Sudan University of Science and Technology

Collage of Graduate Studies

Environmental Engineering Program

Some Aspects of Groundwater and Tap Water Quality in Sharq El-Niel–Khartoum City–Sudan

بعض ملامح نوعية المياه الجوفية والمياه المنزلية في منطقة شرق النيل– الخرطوم – السودان

A Thesis in Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Engineering

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قال تعالى:

{وَهُوَ الَّذِي خَلَقَ مِنَ الْمَاءِ بَشَراً فَجَعَلَهُ نَسَباً وَصِهْراً وَكَانَ رَبُّكَ قَدِيراً}

سورة الفرقان (54)

Dedication

To the light that enlightens me the path of success... Dad,

And who taught me success and patience and steadfastness no matter how circumstances change... Mom,

To my brothers and sisters who always take care of me,

To those who made optimism on my way andhelp me, without feeling their turn, so they have all the thanks.

Acknowledgement

I would like to thank my supervisor Dr. AbdellatifMukhtar Ahmed who gave me a lot of advice and guide me in the right direction throughout my research.

My gratitude also to all who helped and encouraged me throughout the study.

Abstract

The study area is located in the east of the Blue Nile, between latitudes 15 20’ to 15 37’ and longitudes 32 31’ to 32 56’.

The purpose of the study is to provide safe water and sufficient quantity to satisfy water requirement for growth and pressure of the population extension of the area.

Main problem is to find out suitability of groundwater for domestic uses and to compare it with tap water in some houses in the area of study.

Water samples were collected from six boreholes and three samples from home taps.

Than the water samples were analyzed physically, chemically and biologically. The results were compared with WHOstandards.

From the results, I found that the water samples are fit for domestic usesas to the WHO standards.

According to the physical and chemical analysis of the boreholes, the study summarizes that this water is suitable for drinking and human use.

The study recommends that boreholes water should be monitored to determine physical, chemical and biological changes every year and to find out if there are any differences between water from boreholes and that from tap at the homes.

المستلخص

تقع منطقى الدراسة في شرق النيل الأزرق، بين خطوط العرض 15 20 ` إلى 15 37 ` وخطوط طول 32 31 ` إلى 32 56 `.

والغرض من الدراسة هو مدى توفر المياه الصالحة للشرب بكمية كافية لتلبية الاحتياجات المائية للنمو والضغط السكاني في المنطقة.

المشكلةالرئيسيةهيمعرفةمدىملاءمةالمياهالجوفيةللاستخداماتالمنزليةومقارنتهابمياهالصنبورفيبعضالمنازلفيمنطقةالدراسة.

تم جمع عينات مياه من ستة آبار وثلاث عينات مياه من ثلاث حنفيات من منازل مختلفة.

تم تحليل عينات المياه فيزيائياً وكيميائياً وبيولوجياً، وتمت مقارنة النتائج مع معايير منظمة الصحة العالمية.

من النتائج وجدت أن عينات المياه صالحة للاستخدام المنزلي فيما يتعلق بمعايير منظمة الصحة العالمية.

وفقًاللتحليلالفيزيائيوالكيميائيللآبار،تلخصالدراسةأنهذاالماءمناسبللشربوالاستخدامالبشري.

توصيالدراسةبضرورةمراقبةمياهالآبارلتحديدالتغيراتالفيزيائيةوالكيميائيةوالبيولوجيةكلعام، ومعرفةماإذاكانتهناكأياختلافاتبينالمياهمنالآباروتلكالموجودةفيالمنازل.

Contents

List of Figures

List of Tables

Chapter one

Introduction

1-1: Background:

Groundwater is all water below the surface of the earth, which is the corresponding name of water on the surface of the earth called surface water.
Groundwater lies in both saturated and unsaturated conditions in the soil layers, and its movement is slow. Groundwater flows from precipitation (e.g. rain and snow) as a process of natural recharge in the hydrological cycle.
The Earth's water cycle begins with oceanic water, which covers about three-quarters of the Earth's surface. Due to its exposure to the sun, evaporation evaporates and the clouds build up. Under certain conditions clouds condense and fall in the form of rain, cold or snow. The various forms of falling water are known as the originals of freshwater, which are the main source of fresh water on the surface of the earth, some of which are carried out to rivers, valleys and lakes.The second section is penetrated into the surface so that most of it remains in the root area of the plants and is again brought back to the surface by plants or wild in the poetic properties. The water reservoir enters the soil and a small percentage of penetration continues to the bottom of the root area under the influence of gravity. When connected to the groundwater, the transient water moves horizontally into the pores of the water-saturated layers and may appear again on the surface in the form of springs in some areas where the level of the Earth's surface falls below that of the water. The spring water is once again on the surface with surface water to the oceans and this water movement is known as the water cycle.[4]

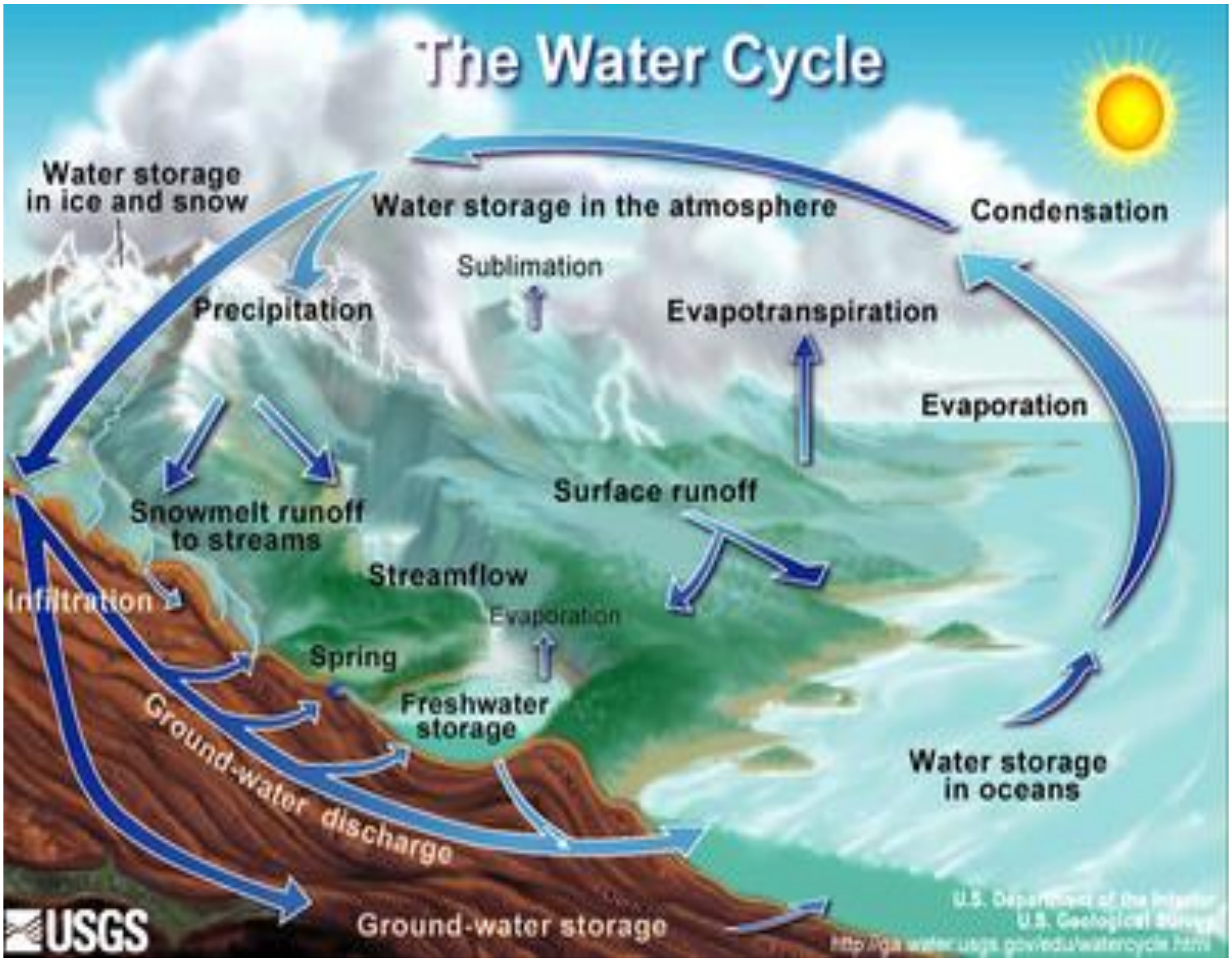

Figure (1.1):The Water Cycle.

Groundwater represents the most important water resource for domestic, agriculture and industrial usage in the world especially in areas where there are no sufficient surface water resources and intensive rain fall.

The study area is one of the most developed parts in Sudan, the development in the area depend to greater extent upon the availability of sufficient amount of groundwater used for the above mentioned purposes. [4]

1-2: Environmental Setting of the Study Area:

1-2-1: Location:

The study area is located in the east of the Blue Nile, between latitudes 15 20’ to 15 37’ and longitudes 32 31’ to 32 56’ cover an area of about 30000 Km^2. The investigation area is bounded from the north by Nahr Elneel state, from the south by Gezira state, and from the west by Blue Nile and Nile Revere.

Figure (1.2): Location of the Study Area.

1-2-2: Climate:

The state of Khartoum is located in the semi-desert climatic zone and its climate is hot to very hot and rainy in summer and dry to cold and dry in winter. The amount of rainfall in the north-east is between 100-200 mm and in the north-west between 200-300 mm and temperatures in the summer between 25 - 40 ° C in the months of April to June and from 20-35 ° C in the months of July to October temperatures continue to decline in the separation between 15-25 ° C in the months from November to March.

1-3: Problem Statement:

Groundwater is essential for the human life, economy, stability, and development as good quality more comfortable source of drinking water attracted the attention globally. In the past, people in the study area depend mainly for their activities on the surface water from the Blue Nile and the River Nile, seasonal steam and few wells extracted water from the groundwater, especially in areas near the Nile, but in remote area they rely on groundwater, although some salinity hazards, biological contaminations as well as insufficient quantity were encountered. With respect to the expansion of residential area and the consequence water demand, more attention should be focused on groundwater to meet the water requirements for present and future development. Accordingly, more interest to evaluate the ground water quality in the study area is the main target.

1-4: Objectives:

-Main Objective:

To assess the groundwater quality in eastern of the Blue Nile, Khartoum state, Sudan.

-Special Objective:

- The chemical parameters of groundwater
- The physical parameters of groundwater
- The bacteriological parameters of groundwater

Chapter Two

Literature Review

2-1:Groundwater:

Groundwater is water contained in the pores of sedimentary rocks that have been established through different times that may be modern or very old for millions of years. Groundwater is an underground wealth of clean, healthy water that is good for human and humanitarian use, stored in the depths of the globe, estimated at 97%, or approximately 100, 000 km^2, while surface water represents only 3% of the total water that forms three-fourths of the globe.Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly throughgeologic formations of soil, sand and rocks called aquifers.Groundwateris the water that occurs below the surface of Earth, where it occupies all or part of the void spaces in soils or geologic strata.Groundwater is water that exists underground in saturated zones beneath the land surface. The upper surface of the saturated zone is called the water table. Groundwater is often more suitable and less susceptible to surface water pollution. Therefore, it is usually used for public water supply. Groundwater provides the largest source of usable water storage.

Underground reservoirs contain much more water than the capacity of all reservoirs and surface lakes.[4]Water is a ubiquitous chemical substance that is composed of hydrogen and oxygen and is vital for all known forms of life.(UNOSIA, 2005)In typical usage, water refers only to its liquid form or state, but the substance also has a solid state, ice, and a gaseous state, water vapor or steam. Watercovers 71% of the Earth's surface.(FAO, 1997a)At present only about 0.08 percent of all the world's fresh water is exploited by mankind in ever increasing demand for sanitation, drinking, manufacturing, leisure and agriculture.(Fry, Carolyn, 2008)

Groundwater is one of the most important sources of water for human life and for flora and fauna. It is generally considered to be safer source of drinking water than surface water where can be contaminated by physical, chemical and biological pollution.

Groundwater contamination occurs when man-made products such as gasoline, oil, road salts and chemicals get into the groundwater and cause it to become unsafe and unfit for human use. Materials from the land's surface can move through the soil and end up in the groundwater.

Groundwater pollution is almost always the result of human activity. At highly populated areas and groundwater are particularly vulnerable. Any activity that may release chemicals or waste into the environment, either intentionally or accidentally able to pollute groundwater.

Contaminated groundwater is less clear and more difficult to clean up than pollution in rivers and lakes. Groundwater pollution often results from improper disposal of waste on the ground. [6]

2-2: Groundwater Resources:

Groundwater is the portion of the Earth's water cycle that flows underground. Groundwater originates from precipitation that percolates into the ground. Percolation is the flow of water through soil and porous rock.

The main source of groundwater is the rain from the sky, whether cold, snow or normal, and the melting of icebergs due to the warming of the Earth over the years and the seasonal and permanent rivers as well, as these sources leak into the earth depending on the type of soil in contact with them. and rocks, the more porous and disjointed the soil or rocks, the more water it leaks from the soil or the porous rigid rock, the rain water, the rivers and the ice; there are other sources of groundwater, as follows:

1. Fossil water:

   Is one of the types of groundwater stored in sedimentary rocks during sedimentation operations hundreds of years ago, and has been retained to the present day.

2. Al-Smelter Water:

It is called modern water, the water associated with the fiery activity and the movement of a fire block over the crust of the earth, or towards its surface, resulting in the explosion of a rich hot water that is stored between the particles of the rock.

3. Salt water:

   Water that is found in coastal areas, also called marine or oceanic waters where it seeps into land rocks.[4]

2-3: Groundwater Location:

Groundwater is all water beneath the surface of the Earth, which is the equivalent of water on the surface of the earth and is called surface water, and groundwater is located in two different regions, namely the saturated water area and the unsaturated zone.

- The unsaturated zone is located directly beneath the surface of the Earth in most areas and contains water and air and has less pressure than atmospheric pressure, which prevents the water in that area from exiting to any well dug, a layer of fish and directly beneath the saturated zone.
- The saturated zone is a layer containing water-bearing materials and all the voids connected to each other are filled with water and the pressure is greater than atmospheric pressure, which allows the water to go out to the well, feeding the saturated area through the infiltration of water from the surface of the earth to this layer through the passage of an unsaturated.[4]

2-4: Utilizations of Groundwater:

Groundwater is an important source of water supply throughout the world. It is used in irrigation, industries, municipalities and rural homes continue to increase.

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 formation and the presence of water.

From the differences in indicted velocity's to the several geophones it may be possible to estimate the depth to the water table or the interface between formations. Resistively 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 glow with various electrode spacing. Since the water increase the conductivity of soil or rock, the presence of groundwater 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 point, large areas may be surveyed rapid by seismic or resistivity methods.

One of the main objectives behind the hydro chemical studies of ground water is to determine its suitability for the different uses.(Mark.G.Hammer,2003)

2-5: The Main Subsurface Sources:

Springs: Groundwater reappears at the ground in the form of springs. Springs are brought about under the following conditions:

-When the surface of the earth drops sharply below the normal groundwater table, the water bearing stream (Aquifer) is exposed to the atmosphere and spring are crated. The formation of such springs created from an overflow of the groundwater table. This type of springs is called as (gravity) or shallow springs and water table in such springs varies with the rainfall.

-When due to an obstruction groundwater is stored in the form of a reservoir and this water is forced to overflow at surface.

Spring of this type is most common. These are formed when an imperious stratum, which is supporting the groundwater reservoir, becomes out crops. The storage capacity of these springs id 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 follow in the form springs.

Such types of springs come across when groundwater arise through 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.

2-6: Drainage Patterns:

The whole area is gently sloping towards the Nile. The terrain is generally flat containing isolated rock exposures.

The drainage pattern is characterized by dendrite upstream then changes into controlled straight and shallow wades on fault of mudstone when approaching the Niles where the whole area is draining towards the Nile

2-7: Wells:

Wells are dug or driven holes to reach the groundwater.

- Types of Wells:
  I. Shallow Well:

This is a dug well up to groundwater 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 seasonal ponds and plant leaves.

II. Deep Well:

This is a dug well, which goes beyond the first impervious layer to reach the water strata below. This water is free from surface contamination, though it may be hard due to nitrites and nitrates.

III. 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.

IV. Tube-Well:

It 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.

V. 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 outside consisting of clay, bricks and cement respectively.
- A parapet about ¾ 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. (Rama,1986)
- Well Cleaning:

This is usually carried out at the end of summer, when water in the well is at its lowest deep. All water, mud, stones etc are removed from the bottom, and the well is disinfected with slaked time (part to 4 parts water) or pot. Permanganate (just enough to make water pinkish). Periodic disinfection of well is carried out at night with 102 mg bleaching power per 1000 gallons of water. This ensures at least 6 hours 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 seasonal pools 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. (Rama,1986)

2-8: Groundwater in Sudan:

Groundwater is potentially available in large areas away from Nile.

Major water aquifers cover about 50% of the surface of the country and occur either in shallow aquifer along the major seasonal steams or in deep aquifer of Nubian sand stone formation.

- The main aquifers exist under three categories:
  I. The Nubian sand stone aquifers.
  II. The detrital quaternary, tertiary. Aquifers.
  III. The recent alluvial wade-fill aquifers.(SSMO, 2002)

2-9: Quality of Groundwater:

Generally, it is recognized that the quality of groundwater is just as important as quantity. All groundwater contain salts in solution that are derived from location and past movement of the water. The quality of groundwater supply depends on its purpose.(SSMO, 2002)

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 method for reporting and comparing results of water analysis. Dissolved gases in groundwater can pose hazards if their presence record under unrecognized. (Jerry,2003)

2-10: Groundwater Contamination:

Groundwater in the subsoil is inherently clean and uncontaminated, but it may be exposed to harmful contamination and bacteria as a result of external factors:

- Agricultural activities:
  Agricultural activities represent the addition of pesticides, fertilizers, soil washing and evaporation processes, as these activities lead to the emergence of many pollutants such as pesticides and dissolved salts.
- Human activities:

Human activities sometimes lead to contamination of groundwater, as a result of leakage of organic waste from sewage systems or ground assembly reservoirs and absorbency pits that are abundant in villages distant from the means of services and sewage systems, where organic wastes contain in varying proportions on nitrogen compounds (ammonia or organic nitrogen).

- Industrial activities:
  Industrial activities are the most dangerous source of groundwater pollution, and their impact depends on the type of industry and the way in which it is disposed of. Of course, most factories do not dispose of their waste and residues directly into the ground, but they may dispose of them in river or sea water, resulting in contamination, and leakage of heavy elements such as lead, zinc, and chromium into the aquifer, thus causing contamination of groundwater.
- Wrongful withdrawal of groundwater:

  The unjust withdrawal of groundwater leads to contamination of the groundwater reservoir.[5]

2-11: Reduction of Groundwater Pollution:

The risk of groundwater contamination can be minimized and reduced by the following methods:

1. Establishment of agricultural drainage systems with good infrastructure.

2. Reduce the use of harmful pesticides that pollute the environment and groundwater, and use non-polluting and environmentally friendly species.

3. Reduction of methods for the unfair withdrawal of groundwater by the development of drought-resistant plant varieties using traditional breeding methods or genetic engineering, in the event of extraction of groundwater for cultivation.

4. Protection of groundwater from a high salinity due to an unjust and irregular withdrawal, as a result of the presence of groundwater over high salinity, or as a result of the interference and mixing of seawater with groundwater.

5. Digging wells in safe depths with the need to regulate the withdrawal rates from those wells.

6. Reduce the presence of ground assembly tanks and drilling rigs by extending sewage systems to remote areas and villages lacking this service.

7. Supplying the wells with clean water until the contamination is moved in an area far from the well sites.

8. Reduce the use of fertilizers, and use less water to irrigate crops.[5]

2-12: Water Quality:

The quality of the aquatic environment can be defined by:

I. By a set of concentrations, specification and physical partition of inorganic or organic substances.
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.

2-12-1: Concept of Water Quality:

Water quality means assessing water quality, determining the concentration of its components and additions to it, and then comparing the results of this concentration with the purpose for which it will be used, for example, distilled water is considered to be one of the most quality forms of water, but it is not suitable for all organisms It is considered an unsuitable environment, so it is not possible to measure quality without specifying the purposes used, because water used in households for drinking and preparing food is different from that used for fish breeding, or those used to irrigate crops, while the seas and oceans are characterized by high quality for many fish species, they are not suitable for some other organisms, including humanity. (Chapman.D,1992)

2-12-2: Water Quality Measurement Standards:

I. Physical measurements of water quality:

- 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 known dimension and covering it in the water

column. The depth at which it is distinguished is used as measure of transparency.

- Temperature:

  Directly affect biological processes in water, where high temperature leads to lower concentration of dissolved oxygen in the water and increase the rate of metabolism of organisms and accelerate the reproduction.

- Electrical Conductivity:

  Electrical conductivity dissociated cations and anions in water determine its electrical conductivity, which is measured by finding the inverse of electrical resistivity between two electrodes one centimeter apart. The electrical conductivity reflects the amount or concentration of dissolved substances in water.

- turbidity:

  Hard bodies that do not soak in water such as algae, sand atoms and bacteria lead to sour water, which reduces the possibility of sunlight entering the water concentrations, thereby reducing photosynthesis and reducing oxygen concentration with increased concentration of dioxide Carbon in water, which negatively affects the organisms that will drink this water, and the water turbidity is measured by using a ski plate painted with color triangles, some black and others white, which enters the water to measure the depth at which the colors disappeared, the more the colors disappear in a less depth, the higher Turbidity ratio, the turbidity meter is expressed in NTU units.

- color, taste and smell of water:

  It is known that water has no taste, no color, no odor, so the presence of any characteristic of these qualities means water contamination.(Kagely,1998)

II. Chemical standards for water quality:

- Salinity:

  Salts are usually found in the water in a natural way, resulting from the melting of rocks or salts in the soil, or in an unnatural way by the human being through the use of chemical fertilizers or mixing potable water with sewage.

- Nitrate and phosphate:

  The increase in nitrate and phosphate in water leads to the rapid reproduction of plant organisms in water, especially algae, which reduces photosynthesis of plants, concentration of oxygen and the death of most organisms living in water, and the increase of nitrate in the waters Drinking leads to their contact with hemoglobin in red blood cells, obstruction of oxygen transmission in the body and the incidence of cyanosis, especially in children.

- Oxygen:
  Organisms that live in water need a certain concentration of oxygen, where the minimum concentration of life in water is 4 mg/l and organisms cannot live in less concentration.
- pH:
  The ratio of acidic or basal water, where pH is measured in the area of 0 14, and when the pH = 7 ratio is equal, if less than 7 is acidic, but more than 7 is the base.
- Iron:
  Iron anaerobic groundwater may contain ferrous at concentrations of up several mg/l, without discoloration turbidity in water when directly pumped from the well. At level above 0.3 mg/l. Iron stains laundry and plumbing fixture.
- 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.
- Sulfate:
  The presence of sulfate in drinking water can cause noticeable taste. It is generally considered that taste impairment is minimal at levels below 250 mg/l.
- Hydrogen Sulfide:
  Hydrogen sulfide in water is estimated to be between 0.05 and 0.1 mg/l. It 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 sulfide by bacterial activity, sulfur is oxidized rapidly to sulfide in well.
- Total Dissolved Solids:
  TDS can have an important effect in the taste of drinking water with a TDS level of less than 600 mg/l is generally considered to be good. Drinking water becomes increasingly unpalatable at TDS level greater than 1200 mg/l. Water with extremely low concentration of TDS may be unacceptable. The presence of high levels of TDS may be also objectionable to consumer

owing to excessive scaling in water pipes, heaters, boilers, etc. Water with concentrations of TDS below 1000 mg/l is usually acceptable to consumers.

- Manganese:
  Concentrations of manganese less than 0.1 mg / l are usually acceptable to consumers. At a level higher than 0.1 mg / l of manganese in water supply stains, sanitary ware and washing, causes undesirable taste in drinks. May lead to accumulation of deposits in the distribution system. Even at a concentration of 0.02 mg / l, manganese often forms a layer on the tubes, which may fade at black deposits.
- Nitrate and Nitrite:
  Nitrate and Nitrite are naturally occurring ions that are part of nitrogen cycle. Naturally occurring levels in surface and groundwater are generally a few milligrams per liter. In many groundwater increase of nitrate level has been observed owing to the intensification of farming practice.
- Fluoride:
  The concentration of fluoride is critical for dental health in children. Too high concentration can result in dental fluorosis, in some children, but small amount is essential for the prevention of dental caries. The desirable concentration varies with age rage 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 at 30 C°.
  Groundwater may contain about 10 mg/l in areas rich in fluoride containing minerals. The guideline value suggested 1.5 mg/l.
- Chloride:
  Large quantities of chlorides are usually present in surface and groundwater, pollution of water by industrials activities might be the cause for further increase in chloride in chloride concentration.
- 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 amount in the range of 0.2 to 2.0 mg/l is toxic many fish.
- Alkalinity:
  The alkalinity of water passing through iron distribution system should be in the range of 30-100 mg/l as $CaCO_3$ to present serious corrosion, up to 200mg/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 react with added alum to form a flock in water coagulation. Bathing or washing in water of excessive alkalinity can change the pH of the lacrimal fluid around the eye, causing eye irritation.

- Hardness:
  Hardness results from the present metallic cautions of which calcium and magnesium are the most abundant in groundwater. These irons 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 water is unsatisfactory for household cleaning purposes. Hence water softening processes for removal of hardness are needed.
  Hardness may be classified as:
    - Temporary hardness: The presence of bicarbonates of calcium and magnesium in water known as temporary hardness.
    - Permanente hardness: The presence of sulfate, chloride and nitrates of calcium and magnesium in water known as permanent hardness.

The degree of hardness in water commonly based on classification listed in table below.

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

- Water hardness:
  Water hardness means the concentration of calcium and magnesium ions combined in water, the more concentrations of these ions increase the hardness of the water, thereby increasing the deposition in salts.
- Heavy metals:
  Minerals in water affect human health, whether natural minerals from rock melting, or industrial minerals caused by wastewater.(Kagely,1998)

III. Biological measurements:

The Bio-criterion principle is based on the measurement of the proportion of organisms, especially invertebrates, which are the most sensitive to pollution, which live and reproduce within the aquatic environment, where the biological coefficient must be between 0 and 10, and the higher the value from six to ten, the criterion for High water quality. [5]

IV. Radiological measurements:

Means radioactive material, which leads to contamination of water, and may be the source of these radioactive materials to the melting of radioactive rocks or the dumping of radioactive waste from factories, hospitals or laboratories in the water, which is considered very serious for its impact on the building of the genetic material of the human DNA It causes mutations, or cancer.

2-12-3:Importance of Water:

Water is considered an economic good, therefore, each unit of it should be used efficiently, equitably and soundly.(Chapman.D.1992)

2-12-4: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 taste, free from odor and color
- Usable for domestic purposes(Chapman.D,1992)

Water is said to be polluted or contamination 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 to provide health care to the community.(Chapman.D,1992)

2-12-5: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 capita is considered an adequate supply to meet the needs for all domestic purposes.(Chapman.D,1992)

2-12-6:Uses of Water in a Community:

There are many uses and the requirements in quantity are varied. Conventionally, it has used convenient in quantity to serve all uses and suitable in quantity to meet drinking requirement.(Rama**,1986)**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 parks.
- Industrial purposes: For processing and cooling.
- Agricultural purposes: Irrigation, power production from hydropower and steam power.

Caring away waste from all manner of establishments and institutions.

Therefore, water is an essential factor in the economic, social and cultural development of a community. It can cause water borne diseases.

Promote rural development and improve quality of life.(Gwort,2001)

2-12-7: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 area.(Warren,2003)

2-13: Water Pollution:

Is to expose the quality of water to changes, whether physical or chemical; This change has a negative effect on organisms; it makes water unfit for the consumption of organisms; and the negative impact directly on the lives of individuals, the family and society is demonstrated as a vital requirement for all living beings above the Earth, they are a major cause of life. Water pollution can be defined as damage, damage or corruption of water quality; Thus, the environmental system is generally disrupted; its capabilities to play a natural role are diminished, and the concept of water pollution includes contamination of all streams of rivers, oceans, lakes, dams and rainwater, Groundwater and Wells.(Warren,2003)

2-14: Types of Water Contamination:

The types of water contamination are divided into two main categories:

- Natural contamination:
  This is the pollution that occurs in the natural characteristics of water to make it unacceptable or suitable for human use; This occurs under the influence of temperatures or salinity or the increase in the number of suspended substances; It is indicated that high salinity rates are often due to higher evaporation in water Lakes or rivers, it leaves a foul odor in the water and changes its color and taste.
- Chemical contamination:
  This is one of the most serious problems facing the human being, as water is contaminated as a result of human intervention by dumping hazardous chemicals into water, such as lead compounds, mercury and insecticides; this contamination is a direct threat to all fish and marine organisms.(Warren,2003)

2-15: Drinking Water Standards:

The purity of water has several criteria including the following:

-Be pure tasteless, no color, no odor.

-free of any impurities, natural or biological plankton, and the presence of any inorganic or organic compounds.

-free of any biological contaminants such as germs, microbes and vectors, and drinking water contains mineral elements at a specified rate, which should not exceed them, including sulfites, carbonate, anion, sodium, magnesium and catenulate Calcium, where increased concentration of magnesium and calcium cause water distress.

-free of heavy metals such as lead, mercury, arsenic, nitrates and iron, the lead ratio may not exceed 10 mg/L.

-The percentage of dissolved substances does not rise above a certain limit.

-be neutral and non-acidic.

-Do not carry any bad effects to health.

-The percentage of oxygen dissolved at 25 º C is between 5 to 8 mg/L and the second carbon-oxidized ratio at the same temperature is between 2 to 3 mg/L.

-the degree of electrical conductivity at 28 º C is equal to 0.0004 Micro banana/cm², and the degree of thermal conductivity at 40.8 º C is equal to 1.555 watts per meter, and the degree of refractive index at 20°c is equal to 1.33 units, and its vapor pressure at 20 hundred degrees is equal to 17.62 mm Hg, and its quality temperature at 1 °c is equal to 1.00 kJ/kg degree.(WHO,2006)

2-16: Accurate Readings of Potable Water:

For the water ingredients accurate readings so it is valid for drinking and these readings are:

Color: Between PT/CO 1-20.

Temperature: 13 to 35°c.

pH value: between 6.5 and 8.5.

TDS mg/L: between 300 and 1500

Sodium: between 20 to 175 mg/L.

Potassium: between 10 to 12 mg/L.

Calcium: between 100 to 200 mg/L.

Magnesium: between 30 to 50 mg/L.

Chloride: between 25 to 200 mg/L.

Sulfites: between 25 to 250 mg/L.

Nitrate: between 25 to 50 mg/L.

Chapter Three

Materials and Methodology

3-1:Data Collection:

Collection of water samples:

Nine water samples for this study were collected from sixboreholes except three samples from home taps.

The Nine water samples for this study were collected in poly ethylene bottles for chemical analysis in 250ml sterile-glass bottle. They were taken to the laboratory (at ambient 25C°).

Then the samples were immediately analyzed.

3-2: Sampling Methods for Physical and Chemical Analysis:

All precautions were considered to collect samples which are representative as far as possible of the water to be examined in accordance with methods of laboratory test of water.

The water samples collected for chemical and physical analysis were used to determine pH, color, temperature, turbidity (NTU), odor, total hardness(TH), total alkalinity (T ALKA), chlorides (CL), nitrates (NO_3), ammonia (NH_3), sulfate (SO_4) and fluoride (F) as the followings:

- The containers (new, clean, plastic bottles with screw cap, 2.5 liter) were used.
- The container was gently washed by distilled water firstly, and then filled with water samples.
- For Tap water the samples were collected from home taps.
- The water samples of groundwater were taken from the source directly via nozzle or tap near the source, before it flows through the network distribution system of reservoirs.

3-3: Sampling Methods for Bacteriological Analysis:

Water sample collected from bacteriological were used to analyze the total account of bacteria, total coli form, and E-coil that carried as follows:

A glass bottles (250 ml) were sterilized in the laboratory by using hot air sterilization method, putting the bottle in an autoclave, 1800 C° for half an hour.

The samples from groundwater were taken from tab located near well. The tab is firstly heated by a gas torch, and then the water allowed to flow for several minutes to ensure it is a true sample from the groundwater.

The bottles (250 ml) were filled to the level just above the rim.

After filling, the bottles removed quickly and immediately the samples were packed into ice till to deliver to the laboratory.

3-4:Methods of Analysis:

- pH was measured by pH meter.

- Electrical Conductivity (EC) was measured at temperature 25C° by conductivity meter.

-Turbidity is measured in NTU: Nephelometric Turbidity Units. The instrument used for measuring it is called nephelometer or turbid meter, which measures the intensity of light scattered at 90 degrees as a beam of light passes through a water sample.

-Sodium (Na) was obtained by 543 nm flame photometer.

-Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) were determined by titration with EDTA – disodium salt solution (0.01 M).

-Fluoride (F^-) was determined by Alizarin visual method (reaction between fluoride and zirconium Dye Lake). Fluoride reacts with dye lake, dissociating apportion of it into colorless complex anion (ZrF_6). As the amount of fluoride increases, the color produced becomes progressively lighter or of different hue.

-Chloride (CL^-) was determined by filtration using standard nitrate solution (0.014) and potassium chromate (5%) solution as an indicator.

-Sulfate (SO_4^{-2}) was determined gravimetrically by ignition. Sulfate is precipitated in HCL solution as barium sulfate, thus by addition of Barium Chloride, the precipitation was carried out near boiling temperature. Then after digestion the precipitate was filtered. Washed with water be free of CL^-, ignited and weighed as $BaSO_4$.

-Bicarbonate (HCO_3^-) was determined by titration against HXL (0.012 N) to pH 4.5 using methyl orange as an indicator.

-Total hardness (TH) was obtained by calculation from Ca^{2+} and Mg^{2+} determined concentrations.

-Nitrate (NO_3^-) was determined by Cadmium reduction method. NO_3^- is reduced almost quantitatively to nitrite (NO_2^-) in the presence of Cadmium. The NO_2^- produced thus determined calorimetrically.

A correction may be made for any NO_2^- present in each sample by analyzing excluding the reduction step. Total alkalinity was obtained by EDTA titration method.

- Total dissolved solids (TDS) were determined by multiplying the electrical conductivity (EC) value obtained by 640.
- According to WHO, total coli from number was determined by membrane filtration method (MF).100 ml water samples were filtered through the membranes using sterile forceps. The membrane filters were placed in the Petri Dishes and the pads which were saturated with membrane laurel broth medium. The dishes were placed in the incubator at 37C° for 24 hours.
  Thermo tolerant (fecal) coli-forms were determined by membrane filtration method. But incubation was done at 44C°.It can be calculated as follows thermo tolerant coli-formper 100 ml equal number of theromotolerant, coli-form calories counted divided by number of ml of sample filtered.

Chapter Four

Result and Discussion

4-1: The Results of Laboratory Analysis:

4-1-1: The Results of Physical Analysis:

Table (4.1) shows the results of physical analysis of six water samples collected from six boreholes in the study area.

Table (4.1) Physical Analysis of GroundwaterSamples in the Study Area:

No.	Locality	Longitude	Latitude	Odor	pH	Taste	Turbi dity
1	Dar El-Salam	32.66272	15.61497	-	6.7	-	-
2	Al-Qadisiyah	32.60244	15.60791	-	6.5	-	-
3	AL-Baraka	32.6476	15.59841	-	6.9	-	-
4	Al-Fayhaa Hay Al-Gamaa	32.61599	15.59557	-	6.8	-	-
5	HayAL-Safa	32.64572	15.6339	-	6.6	-	-
6	Al-Naseem	32.64553	15.64748	-	6.9	-	-

Table (4.2) shows the results of physical analysis of three water samples collected from home taps in three homes selected from the study area.

Table (4.2) Physical Analysis of Home Tapein the Study Area:

No.	Locality	Odor	pH	Taste	EC	Turbidity
1	Dar El-Salam	-	6.7	-	409	-
2	Al-Fayhaa Hay Al-Gamaa	-	6.8	-	441	-
3	Al-Naseem	-	6.9	-	1006	-

The physical analysis of the water samples revealed that all water samples are within the permissible limit of WHO standards.

Thus the color and turbidity are normal and odor, smell and taste are acceptable. pH for water samples is within the standard level.

There is an increase in electrical conductivity in Elnaseem area, which is an indicator of the presence of dissolved salts in the water.

4-1-2: TheResults of Chemical Analysis:

Table (4.3) shows the results of chemical analysis of six water samples collected from six boreholes in the study area.

Table (4.3) Chemical Analysis of GroundwaterSamples in the Study Area:

No.	Locality	Longitude	Latitude	TDS	TH	T ALKAL	EX ALKAL	HCO_3 ALKA	CL^-
1	Dar El-Salam	32.66272	15.61497	216	230	268.4	55.544	268.4	63.19
2	Al-Qadisiyah	32.60244	15.60791	662.2	240	292.8	55.968	292.8	80.94
3	AL-Baraka	32.6476	15.59841	371	214	244	31.8	244	26.98
4	Al-Fayhaa Hay Al-Gamaa	32.61599	15.59557	216.3	156	195.2	41.552	195.2	8.52
5	HayAL-Safa	32.64572	15.6339	424.2	228	207.4	-21.836	207.4	49.7
6	Al-Naseem	32.64553	15.64748	462	150	207.4	60.844	207.4	14.2

No.	Locality	SO_4^{-2}	Ca^{-2}	Mg^{-2}	Na	F^-	No_3^-	No_2^-	NH_4
1	Dar El-Salam	136.67	80	3.888	115.1903	0.4	7.92	0.0693	0.427
2	Al-Qadisiyah	105	51.2	27.216	102.8722	1.47	0	0	0.0122
3	AL-Baraka	42	36.8	29.646	30.62284	0.08	6.6	0.0363	0.1342
4	Al-Fayhaa Hay Al-Gamaa	1	35.2	16.524	7.926765	0	6.6	0.0627	0
5	HayAL-Safa	64	17.6	44.712	40.33096	0.15	0	0.0033	0.0366
6	Al-Naseem	26	29.6	18.468	30.92188	1.52	26.84	0	0.061

Table (4.4) shows the results of chemical analysis of three water samples collected from home taps in three homes selected from the study area.

Table (4.4) Chemical Analysis of Home Tape in the Study Area:

No.	Locality	TDS	TH	T ALKAL	EX ALKAL	HCO_3 ALKA	CL^-	SO_4^{-2}	Ca^{-2}	CO_3 ALKA
1	Dar El-Salam	286.3	170	219.4	52.364	207.4	10.934	5	39.2	12
2	Fayhaa Hay Al-Gamaa	308.7	182	198.2	41.552	195.2	28.826	36	31.2	3
3	Al-Naseem	704.2	236	189	0	183	123.256	146	40.8	6

No.	Locality	Mg^{-2}	Na	F^{-}	No_3^{-}	No_2^{-}	NH_4
1	Dar El-Salam	17.496	12.87	0.09	3.52	0	0.0488
1	Al-Fayhaa Hay Al-Gamaa	25.272	18.44	0.44	6.16	0.0132	0.0976`
3	Al-Naseem	32.562	144.3	0.76	11.44	0.0396	0.061

The chemical analysis of the water samples revealed that all water samples are within the permissible limit of WHO standards.

The highest percentage of TDS was in Al-Qadisiyah area (662.2) and in Dar El-Salam was the lowest (216), while the taps for houses were the highest for TDS in Al-Naseem area (704.2).

The percentage of Chloride in the Fayhaa Hay Al-Gamaa area was the lowest (8.52) and the highest in Al-Qadisiyah (80.94), while in household taps, the proportion was high in Al-Naseem area (123.256) and the lowest in Dar El-Salam (10934).

In the area of Dar El-Salam, the proportion of Sulfate high (136.67) and in the Fayhaa Hay Al-Gamaa was the lowest (1), while the taps for houses were the highest for Sulfate in Al-Naseem area (146).

The highest percentage of Calcium was in Dar El-Salam area (80) and in Hay AL-Safawas the lowest (17.6), while the taps for houses were the highest for Calcium in Al-Naseem area (40.8).

In the area of Hay AL-Safa, the proportion of Magnesium high (44.712) and in Dar El-Salam was the lowest (3.888), while the taps for houses were the highest for Magnesium in Al-Naseem area (32.562).

The highest percentage of Sodium was in Dar El-Salam area (115.1903) and in the Fayhaa Hay Al-Gamaa was the lowest (7.926765), while the taps for houses were the highest for Sodium in Al-Naseem area (144.3).

The highest percentage of Fluoride was in Al-Naseem area (1.52), while the taps for houses were the highest for Fluoride in Al-Naseem area (0.76).

4-1-3: TheResults of BiologicalAnalysis:

Bacteriological water analysis is a method of analyzing water to estimate the numbers of bacteria present and find out what sort of bacteria they are. It represents one aspect of water quality. It is a microbiological analytical procedure which uses samples of water and from these samples determines the concentration of bacteria, to ensure that water is safe for human consumption.

Table (4.5) shows the results of biologicalanalysis of three water samples collected from home taps in three homes selected from the study area.[4]

Table (4.5) BiologicalAnalysis of Home Tape in the Study Area:

No.	Locality	E-Coli	Total Coliform
1	Dar El-Salam	0	-
2	Al-Fayhaa Hay Al-Gamaa	0	7
3	Al-Naseem	0	5

The biological analysis are free of E-Coli and are therefore considered harmless and safe to drink and human use.

Chapter Five

Conclusions and Recommendations

5-1: Conclusions:

Samples were taken from boreholes, analyzed to see their quality and conformity with the World Health Organization, as well as samples from home taps, which their origin was from groundwater to see the physical and chemical changes and their suitability for human use.

After matching them with the WHO standards, I concluded that physical, chemical and biological analyzes were in the normal range.

According to the physical and chemical analysis of water samples and the investigation of their parameters, it is concluded that the water is safe and fit for drinking and other purposes.

5-2: Recommendation:

1- I recommend monitoring water wells and household taps every year to determine the physical and chemical changes of water to assess water quality.

2- I recommend radioactivity analysis of water.

3-I recommend doing biological analysis of water every year, to find out the amount of bacteria in the water because it is the main cause of some water-borne diseases such as cholera and schistosomiasis.

References

1- FAO, 1997a. FAO (1997). Chemical analysis manual for food and water; 5th Ed, food and agriculture organization, Rome 1:20 – 26. (Peter H. Gleick 2002)
2- Fry, Carolyn (2008). The Impact of Climate Change: The World's Greatest Challenge in the Twenty-first Century , New Holland Publishers Ltd
3- Gwort, A.C. Ratnaya D.D.2001. Water Supply, Gray, Delhi
4- https://en.wikipedia.org/wiki/Groundwater
5- https://en.wikipedia.org/wiki/Bacteriological_water_analysis
6- https://www.groundwater.org/get-informed/groundwater/contamination.html
7- Jerry. A. 2003. Basic Environmental Technology. Rentice Hall, USA
8- Kagely. S,E.1998. The Chemistry of Water; congress cataloging, USA
9- Rama, 1986.National Water Corporation Report
10- SSMO. (2002) Guide Lines for Drinking Water Quality
11- United States Department of the Interior (1977). Ground Water Manual (First Ed.). United States Government Printing Office. p. 4
12- UNOSIA, 2005 .Water for life the United Nations office to support the International Decade for Action 2005 – 2015 / UN
13- Warren G. Mark G.Hammer. 2003 Water Supply and Pollution Control 7□ □ Edition, London
14- WHO, 2006. Guide Lined for Drinking Water Quality, set up in Geneva

Appendixes

Potable water specifications by WHO:

The World Health Organization (WHO) has identified 62 drinking water standards, such as physical, chemical, microbiological, and sensory, which are recognized by humans through the senses.

Natural characteristics of drinking water:

Color: The color shall be acceptable not exceeding 50 units in platinum cobalt scale.

Taste: To be acceptable palatable.

Odor: Healthy drinking water has no odor and no odor.

Turbidity: It should be clear. The maximum turbidity in the treated water is 5 units, and in the groundwater there is 52 units measured by Jackson.

Dissolved oxygen at 25 ° C 5-8 mg / l.

Dissolved carbon dioxide at 25 ° C 2-3 mg / L.

Electrical conductivity at 18 ° 0.0004 ميكرm / cm2.

Thermal conductivity at 40.8 ° C 1.555 W / m Degree.

The refractive index at 20 ° C is 1.33 units.

Steam pressure at 20 ° C 17.62 mmHg.

Specific heat at 1 ° C 1.00 kJ / kg. Degree.

Specific temperature at 20 ° C 0.99 kJ / kg. Degree.

Density at 4 ° C 1.00 g / cm3.

Density at 20 ° C 0.99823 g / cm3.

Freezing point is 0 ° C.

The boiling point is 100 ° C.

Potential heat of evaporation at 20 ° C 584.9 g.

Surface tension at 20 ° C 72.75 DIN / cm.

Toxic and chemical substances:

Water should be free of toxic elements and chemicals, but if they appear with the test they should not exceed the limit.

Material	Ratio mg/L
Lead	1.0
Arsenic	50.0
Zinc	15
Phenol	200.0
Sulfate	400
Chlorides	600
Magnesium	150
Calcium	200
pH	6.5-9.2
Manganese	5.0
Iron	1
Nitrates	45 (maximum)
Fluorinate	8.0 (maximum)
Mercury	0-100

Cadmium	10.0
Cyanide	50.0

WHO Drinking Water Specification Table:

Characteristic/Ingredient	Global Standard in mg/L
Color (TCU)	15
TDS	1000
Suspended Solids	0
Turbidity (NTU)	5
PH	6.5-8.5
Dissolved Oxygen	0
Water Hardness	500
Nitrogen ammonia	0
Ammonium	0
Nitrate Nitrogen	10
Nitrate	0
Nitrite	0
Phosphorus	0
BOD limits	0
BOD Sodium	200
Chloride	250
Sulfate	400

Sulfide	0
Fluoride	1.5
Boron	0
Cyanide	0.1
Aluminum	0.2
Arsenk	0.05
Barium	0
Cadmium	0.005
Chromium	0.05
Cobalt	0
Copper	1
Iron	0.3
Lead	0.05
Manganese	0.1
Hg	0.001
Nickel	0
Selenium	0.01
Zinc	5
Petroleum	0
Total Pesticides	0
Individual Pesticides	0
Aldrin and Dieldrin (Insecticides)	0.03
Dichlorobiphenyltrichloroethane	1

Lindane (gamma - HCH)	3
Methoxy Chlorine	30
Gasoline	10
Hexachlorobenzene	0.01
Pentachlorophenol	10
Phenols	0
Cleaners	0

Sudanese Standard for Total and Fecal Coliform (Colony/100ml):

- Standard for Total Coliform: 10

- Standard for Fecal Coliform: 0