shaped bacteria capable of growth in the presence of bile salt or other surface agent with similar growth-inhiting properties and able to ferment lactose at 35-37°c with the production of acid, gas and aldhyed within 24-48 hours. They are also oxidase-negative and non spore-forming. Coliform bacteria should not be detectable in treated water supplies and, if found, suggest inadequate treatment, post treatment contamination, or excessive nutrients (WHO, 1995).

2-8 Water related diseases:

Up to 80% of all sickness and diseases in the world is caused by inadequate sanitation, polluted water, or un availability of water Approximately three out five persons in developing countries do not have access to safe drinking water and only about one of four has any kind of sanitation facility (WHO, 1971).

Pollution and contamination can lead to water-related diseases which causing a great suffering to whole communities causes of high morbidity and mortality in developing countries, especially in infants under the age of five.

Children are particularly vulnerable to faecal-oral diseases transmission (Stockman, 1994).

Water related diseases could be further divided into four categories:-

- **Water-washed diseases**: Which are caused by insufficient water for personal hygiene example, dysentery-diarrhea.
- **Water-borne diseases**: Which are caused by drinking water contaminated with the harmful organisms. As example hepatitis, typhoid and cholera.
- **Water based diseases**: Which arise through agent, which spend part of their lives in aquatic amimls. As example Schistosomiasis, and Guinea worm.
- **Water related insect vector diseases:** Which are due to insects that spend part of their lives in water and transmit parasites to man. As example: plasmodium spp (WASH, 1982).

2-9 Water pollution:

The world health organization consider water to be polluted when charged in composition or condition, directly or indirectly, as a result of man's activities, making them unsuitable, or less suitable for any or all of functions or purposes for which they would be suitable in their natural state (WHO,1988).

The maximum permitted concentration of various substances in public water supply is controlled throughout the world by legislation and varies to some extent for country to country (Overman, 1976).

2-9-1 Pollution of ground water:

Groundwater pollution may be defined as the artificially induced degradation at natural ground water quality. Pollution can impair the use of water and create hazard to public health through toxicity or the spread of diseases. Most pollution originates from disposal of waste water following the use of water for any of a wide variety of purposes. Thus, a large number of source and causes can modify ground water quality (David, 1995).

Polluted groundwater is extremely difficult to purify on account of its slow flow rates, inaccessibility and its huge volume. Aquifers are becoming increasingly polluted as a result of human action in three forms:

1- Pollution from urbanization:

Urbanization introduces many changes to the aquifers that lie under cities. Natural recharge mechanisms are modified or replaced and new ones introduced. Leakages and seepages from mains water and sanitation system become an important part of the hydrological cycle in the urban environment.

Many sub-city aquifers are polluted with human wastes in Sudan. Septic tank, pits and latrine are common in Sudan and operated inefficiently. Effluent is often discharged directly into inland waterways; hence pollutants find their way into underlie aquifer. In a city like Khartoum, which has over 0.5 million of septic tanks and latrines, the ensuring pollution is serious.

Other forms of excreta disposal can even be more dangerous since they often drain directly into the ground, carrying with them pathogens responsible for many human diseases.

Since about 50%, drinking water in Khartoum is provided by groundwater, which is inadequately protected from pollutions causing, pathogens like helminthes, protozoa bacteria and virus. Most the pathogens of will be reduced within 10 day, however, some of them 200 days. Wastewater discharge and solid waste disposal can also give rise to serious ground water pollution.

2- Pollution from industry:

Nearly all industries produce liquid effluent in developing countries, no strict legislation has insured that much of this effluent is properly treated, where industries are commonly sited on the outskirts of towns and cities, these industries generate effluent containing spend acids, oils, fuels and solvents, many of which are discharged directly into the ground or nearby water sources. These effluents also often contain high levels of metals such as iron, zinc, chromium and cadmium.

Many are highly toxic, even carcinogenic. High concentration of chromium and cyanide may be found in shallow groundwater. Mining and petroleum extraction pose special risks to ground water. Removing the protective layer above an aquifer, leaving it more vulnerable to pollution. Deep mines or oil fields may produce fluids that are disposed of at the surface and may therefore contaminate the aquifer.

3- Pollution from agriculture:

Agriculture is responsible for the serious pollution of many aquifers; the main problem arises from the intensive use of nitrogen-rich fertilizers and of pesticides. High level of nitrates and in some areas pesticides in groundwater have been identified as originating from intensive agriculture (Tag Elsir and etal, 2000).

Table (2-2): Principal Chemical Constituents in Groundwater, their Sources, Concentration, and Effect on Usability

(Modified from G. N. Durfer, and E. Baker, USGS Water-Supply Paper 1812, 1964)

Constituent	Major Natural Sources	Constituent in Natural Water	Effect on Usability of Water
Silica (SiO_2)	Feldspars, ferromagnesium and clay minerals, amorphous silica, chert, opal	Ranges generally from 1.0 to 30 mg/l, although as much as 100 mg/l id fairly common; as much as 4000 mg/l is found in brines	In the presence of calcium and magnesium, silica forms a scale in boilers and on steam turbines that retards heat; the scale is difficult to remove, silica may be added to soft water to inhibit corrosion of iron pipes.
Iron (Fe)	Igneous rocks, amphiboles, ferromagnesium micas, ferrous sulfide (FeS), ferric sulfide or iron pyrite (FeS_2), magnetite (Fe_3O_4) sandstone rocks, carbonates, and sulfides or iron clay minerals.	Generally less than 0.50 mg/l in fully aerated water. Groundwater having a pH less than 8.0 may contain 10 mg/l; rarely as much as 50 mg/l may occur. Acid water from thermal springs, mine wastes, and in dustrial wastes may contain more than 6000 mg/l.	More than 0.i mg/l precipitates after exposure to air; causes turbidity, stains plumbing fixtures, laundry, and cooking utensils, and imparts objectionable tastes and colors to foods and drinks, more than 0.2 mg/l is objectionable for most industrial uses.
Manganese (Mn)	Manganese in natural water probably comes most often from soils and sediments. Metamorphic and sedimentary rocks and mica biotite and amphibole minerals contain large amount of manganese.	Generally 0.20 mg/l or less, groundwater and acid mine water may contain more than.	More than 0.2 mg/l precipitates upon oxidation; causes undesirable tastes, deposits on foods during cooking, stains plumbing fixtures and laundry, and fosters growths in reservoirs, filters, and distribution systems.
Calcium (Ca)	Amphiboles, fedspars, gypsum, pyroxenes, aragonite, calcite, dolomite, clay minerals	Generally less than 100 mg/l, brines may contain as much as 75.000 mg/l.	Calcium and magnesium combine with bicarbonate, car bonate, sulfate and silica to form heat retarding, pipe clogging scale in boilers and in other heat-exchange equipment. Calcium and magnesium combine with ions of fatty acid in soaps to form soapsuds; the more soap required to form suds. a high concentration of magnesium has a laxative effect, especially on new users of the supply.
Magnesium (Mg)	Amphiboles, olivine, pyroxenes, dolomite, magnesite, clay minerals	Generally less than 50 mg/l; ocean water contain more than 1000 mg/l, and brines may contain as much as 57.000 mg/l.	
Sodium (Na)	Feldspars (albite), clay minerals, evaporates, such as halite (NaCI) and mirabilite ($Na_2SO_410H_2o$) industrial wastes.	Generally less 200 mg/l, about 10.000 mg/l in seawater; about 25.000 mg/l in brines	More than 50 mg/l sodium and potassium in the presence of suspended matter causes foaming, which accelerate scale for mation and corrosion in boilers. Sodium and potassium carbonate in recalculating cooling water can cause deterioration of wood in cooling towers. More than 65 mg/l of sodium can cause problems in ice manufacture

Table (2-2)Continued

Constituent	Major Natural Sources	Constituent in Natural Water	Effect on Usability of Water
Carbonate (CO_3)		Commonly less than 10 mg/l in groundwater. Water high in sodium may contain as much as 50 mg/l of carbonate	Upon heating, bicarbonate is changed into steam carbon dioxide and carbonate. The carbonate combines with alkaline earths-principally calcium carbonate that retards flow of heat through pipes. Water containing large amounts of bicarbonate and alkalinity is undesirable in many industries
Bicarbonate (HCO_3)	Limestone, dolomite	Commonly less than 500 mg/l except in water highly charged with carbon dioxide	
Sulfate (SO_4)	Oxidation of sulfide ores; gypsum, snhydrite	Commonly less than 300 mg/l except wells influenced by acid mine drainage. As much as 20.000 mg/l in some brines.	Sulfate combines with calcium to form an adherent, heat retarding scale. More than 250 mg/l is objectionable in water in some industries. Water containing about 500 mg/l of sulfate testes bitter; water containing about 1000 mg/l may be cathartic
Chloride (C1)	Chief source is sedimentary rock (evaporates), minor sources are igneous rocks	Commonly less than 10 mg/l in humid regions but up to 1000 mg/l in more arid regions. About 19.300 in seawater; and as mush as 200.000 mg/l in brines	Chloride in excess of 100 mg/l imparts a salty taste. Concentration greatly in excess of 100 mg/l may cause physiological damage. Food process less than 250mh/l. some in dustries-textile processing paper manufacturing. And synthetic rubber manufacturing desire less than 100 mg/l.
Fluoride (F)	Amphiholes (hornblende), apatite, fluorite, mica	Concentration generally do not exceed 10 mg/l. concentrations may be as much as 1600 mg/l in brines	Fluoride concentrations between 0.6 and 1.7 mg/l in drinking water has a beneficial effect on the structure and resistance to decay of children's teeth. Fluoride in excess of 1.5 mg/l in some areas causes "mottled enamel" in children's teeth. Fluoride in excess of 6.0 mg/l causes pronounced mottling and disfiguration of teeth
Nitrate (NO_3)	Atmosphere, legumes, plant, debris, animal excrement	Commonly less tan 10 mg/l	Water containing large amounts of nitrate (more than 100 mg/l) is bitter tasting and may cause physiological distress. Water from shallow wells containing more than 45 mg/l has been reported to cause methemoglobinemia in infants. Some amounts of nitrate help reduce cracking of high pressure boiler steel
Dissolved solids	The mineral constituents dissolved in water constitute the dissolved solid	Commonly contains less than 5000 mg/l, some brines contain as much as 300.000 mg/l	More than 500 mg/l is undesirable for drinking and many in dustrial uses. Less than 300 mg/l desirable for dyeing of textiles and the manufacture of plastics, pulp paper, rayon. Dissolved solids cause foaming in steam boilers, the maximum permissible content de creases with increases in operating pressure

(David, 995)

2-10 Ground water protection:

The most significant risk to human health related to drinking water quality is from microbiological particularly fecal contamination. Health protection thus demands, that sources of microbiological contamination are located sufficiently far from drinking water sources so as minimize or eliminate the health risk. When abstraction from a water source for consumption is being considered, the minimum safe distance for all potentially polluting activities should be fixed during the planning stage. Both surface and ground water sources of drinking water quality in its natural state is generally of good quality, and because subsurface water movement is relatively slow, it is usually easier to control sources of contamination of groundwater than it is for surface water source. The minimum safe distance should be determined from the time taken by contaminants to travel from their source to the source of drinking water. This will depend on local conditions, the most important of which are the geological and hydrological conditions of the area, the quantity of fecal matter likely to be discharged, and the number of existing and planned sources of contamination. It is therefore very difficult to specify a universally applicable minimum distance between the location of, for instance, pit latrines and a water source. In an area where the a aquifer is highly permeable the minimum safe distance for a latrines will be far greater than area where a relatively thick and impermeable un saturated zone over lies an aquifer of relatively low permeability (WHO, 1997).

The direction of flow of groundwater in an area will also influence the MSD, as a general rule, shallow groundwater movement reflects surface topography; source of contamination should therefore be located downhill of drinking water source wherever possible (WHO 1997).

2-11 Water treatment process:

The purpose of water treatment is to produce water that is safe and wholesome. The components of a typical water treatment system comprise one or more of the following manures:

1- Storage:

By mere storage, the quality of water improves. Physically: About 90 per cent of the suspended impurities settle down in 24 hours by gravity. The water becomes clearer. Chemically: Certain chemical changes also take place during storage, the aerobic bacteria oxidize the organic matter present in the water with the aid of DO. As the result, the content of free ammonia is reduced and a rise in nitrate occurs. Biological, the pathogenic organisms gradually die out. It is found that when by river water storage the total bacterial count drops is by as much as 90 percent in the first 5-7 days (Park, 2002)

2- Filtration:

Filtration is the second stage in the purification of water and quite an important, because 98-99% of bacteria are removed by filtration. Two types of filters are in use: "slow sand" filters and "rapid sand" filters (Park, 2002).

3- Disinfection:

The principle reason for disinfecting drinking-water is to ensure the destruction of pathogens, entering the distribution system (WHO, 1984).

Water may be disinfected by various physical or chemical means:-

- Boiling.
- Ultra violet radiation.
- Chemical procedures.

The most commonly used chemical reagent are chlorine and its compounds (WHO, 1995) on small scale, water can also be disinfected by small quantities of metals or metal salt, this phenomenon is called oligdynamic action of metals or metal salt (Metcalf and etal,1991).

Chlorinating of water at house hold level can be applied as an emergency measure or as a part of every day life in some cases, the water needs pretreatment like filtering in order to remove turbidity (Tom and et al, 1997).

Disinfection of wells:-

Wells are the main source of water supply in the rural areas. The need often arises to disinfect them, sometimes on a mass scale during epidemics of cholera and gastroenteritis. The most effective and cheapest method of disinfecting wells is by bleaching power. Potassium permanganate should not be used, as it is not a satisfactory disinfection agent.

Steps in Well Disinfection:

1- Find the volume of water in well:

a- Measure the depth of water column … (h) meter.

b- Measure the diameter of well … (d) meter.

c- Substitute h and d in:

$$\text{Volume (liter)} \quad \frac{3.14 \text{ X } d^2}{4} \text{ X h X } 1000$$

d- One cubic meter = 1000 liter of water.

2- Find the amount of bleaching powder required for disinfection:

Estimate the chlorine demand of the well water by horrock's apparatus and calculate the amount of bleaching powder required to disinfect the well. Roughly, 2.5 grams of good quality bleaching powder would be required to disinfect, 1000 liter of water. This will give an approximate dose of 0.7mg of applied chlorine per liter of water (Park, 2002)

3- Dissolve bleaching powder in water:

The bleaching powder required for disinfecting the well is placed in a bucket and made into a thin paste. More water is added till the bucket is nearly three – fourths full. The content are stirred well, and allowed to sediment for 5 to 10 minutes when time settles down. The supernatant solution which is chlorine solution is transferred to another bucket, and the chalk or lime is discarded.

4- Delivery of chlorine solution into the well:

The bucket containing the chlorine solution is lowered some distance below the water surface, and the well water is agitated by moving the bucket violently both vertically and laterally. This should be done several times so that the chlorine solution mixes intimately with the water inside the well.

5- Contact period:

A contact period of one hour is allowed before the water is drawn for use.

6- Orthotolidine arsenite test:

It is good practice to test for residual chlorine at the end of one hour contact. If the “free” residual chlorine level is less than 0.5mg/liter, the chlorination procedure should be repeated before any water is drawn. Wells are best disinfected at night after the day’s draw off. During epidemics of cholera, wells should be disinfected every day (Park, 2002)

Adsorption:

Is a physical process in which dissolved molecules or small particles "the adsorbs" are attracted and become attached to the surface of something larger "the adsorbent". An activated carbon adsorbs dissolved molecules and sub-micro particles, heavy metals like lead and cadmium that gets to water from corrosion of plumping materials (Everpure, 2000).

4- Aeration:

Aeration is a process used in preparing potable water. It may be used to remove:

- Undesirable gases dissolved in water (degasification) or
- To add oxygen to water to convert undesirable substances to more manageable from (oxidation).

- Volatile liquids such as humic acids and phenols.
- Iron and manganese (precipitate after aeration).Aeration is more often used to treat ground water (Howards,1986).

5- Removal of turbidity

Turbidity refers to solids and organic matter that do not settle out of water. Groundwater is rarely turbid unlike surface water which often contains suspended solids and colloidal or soluble organic matter. Shallow Groundwater taken from area near swamp and marshes, however may by high insoluble organic matter. Eliminating turbidity not only increases the aesthetic quality of water, it also helps remove contaminants that cling to suspended solids and inhibits the formation trihalomethanes, after treatment, by removing organic precursor substances. Maximum contaminant level has been established for turbidity because solid in water can interfere with disinfection process and microbiological determinations.

6- Removal of inorganic substances:

Research by U.S "EPA" shown that no one treatment method is effective for removing all inorganic chemicals. The most effective treatment methods are presented in table (2-3) other metallic ions such as iron, manganese, calcium and magnesium are not harmful at concentration found in ground water, but are often remove or reduced in concentration for taste, color or other reasons. Table (2-4) lists general treatment processes that remove suspended, colloidal, and dissolved solids. Conventional coagulation and lime softening are the principal methods, although ion exchange and reverse osmosis are some times used. Other methods such as distillation my be effective in removing these contaminants in homes, but are too expensive for large scale systems (Flecher, 1986).

7- Removal of fluoride:

High fluoride levels in groundwater can be removed by filtering through bone char. Which can subsequently be regenerated and this approach has been adopted for small community water supplies (WHO, 1997).

8- Removal of Iron and Manganese:-

Both well and surface waters, but particularly the former are likely to have iron dissolved with them as the result of Carbon dioxide coming in contact with Iron are form soluble ferrous bicarbonate. Manganese may be associated with the iron and in this case removal is more difficult.

Treatments required for removal of iron and Manganese will depend upon the conditions under which they exist in the water. Iron alone in the absence of organic matter can usually be removed by simple aeration followed by sedimentation and filtration. Combinations of iron and Manganese or iron alone, loosely bound to organic mater may require aeration in trickling beds containing coke, gravel, or crushed pyrolusite, followed by sedimentation and filtration. In other cases aeration, chlorination, or chlorination alone, followed by sedimentation and filtration will be more efficient. If organic acids are also present, aeration, dosage with lime, sedimentation, and Filtrations are effective. Well waters containing no dissolved oxygen can be treated without aeration sodium zeolite units and manganese zeolite if necessary. Soft well waters without oxygen can be treated by feeding time into enclosed mixing and settling tank, followed by a pressure filter. Sedimentation, where mentioned above, usually also must be aided by coagulation, and the filters, where bacteriological contamination is not present, may be of the pressure type (Steel, 1960).

9- Water softening:

Water softening is defined as the removal of hardness from water. It is essential to soften the water to make it safe for public uses.

The advantage of softening is:

- Reduction of soap consumption.
- Lowered cost in maintaining plumbing fixtures.
- Removed taste of food preparation.

The methods of removing temporary hardness is boiling or by adding lime (Santosh, 2005).

10- Removal of *coliform organism*:

In the past, most groundwater was of such high quality that disinfection, although often required by law, was probably the unnecessary. Today, presence of microbes in groundwater is becoming more wide spread, and more rigorous treatment of groundwater is required. For example Gaiadia limblia has spread from mountain streams in the Rocky Mountain to wells in Clorado, Montana, and other western states. In large water treatment system, the Giardia cysts generally cannot be removed by disinfection alone, although recent research has shown that ozone is effective in deactivating cysts of some giardia species (Wickramana etal, 1985).Diatomaceous earth or granular-media filtration methods must also be used.

Table (2-3) Most Effective Treatment Methods for Removal Of Inorganic Contaminants

Contaminant	Most effective methods
Arsenic As^{+3}	Ferric sulfate coagulation, pH 6-8 Alum coagulation, pH 6-8 Excess lime softening Oxidation sulfate coagulation
As^{+5}	Ferric coagulation, pH 6-7 Alum coagulation, pH 6-7 Excess lime softening
Barium (Ba)	lime softening, pH 10-11 ion exchange
Cadmium Cr^{+3}	Ferric sulfate coagulation, pH 6-9 lime softening Excess lime softening
Cr^{+3}	Ferrous sulfate coagulation, pH 7-9-5
Fluoride (F)	Ion exchange with activated-alumina or bone-char media
Lead (Pb)	Ferric sulfate coagulation, pH 6-9 Alum coagulation, pH 6-9 lime softening Excess lime softening
Mercury (Hg) Inorganic Organic	 Ferric sulfate coagulation, pH 7-8 Granular activated carbon
Nitrate (NO_3)	Ion exchange
Selenium Se^{+4} Se^{+6}	Ferric sulfate coagulation, pH 6-7 Ion exchange Reverse osmosis Ion exchange Reverse osmosis
Silver (Ag)	Ferric sulfate coagulation, pH 7-9 Alum coagulation, pH 6-9 lime softening Excess lime softening

(U.S. EPA, 1978)

Table (2-4) Water and Waste Treatment Processes

Process	General use or capability	Advantage	Disadvantage
Coagulation sedimentation, and filtration	Reduction in suspended solids by 90-98%	Low cost Simplicity	Large area required Dose not remove dissolved salts or dissolved organics
Softening	Reduction in hardness level by 95-100%	Relatively low in cost for low hardness water Simplicity	Requires frequent regeneration Chemical regeneration need increases linearly with hardness
Ion exchange	Reduction of dissolved salts by 95-100%	Can reach very low levels of salinity	Does not remove dissolved organics Requires regeneration chemical which adds to waste loading
Biological treatment	Reduction of organic loading by 50-90%	Low in cost	Subject to upsets and variations Cannot remove more than 90% of organic loading which is subject to biological degradation
Carbon columns	Reduction of absorbable organic loading by 95-100%	Effective way to remove small quantities of organic	Relatively expensive regeneration Remove only specific organic
Evaporation	Removal of dissolved solids and suspended solid	Well demonstrated Can handle wide range of application	High energy use
Reverse osmosis	Reduction of nearly all contaminants by 90-95%	Simple Low energy utilization	Membrane subject to fouling or deterioration if Not properly operated Not effective to very low molecular weight organics General requires some form of pretreatment Limited chemical compatibility

(Office of Water Research and Technology, 1979)

2-12 Water distribution:

- Water distribution systems are needed to convey the water drawn from the source, through treatment and storage facilities, to the point where it is delivered to the users.
- Water distribution system should be kept simple. They should .however be designed and constructed in a proper way as they represent a substantial capital investment that should always be useful and cost effective.
- An appropriate water distribution system should ensure an even converge of water need among the places of population.
- The design, construction, operation and maintenance of the water supply system should be carried out bearing in mind the need to minimize water wastage. This is particularly. Important in systems based on low yield water source or on those requiring treatment or pumping.

Water distribution system should be built to deliver the required quantity of water to individual users and under satisfactory pressure. The main system components are the pipelines, other basic component are break pressure tanks, valves, service reservoirs and watering points(UNHCR, 1992).

CHAPTER 3

Methodology

3- Materials and Methods

This study was conducted at Omdurman city in the period from August 2006 to March 2007.

3-1 Study Area:

Geographical Location:-

Omdurman is a significant city that constitutes part of the triple capital of the Sudan .It is situated at the junction of the Blue and the White Nile and is bounded by latitudes 15° - 30 – 15° - 45 N and longitutedes 32° -20 – 31° S.

htt:www.khartoum State. Com

This study was carried out in Omdurman (Omdurman, Ombadah and Kararri localities)

Climate:-

The climate conditions of the study area generally is Khartoum state climatic condition characterized as very hot in summer (maximum temperature is 45°c), cold dry in short winter that begins in January extending to march every year, (temperature between 20-30°c, and mean relative humidity is less than 16%).

The rainy season is of short duration, begins in June and rise to peak rain fall in august ranging between (100-200mm) annually (K.P.H.S.M. Reports, 1999).

Demography:-

Omdurman has a population of about 2.758.401 persons (Omdurman locality 508,401 person, Kararri 750.000 persons, Ombada 1.500.000 persons).

The ethnic constitution of population is diverse and there are an intensive migration from the different states of the Sudan. (important characteristics of Khartoum state localities Report 2004).

Socioeconomic Status:-

There are three socioeconomic levels:

1. High socioeconomic level.
2. Medium socioeconomic level.
3. Low socioeconomic level.

Sanitation:-

In the new peripheral, Harras are (neighborhoods) very poor with low sanitary standard, and with no system for solid waste disposal.

Health services:-

In a country torn by wars and poverty, more facilitated hospitals are needed in the whole of Sudan. Furthermore being a highly-populated city, small private clinics that are scattered throughout the city, are a common sight, especially close to Hay Alshuhada.

Some Hospitals Include:

- Omdurman Teaching Hospital, a public hospital with an emergency centre.
- Blue Nile Hospital, a private hospital
- Aldayat Teaching Hospital, a public hospital specializing in pregnancy and delivery
- Army Hospital
- Altigany Almahy Teaching Hospital, a public historical hospital specializing in psychological and mental disorders.

Education:-

There are several educational institutions in Omdurman. Some of the notable high schools include:

- Abu Kadok High Secondary School.
- Almutmar High Secondary School.
- Omdurman Ahlia High Secondary School.
- Omdurman High Secondary School.
- Wadi Saydna High Secondary School- one of famous historical high schools in Sudan.

Colleges and universities include:

- Ahfad University for Women.
- College of Technological Sciences.
- Omdurman Ahlia University.
- Omdurman Islamic University.
- University of Holy Quran and Holy Sciences.

Furthermore, there are several public libraries in Omdurman. Albashir Alrayah Library is a famous library, a hot destination for students, researchers and intellectuals. The library hosts several lectures and panels offered by various guest speakers and organizations.

Transportation and Communication:-

The study area has streets that link all parts of Omdurman (Ombada, Omdurman, Kararri, localities) and also three bridges connecties with Khartoum and Khartoum North,(Omdurman bridges

Shambatt bridges Elfethab bridges), and also is served with telephone, internet…… etc.

Electricity:-

The study areas are supplied with public electricity, but the major new expansions of Omdurman are without electricity. htt:www.KhartoumState.Com

Water supply:-

Table No (3-1): Statistical overview of hydrochemical characteristics of groundwater

Parameters	Eastern area			Central area			Omdurman area		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
PH	6.5	8.4	7.6	7.2	8.4	7.8	6.8	9.6	7.7
EC (μs/cm)	281	4070	918	263	3180	718	116.1	4690	867
TDS	150	2890	626	184	2204	492	180	3283	751
Hardness	52	618	208	42	920	174	70	950	194
Alkalinity	124	372	232	75	573	239	2	402	30.3
HCO-3	122	372	237	98	573	233	110	402	239
Cl-	12	817	105	10	585	78	12	1007	137
Na+	25	980	116	8	304	96	16	504	127

p://www.worldsummit2002.org/texts/SudanR-ASIM.pdf

3-2 Sample size:-

Table No (3-2): Number of Samples form Khartoum State:-

No	Sources	Number of Population	Total of Samples
1	Boreholes Served with direct Net work	1404848	151
2	Boreholes Not Served with Direct Net work	1775611	188
3	Total	3180459	339

Note:- The calculation of samples according to (1) samples per (10000) population, plus 10 additional samples (WHO, 1993).

Table No (3-3): The total and Target Number of Boreholes in Khartoum State.

No	Area	Total of Boreholes			Target of Boreholes		
		Served by Direct Net work	Not Served by Direct Net Work	Total	Served by Direct Net work	Not Served by Direct Net Work	Total
1	Khartoum	11	0	11	1	0	1
2	Jabel Awlia	109	28	137	11	3	14
3	Omdurman	34	19	53	3	2	5
4	Karrari	53	17	70	5	1	6
5	Ombada	8	28	36	1	3	4
6	Bahri	65	12	77	7	1	8
7	Sharq Elnil	67	7	74	7	1	8
8	Total	347	111	458	35	11	46

The number of boreholes selected was 46 which represent about 10% from the total number of boreholes in Khartoum state. Sample was determined by the ministry of health.

In the study area, the number of boreholes selected are 15, nine of them were served by direct network while six are not served by direct net work.

The following tables show the distribution of samples over the study area.

Table (3-4) the total number of samples from the Khartoum state from boreholes not connected direct to network

No	Locality	Target of boreholes	Of sample			Total
			Source	Water tower	Distribution system	
1	Kh	-	-	-	-	-
2	Jabal awlia	3	3	3	45	51
3	Omd	2	2	2	31	35
4	Kararri	1	1	1	15	17
5	Ombada	3	3	3	45	51
6	Bahri	1	1	1	15	17
7		1	1	1	15	17
8	Total	11	11	11	166	188

Table (3-5) the total number of samples from the Khartoum state from boreholes connected direct to network

No	Locality	Target of boreholes	Of sample			Total
			Source	Water tower	Distribution system	
1	Kh	1	1	1	2	4
2	Jabal awlia	11	11	11	26	48
3	Omd	3	3	3	7	13
4	Kararri	5	5	5	12	22
5	Ombada	1	1	1	2	4
6	Bahri	7	7	7	16	30
7	Sharg Alnil	7	7	7	16	30
8	Total	35	35	35	81	151

Table No (3-6): The Total Number of Samples in the Study Area from Boreholes Served by Direct Net wok:-

No	Area	No. of Target Boreholes	No. of Samples			Tot al
			Source	Water Tower	Distribution System	
1	Omdurman City	9	9	9	21	39

Table No (3-7): The Total Number of Samples in the Study Area from Boreholes Not Served by Direct Network:-

No	Area	No. of Target Boreholes	No. of Samples			Total
			Source	Water Tower	Distribution System	
1	Omdurman City	6	6	6	91	103

Number of Target Samples According the Localities

Table No (3-8): (1) Sample from Boreholes Served Direct by Network

Localities	No. of target boreholes	No of samples			Total
		Source	**Towers**	**Distribution system**	
Omdurman	3	3	3	7	13
Kararri	5	5	5	12	22
Ombada	1	1	1	2	4

Table No (3-9): (2) Samples from Boreholes not served Direct by Network

Localities	No. of target boreholes	No of samples			Total
		Source	**Towers**	**Distribution system**	
Omdurman	2	2	2	31	35
Kararri	1	1	1	15	17
Ombada	3	3	3	45	51

3-3 Samples Collection:-

Water samples for bacteriological examination were collected in a sterilized bottle. The out side of the tap was sterilized by flame, and then water was allowed to run for two minutes to wash out any organism in the pipe. The bottle was then filled with water and closed immediately. Samples should be clearly labeled with the site, date, time and nature of their work. Then water samples were transported to the public health laboratory– Khartoum state for analysis. Water samples for the chemical and physical examination where collected in the clean bottles of 500ml.

3-4 Laboratory Analysis:-

Chemical, Physical and Bacteriological analysis.142 Samples of water were collected for the bacteriological analysis .Samples for bacteriological examination were collected in sterile bottles of 250 ml size.

15 Samples of water according to the number of wells in study area were collected for chemical and physical analysis.

1- Bacteriological analysis:-

Presence – absence test for total coliform bacteria:-

Presence – absence tests may sometimes be appropriate where positive results are known to be rare. They are not quantitative and, as their name suggests, they indicate only the presence or absence of the indicator sought. Such results are of little use in countries or situations where contamination is common and the purpose of the analysis is then to determine the degree of contamination rather than simply to indicate its presence. Thus presence – absence tests are not recommended for use in the analysis of the surface water, untreated small – community supplies in countries where operation and maintenance difficulties may occasionally occur.

Before a decision is taken to use the presence – absence test for the analysis of a water source, the results obtained by the test should be compared with those obtained with a recognized, quantitative method of analysis. Approximately 100 samples should be examined by both methods (WHO, 1997).

Preparation of medium:-

The medium used for the presence-absence test for coliform bacteria are lauryl tryptose sulphate broth, make this media double strength when examining 50ml sample.

1. Dissolve the dehydrated lauryl tryptose sulphate broth sequentially in water, without heating.
2. Dispense 50ml of the medium into screw-cap glass dilution bottles of capacity 250-300 ml. A fermentation tube is necessary.
3. Autoclave for 12 minutes at 121°c, limiting the total time in the autoclave to 30 minutes or less.
4. Measure the PH of the medium after autoclaving; it should be 6.8

1- Presumptive Test: -

1. Mix the sample thoroughly by inverting the sample bottle several times.
2. Add 50ml of the sample to the dilution bottle.
3. Incubate at 35°c and examine after 48 hours.

4. A positive result is indicated by the production of gas and turbidity and regarded as a positive presumptive test (WHO, 1997).

2- Conifirmative Test:-

Each gas positive presumptive tube was inoculated into a tube containing 5ml brilliant green bile broth with inverted Durham's tube.

All tubes were incubated at 44-45°c for 24 hours to detect feacal coliform. Negative tubes were described and results were recorded. Positive tubes were shown by gas production and turbidity appearance.

i- *E.coli* test (completed test)

A loop full of brilliant green positive tubes inoculated into 5ml of peptone water and incubated at 44-45°c for 24hours, a drop of kovac's reagent (0.2-0.3ml) was added. The dark red colour on the surface culture indicated a positive test for indol. The only *coliform bacteria* that is capable of producing indole from medium containing tryptophane at 44-45°c is *Ecoli* (Mackie and Macartney,1997).

ii- Confirmative E.Coli Test:-

Insulate EMB media E.Coli produce green metallic cheen.

2- Chemical Analysis:-

1-Nitrite (NO2):-

1- Pipette 5ml of the sample in to a test tube.

2- Add 1 blue micro spoon ful of NO_2-1AN.

3- Shake vigorously to dissolve the solid substance.

4- Check the PH, specified range: PH 2—2,5.

5- If required, add dilute sodium hydroxide solution or sulfuric acid drop by drop to adjust the PH.

6- Reaction time 10 minutes.

7- Transfer the solution in to a corresponding cell.

8- Select method with Auto Selector.

9- Place the cell in to the cell compartment.

2-Nitrate:-

1- Pipette 4ml of NO_3-1 in to an empty round cell.

2- Add 0.5 ml of the sample, do not mix.

3- Add 0.5 ml of NO_3-2 and mix. (Caution, cell becomes very hot).

4- Reaction time 10 minutes.

5- Transfer the solution into a corresponding cell.

6- Select method with auto selector.

7- Place the cell into the cell compartment.

3-Chloride:-

1- Check the PH of the sample, specified range: PH 1-12.

2- If required, add dilute nitric acid or ammonia solution drop by drop to adjust the PH.

3- Pipette 1 (for 10 -250 mg/L) or 5ml (2.5 -25 mg/L) of the sample into a test tube.

4-Add 2.5 ml Cl-1 and mix.

5-Add 0.5 ml Cl-2 and mix.

6- Reaction time 1 minute.

7- Transfer the solution into a cell.

8- Select method with auto selector.

9- Place the cell into the cell compartment.

4-Fluoride:-

1- Reagent F-1 (2ml).

2- Pipette into a test tube.

3- Pretreated sample (10-40°c) 5ml.

4- Add using pipette and mix.

5- Reagent F-2 (1 level blue micro spoon in the cap of the F-2 bottle).

6- Add and shake vigorously until the reagent is completely dissolved.

7- Leave to stand for 5min (reaction time), then fill the sample into 10 ml cell, and measure in the photometer.

5- PH Measuring (PH Cond. 340 i):-

1- Connect PH electrode to the measuring instrument.

2- Plug the electrical socket in to the mains line.

3- Switch on the PH meter by press (Open) key.

4- Remove the cap from the electrode

5- Wash the electrode by distilled water and the sample.

6- Immerse the electrode in the sample.

7- Press (AR- Auto Red); key to activate auto reading measurement (AR) appears on the display.

8- Press (RUN/Enter) to start the measuring until the reading stable record the measuring value.

6-TDS Measuring:-

(Portable conductivity meter – model a ccumet AP75).

1- Rinse the probe with deionized or distilled water before use, shake or air dry (to avoid contamination or dilution of your sample), rinse probe with a small volume of your sample liquid.

2- Press on (ON /OFF key) to switch on meter the MEAS a nnunciator appears on the top center of the display.

3- Before taking reading ,calibrate READY indicator and HOLD auto end point function by:-

3-1- Press setup key to enter to set up mode.

3-2- Press the Δ and ◊ keys to scroll through subgroups until you viet parameter P4.0.

3-3-Press the ENTER key to select parameter 4, 1.

3-4-Press the Δ and ◊ keys to select the on and HOID together switches the auto endpoint feature on.

3-5-Press the ENTER key to confirm selection.

3-6- Press the (AL/MEA) key to return measurement mode.

4- Dip the probe in to the sample (when dipping the probe must be immersed above the second steelband stir the probe gently in the sample to create homogenous sample.

5- When reading stabilize REDY and HOID appears on the display.

60 Record the reading value with the temperature in the results book.

7-Press the HOID key to release the display freezes.

3- Physical Analysis:-

1-Taste and Odour:-

Taste of water sample measured by tasting.

Odour of water measured by smelling.

2- Conductivity:-

(Measuring PH/Cond 340i).

1. Connect the conductivity electrode to the measuring instrument.
2. Plug the electrical socket in to the mains line.
3. Switch on the PH meter by press (Open) key.
4. Wash the electrode by distilled water and the sample.
5. Immerse the electrode in the sample.
6. Press (AR- Auto Red), key to activate auto reading measurement (AR) appears on the display.
7. Press (RUN/Enter) to start the measuring until the reading stable record the measuring value.

CHAPTER 4

Results and Discussion

4- Results and Discussion

Table No (4-1): Chemical Examination of Water From Boreholes in Omdurman area

No	Well/Name	F^-	$NO2^-$	$NO3^-$	CL^-	PH	T.D.S
1	Jabarona Asqure (5)	.89	<0.03	2.6	56	7.53	363 mg/ l at 22.1°c
2	Darelslam ombada asqure (11-12)	.78	<0.03	2.6	49	7.3	391 mg/l ar 22.4°c
3	Alamereia Asqure (44) – Awed Elkarem	1.05	<0.03	2.5	54	7.33	343 mg/l at 22.5°c
4	Teba Eliahamda	0.38	0.05	<2.2	5	7.5	270 mg/l at 21.9°c
5	Elgeaha (2) Elslha	095	0.05	<2.2	232	7.58	959 mg/l at 21.5°c
6	Elkede Awlad Haj Elteep	.0.06	<0.03	9.3	79	7.88	495 mg/l at 21.7°c
7	Elnoba South Karrari	0.35	<0.03	<2.2	4	7.68	223 mg/l at 22.5°c
8	Elsrorab – Elkawahla Kararri	0.25	<0.03	<2.2	12	7.59	296 mg/l at 23.2°c
9	Elthowera Elhara (53) Kararri	0.24	<0.03	<2.2	5	7.43	187 mg/l at 23.2°c
10	Elthowra Elhara (59) Kararri	0.37	<0.03	<2.2	23	7.4	276 mg/l at 23.7°c
11	Elshatabe Factor Kararri	0.35	<0.03	<2.2	65	7.62	348 mg/l at 22.9°c
12	Ombada Elhara (15)	0.54	<0.03	6.4	13	7.16	283 mg/l at 25.6°c
13	Jebial Eltrena South	0.27	<0.03	2.2	45	7.45	27 mg/l at 25.1°c
14	Elsahab For Water Factory	0.43	<0.03	23.5	72.50	7.18	1023 mg/l at 25.5°c
15	Faculty of Engineering University of Omdurman Alslamia	0.22	0.09	3.1	97	7.37	417 mg/l at 25.7°c

Table No (4-2): Relationship Between TDS and Conductivity in Study Area

No	Well/Name	TDS	Conductivity	TDS/ Conductivity
1	Jabarona Asqure (5)	363 mg/ l at 22.1°c	695 ms/cm at 22.0°c	0.52
2	Dar Elslam Ombada Asqure (11-12)	391 mg/l at 22.4°c	729 ms/cm at 22.6°c	0.53
3	Alamereia Asqure (44) – Awed Elkarem	343 mg/l at 22.5°c	629 ms/cm at 22.1°c	0.54
4	Teba Eliahamda	270 mg/l at 21.9°c	506 ms/cm at 22.1°c	0.53
5	Elgeaha (2) Elslha	959 mg/l at 21.5°c	1815 ms/cm at 21.6°c	0.52
6	Elkede Awlad Haj Elteep	495 mg/l at 21.7°c	939 ms/cm at 21.6°c	0.52
7	Elnoba South Karrari	223 mg/l at 22.5°c	430 ms/cm at 22.3°c	0.51
8	Elsrorab – Elkawahla Kararri	296 mg/l at 23.2°c	559ms/cm at 23.1°c	0.52
9	Elthowera Elhara (53) Kararri	187 mg/l at 23.2°c	353 ms/cm at 32.1°c	0.52
10	Elthowra Elhara (59) Kararri	276 mg/l at 23.7°c	521 ms/cm at 32.5°c	0.52
11	Elshatabe Factor Kararri	348 mg/l at 22.9°c	658 ms/cm at 32.0°c	0.52
12	Ombada Elhara (15)	283 mg/l at 25.6°c	555 ms/cm at 24.7°c	0.50
13	Jebial Eltrena South	27 mg/l at 25.1°c	526 ms/cm at 25.5°c	0.51
14	Elsahab For Water Factory	1023 mg/l at 25.5°c	1928 ms/cm at 25.2°c	0.53
15	Faculty of Engineering University of Omdurman Alslamia	417 mg/l at 25.7°c	526ms/cm at 24.9°c	0.79

Table No (4-3):

Physical Examination of Water from Boreholes in Omdurman area

No	Well/Name	Odour	Taste	Conductivity
1	Jabarona Asqure (5)	Acceptable	Acceptable	695 ms/cm at 22.0°c
2	Dar Elslam Ombada Asqure (11-12)	Acceptable	Acceptable	729 ms/cm at 22.6°c
3	Alamereia Asqure (44) – Awed Elkarem	Acceptable	Acceptable	629 ms/cm at 22.1°c
4	Teba Eliahamda	Acceptable	Acceptable	506 ms/cm at 22.1°c
5	Elgeaha (2) Elslha	Acceptable	Acceptable	1815 ms/cm at 21.6°c
6	Elkede Awlad Haj Elteep	Acceptable	Acceptable	939 ms/cm at 21.6°c
7	Elnoba South Karrari	Acceptable	Acceptable	430 ms/cm at 22.3°c
8	Elsrorab – Elkawahla Kararri	Acceptable	Acceptable	559ms/cm at 23.1°c
9	Elthowera Elhara (53) Kararri	Acceptable	Acceptable	353 ms/cm at 32.1°c
10	Elthowra Elhara (59) Kararri	Acceptable	Acceptable	521 ms/cm at 32.5°c
11	Elshatabe Factor Kararri	Acceptable	Acceptable	658 ms/cm at 32.0°c
12	Ombada Elhara (15)	Acceptable	Acceptable	555 ms/cm at 24.7°c
13	Jebial Eltrena South	Acceptable	Acceptable	526 ms/cm at 25.5°c
14	Elsahab For Water Factory	Acceptable	Acceptable	1928 ms/cm at 25.2°c
15	Faculty of Engineering University of Omdurman Alslamia	Acceptable	Acceptable	526ms/cm at 24.9°c

Table No (4-4) Bacteriological examination of water from boreholes

Served directly by network in Omdurman locality

No	Name of Boreholes	Samples From Boreholes					Samples From water Towers					Samples From Houses				
		No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%
1	Elgeaha	1	1	100	-	-	1	-	-	1	100	16	1	6.25	15	93.75
2	Elsehab Factory For Water	1	-	-	1	100	1	-	-	1	100	1	-	-	1	100
3	Jebail Eltena	1	-	-	1	100	1	-	-	-	-	6	2	33.3	4	66.7
4	Faculty of Engineering University Omdurman Eleslamia	1	1	100	-	-	1	1	100	-	-	1	1	100	-	-
5	Total	4	2	50	2	50	3	1	33.3	2	66.7	24	4	16.67	20	83.3

Table No (4-5) bacteriological examination of water from boreholes

Not served directly by network in Omdurman locality

No	Name of Boreholes	Samples From Boreholes					Samples water From Towers					Samples From vendors					Samples From Houses				
		No. of sample	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%
1	Ekkedy Awad Haj Elteep	1	-	-	1	100	1	1	100	-	-	2	-	-	2	100	13	-	-	13	100
2	Total	1	-	-	1	100	1	1	100	-	-	2	-	-	2	100	13	-	-	13	100

Table No (4-6) Bacteriological Examination of Water from Boreholes

Served Directly by Network in Karrari locality

No	Name of Boreholes	Samples From Boreholes					Samples water From Towers					Samples From Houses				
		No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%
1	Elnoba south	1	1	100	-	-	-	-	-	-	-	3	-	-	3	100
2	Elsarorab	1	-	-	1	100	-	-	-	-	-	4	-	-	4	100
3	Elhara 53	-	-	-	-	-	1	-	-	1	100	3	-	-	3	100
4	Elhara 29	1	1	100	-	-	-	-	-	-	-	5	5	100	-	-
5	Elshatay factor	-	-	-	-	-	1	1	100	-	-	2	2	100	-	-
6	Total	3	2	66.7	1	33.3	2	1	50	1	50	17	7	41.18	10	58.826y

Table No (4-7) Bacteriological Examination of Water from Boreholes

Not Served Directly by Network in Karrari locality

No	Name of Boreholes	Samples From Boreholes					Samples From water Towers					Samples From vendors					Samples From Houses				
		No. of sample	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%
1	Elahamada	1	1	100	-	-	-	-	-	-	-	-	-	-	-	-	16	14	78.5	2	12.5
2	Total	1	1	10	-	-	-	-	-	-	-	-	-	-	-	-	16	14	78.5	2	12.5

Table No (4-8) Bacteriological Examination of Water from Boreholes

Served directly by network in Ombada locality

No	Name of Boreholes	Samples From Boreholes					Samples water From Towers					Samples From Houses				
		No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%
1	Dar Elsalam Acquire (12)	1	1	100	-	-	-	-	-	-	-	16	10	62.3	6	37.5
2	Ambada Elhara (15)	1	-	-	1	100	-	-	-	-	-	3	2	66.7	1	33.3
3	Total	2	1	50	1	50	-	-	-	-	-	19	12	63.2	7	36.8

Table No (4-9) Bacteriological Examination of Water from Boreholes

Not served directly by network in Ombada locality

No	Name of Boreholes	Samples From Boreholes					Samples From water Towers					Samples From vendors					Samples From Houses				
		No. of sample	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%
1	Jabarona	1	-	-	1	100	1	-	-	1	100	3	2	66.7	1	33.3	12	9	75	3	25
2	Ombada Elameria	1	-	-	1	100	1	-	-	1	100	3	-	-	3	100	12	10	83	2	26.7
3	Total	2	-	-	2	100	2	-	-	2	100	6	2	33.3	4	66.7	24	19	79.2	5	20.8

Table No (4-10) Bacteriological Examination of Water

From locations in the study area

No	Name of Boreholes	Samples From Boreholes					Samples From water Towers					Samples From vendors					Samples From Houses				
		No. of sample	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%	No. of Samples	+ve	%	-ve	%
1	Jabaroba	1	-	-	1	100	1	-	-	1	100	3	2	66.7	1	33.3	12	9	75	3	25
2	Ombada Elameria	1	-	-	1	100	1	-	-	1	100	3	-	-	3	100	12	10	83	2	16.7
3	Elzedy Awad Haj Elteep	1	-	-	1	100	1	1	100	-	-	2	-	-	2	100	13	-	-	13	100
4	Elahamada	1	1	100	-	-	-	-	-	-	-	-	-	-	-	-	16	14	78.5	2	12.5
5	Elgeaha	1	1	100	-	-	1	-	-	1	100	-	-	-	-	-	16	1	6.25	6	93.75
6	Dar Elsalam Block 12	1	1	100	-	-	-	-	-	-	-	-	-	-	-	-	16	10	62.5	6	37.5
7	Ambada Elhara (15)	1	-	-	1	100	-	-	-	-	-	-	-	-	-	-	3	2	66.7	1	33.3
8	Wlswhab Factory For Water	1	-	-	1	100	1	-	-	1	100	-	-	-	-	-	1	-	-	1	100
9	Jebail Atena	1	-	-	1	100	-	-	-	-	-	-	-	-	-	-	6	2	33.3	4	66.7
10	Faculty of Engineering University Omdurman Eleslamia	1	1	100	-	-	1	1	100	-	-	-	-	-	-	-	1	1	100	-	-
11	Elnoba South	1	1	100	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	3	100
12	Elsaroran Alkawahla	1	-	-	1	1001	-	-	-	-	-	-	-	-	-		4	-	-	4	100
13	Elthwra Elhara (53)	-	-	-	-	-	1	1	100	-	-	-	-	-	-	-	5	5	100	-	-
14	Elthwra Elhara (29)	1	1	100	-	-	-	-	-	-	-	-	-	-	-	-	2	2	100	-	-
15	Elshatabi Factor	-	-	-	-	-	1	1	100	-	-	-	-	-	-	-	2	2	100	-	-
	Total	13	6	46.2	7	53.8	9	3	33.3	6	66.7	8	2	2.5	6	75	113	56	49.6	57	50.44

To a achieve the study objectives, data were collected for 15 boreholes in the study area, water sampling activities followed by chemical, physical analysis and bacteriological testing. The water source at study area was also visited.

Omdurman Town:

The geological formation of the area is dominated by the presence of mudstone. In certain locations shallow sandy layers on top are followed by mudstone in deeper layers. Outcrops of basaltic rocks are identified within certain areas.

Groundwater is found in depth between 15 to 50m from ground surface, most of wells in omdurman have hard water (high and medium concentration of Ca CO_3, Na_2CO_3).

In areas where septic tanks and disposal wells are used, occurrence of organic pollution was identified. In many locations in this town, there is the tendency by residents to dig deep wells more than 30m in order to dispose off effluents of septic tanks. This is a direct injection of pollutants into groundwater which is very risky to ground water resources (IHP, national committee of Sudanese, national commission for education, science and culture, (2000, Amal et al)

Chemical assessment:

The chemical characteristic of groundwater resource in the study area focused on the following parameters; PH, nitrite, nitrate, fluoride, chloride and TDS, to assess the general situation of potable water source and compare the result with guidelines and recommended levels used in Sudan.

International standards for drinking water includes specific rules defining acceptable limits of significant physical and chemical characteristics of water delivered to consumers, the chemical parameters which were investigated in study area are illustrated as the follows:-

Table No.(4-1) shows that the concentration of fluorides in all boreholes in the study area ranged between(0.22 mg/l) in boreholes of the Faculty of Engineering - Omdurman Islamic University to (0.06) in Elkede boreholes, this range illustrates that fluoride is in agreement with standards of (SSMO) that stated the maximum permissible level as(0.5 mg/l). Also with reference to the results in Table No.(4-1), nitrites (No_2) and nitrates (No_3) values showed large variations and fluctuations in the study area. This due to transformation of those nitrogen compounds from one shape to another. This is in contradiction with Lewis and Hutton (1980) who explained that nitrite, ammonia in the natural water are presumabley similar to the source and stated that the oxidation of nitrogen is probably controlled by biochemical process, however the concentration of nitrite in study area ranged between(< 0.03 mg/l) in most of boreholes to(0.09 mg/l). This is in agreement with the (WHO, 1995) recommendations, which states nitrite levels in surface and groundwater are generally in the range of few milligram per liter. Where as the nitrate values ranged between (2.2 to 23.5) mg/l. These are also less than the maximum permissible level set by WHO, which is (50mg/l).Chlorides usually present in groundwater, pollution of water by industrial activities might cause further increases in chloride concentration (INWRDAM, 1997). The study illustrates in table No.(4-1) the concentration of chlorides in the study area range between (5 to 23) mg/l in majority of Boreholes except in Elsahab factory Borehole (7250mg/l). The concentration of chloride is more than the maximum permissible level set by (SSMO) which is 250mg/l this may be due to industrial pollution. PH is a measure of acidity in groundwater and expressed as pH = - log [H^+]. Where H^+ is hydrogen ion concentration. The result presented in table No.(4-1) reveals that pH values in all locations in the study area is within range between (7.18 to 7.88). This range is in agreement with (WHO) recommendation, that states an acceptable PH of drinking water is between (6.5 to 8.5). Also the result presented in table No.(4-1) reveals that TDS concentration of majority of Boreholes in the study area were within (187 to 956) mg/l. This is in agreement with (SSMO) which states the maximum permissible of TDS as (1000mg/l). Where as the result shows that the level of TDS in Elsahab factory Borehole (1023mg/l) is more than the standard. (Park,2002)stated that the presence of high level of TDS in drinking water may be objectionable to consumers owing to excessive scaling in water pipe, heater and boilers. On the other hand, with reference to result present in table No.(4-2), there is significant relationship between TDS and conductivity in drinking water source, (AbdelRhman ,1993) previously stated that there is a close relationship between TDS and conductivity. It was also observed that high TDS relate to high conductivity as in this study.

Physical assessment:

Generally and with reference to result presented in table No.(4-3) all water samples collected from Boreholes in the study area were found to be acceptable in odour because, groundwater is characterized by odorless and colorless, appearance due to effect of filtration(William,1966). Also the result reveals that the taste was acceptable.

Microbial indicators for bacteriological contamination:

The major indicator organisms are *E.coli*, *Thermotolernt* and other *Coliform* bacteria. Some pathogenic bacteria such as typhoid bacillus, dysentery bacilli and vibrio cholera, which may contaminate water, are extremely difficult to isolate directly from water. However, it is very fortunate that they are always accompanied by large number of *E.coli* (WHO, 1995 and Smith, 1948). The bacteriological analysis of water is done primarily to determine its portability and fitness for drinking. The sanitary acceptability of water quality is presently judged by bacteriolcal standard. The international standard for drinking water adopted by (WHO) and (SSMO) stated that water intended for human consumption must be free from organism hazardous to health. The bacteriological results of samples collected from water source (Boreholes) in the study area which include (Omdurman, Karrari, Ombada localitie) illustrated as the following:

Omdurman locality:

The result presented in table No.(4-4) for water analysis from Boreholes connected direct to network showed that (50%) of samples were polluted by *thermotolerant coliform* where as (50 %) of sample were not polluted. The result also revealed that (33.3%) of total samples from water towers were polluted by *thermotolerant* where as (66.7%) were not polluted. However (16.67%) of total samples from houses were polluted by *E. coli* and *thermotolerany* and (83.3%) were not polluted. The result presented in table No.(4-5) for water analysis from boreholes, not connected direct to network shows that samples from boreholes, vendors, and houses were safe (100%),where as the samples from water towers were polluted (100%) by *E. coli* and *thermotolerant*.

Karrari locality:

Table No.(4-6) reveals that (66.7%) of samples from boreholes connected direct to network were polluted by *E. coli thermotolerant*, where as (33.3%) not polluted, also the result illustrates that (50%) of samples from water towers were polluted by *thermotolerant*, also (41.18%) of sample from houses were polluted by *thermotolerant* and E. coli.

Table No.(4-7) for water analysis from boreholes not connected direct to network reveals that the sample was polluted (100%) by *E. coli* and *thermotolerant*, and (78.35%) samples from houses polluted by E. coli and *thermotolerant*.

Ombada locality:

Table No.(4-8) for water analysis from boreholes connected direct to network reveals that (50%) of samples from boreholes were polluted by *E. coli* and *thermotolerant*, also (63.25%) of samples from houses were polluted by *E. coli* and *thermotolerant*.

Table No.(4-9) shows that the samples from boreholes not connected directly to network and samples from water towers were safe (100%), where as (33.3%) of samples from vendors were polluted by *E. coli* and *thermotolerant*, also (79.2%) of samples from houses were polluted by *E. coli* and *thermotolerant*.

Table No.(4-10) fig (1) illustrate that (46.2%) of samples from total boreholes in the study area were polluted and this is incontradiction with (WHO) recommendation. Nevertheless, it is thought that the presence of *thermotolerant* coli form is probably due to absence of inspection and poor water quality control methods that are used in potable water resource. This is in agreement with the (WHO,1981) which states that typically (70 - 80%) of small supplies are contaminated in developing countries that failing to apply standard of water quality control methods as far at the well structure is concernd, (Campell and Lehr, 1973) described the following means by which pollution may occur:

- Via an opening in the surface cap or seal or between the casing and the base surface movement pump.
- As a result of reverse flow through the discharge systems.
- Through the distribution zone immediately surrounding the casing.
- Via improper constructed and sealed gravel pack due to the in ability of well structure, or seepage resulting from reduced effectiveness of surface seal.

- As a result of the grout or cementing material forming the seals failing through cracking... etc.

In addition to the above mentioned, the building of latrines near the wells (less than 30 meter) increases the risk of contamination, this is in agreement with the study results observed, some site of boreholes the in study area are within a distance less than 30 meter from latrines, also for some boreholes in the study area there is a water recharge, this may increase contamination. In the other sites there is no direct tap from boreholes in certain locations. With the reference to result presented in table No.(4-10), fig (2) (33.3%) of samples from water towers were polluted, this is may be due to the improper design of water towers and also it was observed that some of the water towers in the study area are open, this lead to contamination by dusts which hold number of contaminants. Where as (66.7%) of samples were safe as the result of good storage the pathogen well removed, this is in agreement with (Park, 2000) who stated that a tremendous drop takes place in bacterial count during storage. The pathogenic organisms gradually die out. It is found that in river water storage the total bacterial count drops by as such as 90 percent in first (5 – 7) days. The study also illustrates that the percentage of polluted water from venders and houses (25%, 40.6%) that presented in table No.(4-10) may occur due to improper designed venders carts or the behaviors of persons who work in water may contaminate water through distribution system by many reason such as damage in pipes, or in pack syphonage … etc.

This is in agreement with (WHO, 1995) which states that, distribution systems are especially vulnerable to contamination when the pressure falls, particularly in the intermittent supplies of many cities in developing countries, underground storage tanks and service must be inspected for deterioration and for infiltration of surface and ground water. It is desirable for the land enclosing underground storage tank to be fenced off to prevent damage the structure. Repir Works to mains offer another possibility for contamination. Local loss of pressure may result in back syphonage leading to contamination of water.

In other side with reference to result presented in fig (3) are notes that the percentage of contaminated samples from houses not connected direct to network were high (62.35%) to comparison with other that connected direct to network. This result explains that proper distribution system play an important role in elimination of water contamination.

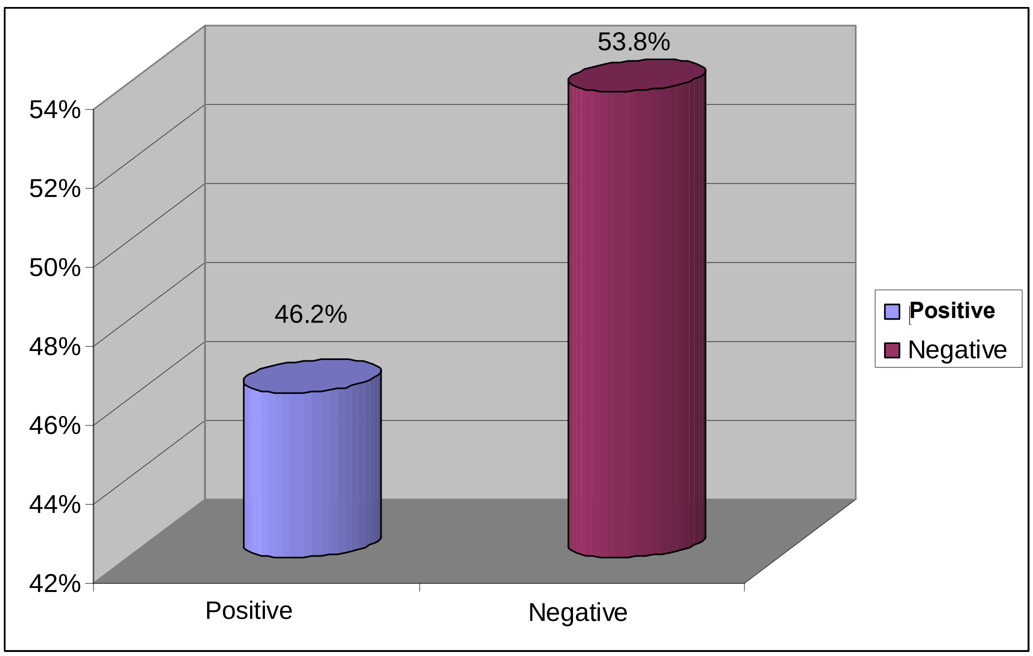


Figure (3) The Pollution of Boreholes in the study area.

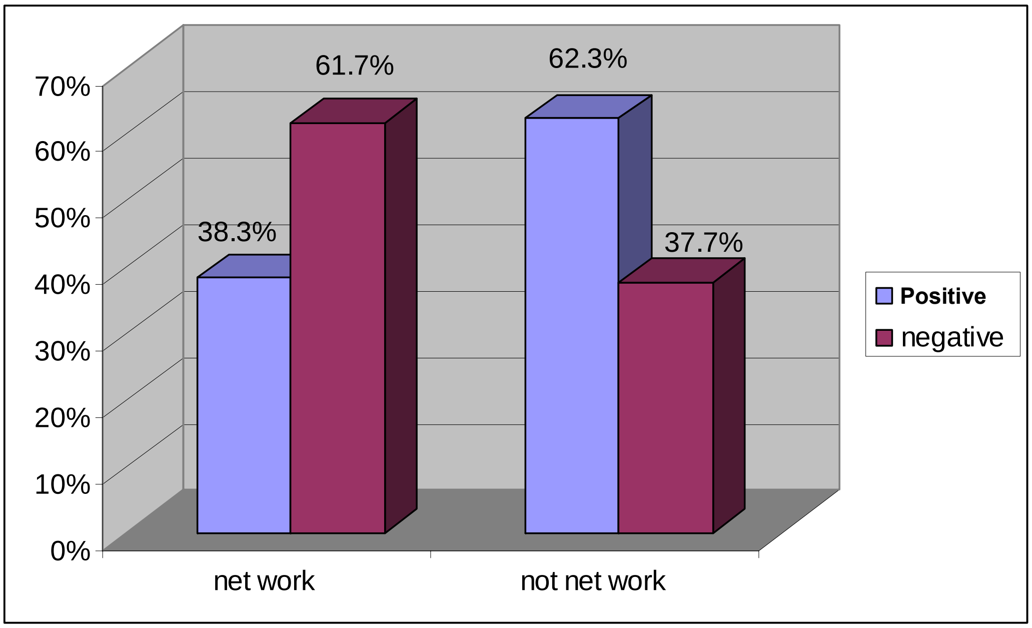


Figure (4) Comparison of Pollution level between houses connected direct, and those not connected direct to net work

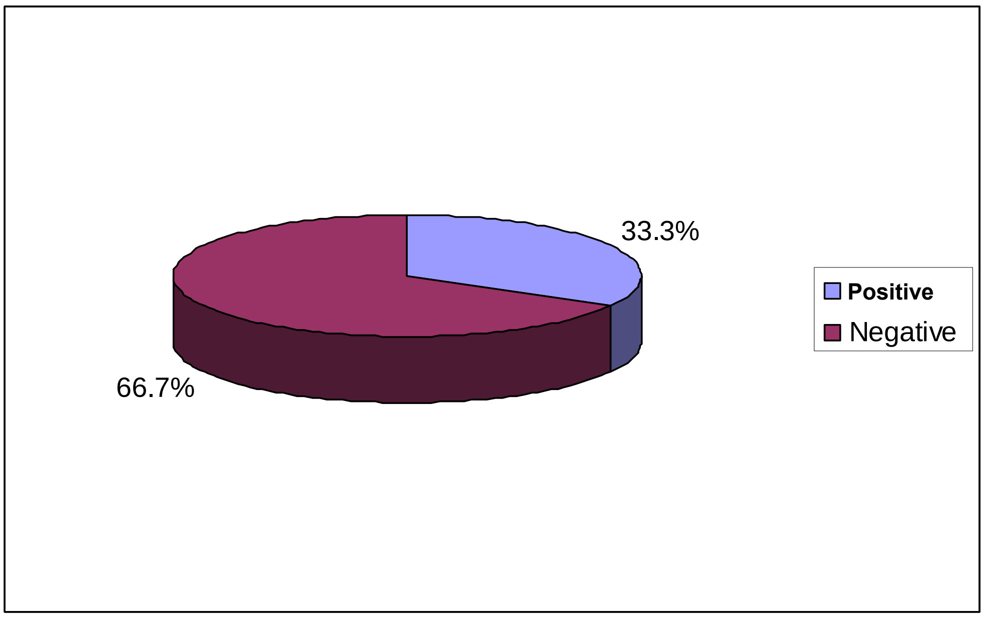


Figure (5) The water Pollution in water towers in the study area

CHAPTER 5

Conclusion and Recommendations

5-1 Conclusions

- Investigation of groundwater quality is very important to health improvement. It eliminates the hazards produced due to water pollution and it protects water source.
- Urbanization introduces many changes to aquifers that lies under cities. Natural recharge mechanisms are modified or replaced, and new ones are introduced.
- Many sub-city aquifers are polluted with human wastes, septic tank, pit latrine are operated inefficiently and discharge directly into inland.
- An important out come of this study showed that, the majority of chemical and physical groundwater quality of Boreholes in Omdurman city is within the acceptable limits for drinking water as proposed by (WHO) and (SSMO) standards.
- Chlorides and total dissolved solids recorded concentrations over allowable standards (7250mg/l, 1023mg/l) in Sahap factory Boreholes.
- Degradation of bacteriological quality of water in Omdurman city.
- High percentage of polluted Boreholes by E.coli and Thermotolerant Cliform.
- The most significant risk to human health related to drinking water quality is from microbiological, particularly feacal contamination.

- Water from houses not connected direct to net work is polluted by Cliform bacteria.
- Observed locations of latrine in many locations in Omdurman city not far from Boreholes.
- There is no treatment system (disinfection) for groundwater in Omdurman city.

5-2 Recommendation

It is recommended that:-

- Well construction should be carried out adequately and according to proper design specifications.
- Soil should be good, and Boreholes should be sited away from pollution sources.
- Site should be at higher level to prevent draining of surface water into Boreholes.
- Septic tank, and latrines should be of a proper design to eliminate infiltration to Boreholes through soil layers.
- Select proper designs for distribution system and avoid the damage in pipes.
- Health protection demands, that sources of microbiological contamination are located sufficiently far from drinking water source so as minimize or eliminate the health risk.
- The Boreholes should be disinfected to insure that water is free from biological contamination.
- Health education and awareness to consumers for how to protect and conserve water within houses from contamination and encourage good behavior for water utilization.
- Establish good monitoring system to early detection of any change of water quality.

- Encourage the research for groundwater quality in order to protect, monitor and control the pollution.
- Application of legislatives acts and regulations for well drilling and proper disposal of effluent.
- Establish groundwater conservation programmes.

CHAPTER 6

References

Reference

- Amal Elfadil, Al Mutaz Abdalla, Nazik Eleasheed, Mouada El Gaeel(2000).Vulnerability of Groundwater Recourses of Sudan to Pollution Risks, Khartoum.
- AbdElRahman. M.A (1993). Sanitary Measure for Protection of Groundwater Quality in Elobied and Eldilling Area. MSc. Thesis U of K.
- Basak .N N (2004). Environmental Engineering Tata Mc Graw. Hill Company Limited. New Delhi.
- Campell and other (1973). Cited in Abd-ElRahman. M. A (1993). Sanitary Measure for Protection of Groundwater Quality in Elobied and Eldilling Area. MSc. Thesis U of K.
- David Jeith Todd (1995). Groundwater Hydrology Second Edition, Johnwiley and Sons. New York.
- Deborah Chapman (1992). Water quality assessment, Chapman and Hall Ltd, 2-6E18HN, Boundary Row, London, Cambridge.
- Ernest W. Steel (1960) Water Supply and Sewerage. Mc Graw. Hill book company, New York.
- Everpure, (2000). Water Quality Issues. INC, New York London.
- Flasher G. Dris Coll, (1986). Groundwater and Wells Second Edition, Johoson Division, St. Paul, Minnesota 55112, United States of America.

- Gordon Maskew Fair, John Charles Geyer, Daniel Alexander, (1966). Water and Wastewater Engineering Volume1. John Wiley, INC. New York, London Sydney.
- Howard S. Peavy Donald, R. Rowe, George Tchobanoglous (1986). Environmental Engineering. Mc Graw. Hill book co, Singapore for Manufacture and Export.
- INWRDAM (1997). Water Resources Management. Islamic Educational, Scientific and Cultural Organization (ISECO). Morocco.
- Izzeldin Ahmed Yousif (2000). Vulnerability of Groundwater Resources of Sudan to Pollution Risk, Khartoum.
- Jousma.G. J. bear, Y. Y Haimes and F. Walter (1989). Groundwater contamination: Use of Models in Decision Making (PS) Klumer Academic. London.
- Karari Province Health Services Management, Reports,(1999).
- Lewis,W.J. and Hutton, L.G (1980) Nitrate Pollution of Groundwater in Botswana.Proc.6th WEDC, Conf. Zaria, Nigeria.
- Lai. D (2006).Water Supply and Waste Water Engineering Sanjeev Kataria for, S.K, Kataria and Sons, Dellhi.
- Metacalf and Eddy (1991). Wastewater Engineering (Treatment, disposal, reuse).Tata Mc Graw. Hill- New Delhi.
- Mackie and Macarthy (1997).Examination of Water Practical Medical Microbiology, 14th ed. Churchill Living Stone .381-83. (1997). New York.
- Overman. M (1976). Water Solution to a Problem of Supply Demand, Revised. The Open University Press London.

- Park. K (2000) Preventive and Social Medicine, Prem Nagar, Jabalpur India.
- Park. K (2002) Preventive and Social Medicine, Prem Nagar, Jabalpur India.
- Ray. K Linsley. Joseph B Franzini (1979). Water Resources Engineering Third Edition. McGraw. Hill Book Company London.
- Richard Feachem, Michael Mc Garry, Duncan Mara (1982).Water, Waste and Health in Hot Climates- Awiley – interscience. New Delhi.
- Raghunath H. M (1987). Groundwater 2nd Edition, K.K Gupta for New Age international (P) Ltd, 4835/24, Ansari Road, Daryaganj, New Delhi.
- Santosh Kumar Gary (2005). Water Supply Engineering. Romesh Chender Khanna. Delhi.
- SNCESO (2000) Vulnerability of Groundwater Recourses of Sudan to Pollution Risks, Khartoum.
- Stockman. D (1994) Guide Lines for Developing Countries International Technology publications Ltd. UK.
- Smith. N. R (1948) cited in Nurain. A.B.O (1998). Domestic Water, Behavioal and Health, Aspects, case study-Gezeria Schme. MSc. Thesis, U.ofK.
- Tage Elsir, Abdalla, Bashir Mohamed Al Hassan, Mohamed Ahmed Khadam, Hamid Omer Ali (2000) Vulnerability of Groundwater Recourses of Sudan to Pollution Risks, Khartoum.

- Tomdeveer J.L, Brikked. F. Bredero. M and Josment. N. Water Supply and Sanitation Report Geneva.
- UNESCO (1997) Down To Last Drop. Geneva.
- UNEP and WHO (1988) Assessment of Fresh Water Quality, A report on the results of the UNEP /WHO Program on health related environmental Monitoring,P.15-29., Nairobi, Kenya.
- UNEP (1997) Transboundary Waters (The of Integrated Management) Geneva.
- UNHCR (1992) Water Manual for Refugee Situations. Programme and Technical Support Section. Geneva.
- Vidya Ratan (1983) Hand Book of Preventive and Social Medicine, Jaypce Protshers Medical, India.
- WHO (1993) Guide Lines for Drinking Water Quality, Geneva.
- WHO (1971) International Standard for Drinking Water 3rd.ed, Geneva.
- WASH (1982) Water and Sanitation for Health Project No 37, Washington.
- WHO (1997) Guide Lines for Drinking Water Quality Volume3, surveillance and Control of Community Supplies, Geneva.
- WMO (1997) The World Day for Water, 22 March Geneva.
- WHO (1992) Annual Report, Geneva.
- WHO (1995). Guide Lines for Drinking Water Quality 2th, Vol.1, Recommendations, Geneva.
- WHO (1981). Drinking Water and Sanitation (1981-1990) Away to Health.1211, Geneva, 27- Switerland.

- William, B. (1966) Textbook of Microbiology18thed, W.B Saunders CO, USA.

Web Site:-

- htt://www. Khartoum State. Com
- htt://en.Wikipedia.org/wiki/ Groundwater.