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Supplementary Research for Master of Environmental Engineering

Evaluation of Drinking Water Quality in El rahad Town

تقييم جودة مياه الشرب بمدينة الرهد

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DEDICATION

Every challenging work always requires a self-dedication and a certain support and guidance. I would like to dedicate this thesis to my parents whose affection, encouragement, and prayers makes me capable to complete this thesis. I would also like to dedicate this to my hardworking respected teachers.

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Abstract

The study dealt with evaluating the water quality of the town of Rahad Abudkenah so that the problem of the study is to treat and know the amount of turbidity increase and color change in the summer months and the following samples were taken from the water of three phases which are the source ,the treatment plant and the house treatment the samples were analysed and matched with scientific, international and Sudanese standards specifications the sample analysed are Physical, chemical and biology , which are represented in the following (pH, turbidity, acidity, TDS , calcium, iron, magnesium 'manganese, acidic, nitrates, nitrites, bacteria)

Based on the results and analyses, the problems were known and the following was found. The increased turbidity rate is the lack of periodic cleanliness in the filters in the station, as well as the lack of chloride addition in the station and review of the network parts related to the distribution.

مستخلص البحث

تناولت الدراسة تقيم جودة مياه مدينة الرهد ابودكنه بحيث تتمثل مشكلة الدراسة في معالجة ومعرفة كمية العكارة الزيادة وتغير اللون في شهور الصيف وتم الاتي اخذ عينات من المياه من ثلاث مراحل وهي المصدر ومحطة المعالجة والمنزل وتم تحليل العينات ومطابقتها بالمواصفات القياسية العلمية والعالمية والسودانية وتم اجراء التحاليل الخاصة بالخواص الفيزيائية والكيميائية والبيولوجية وتتمثل في التالي (الرقم الهيدروجيني ، العكارة، القاعدية، الاملاح الذائبة الصلبة، الكالسيوم ،الحديد ، الماغنسيوم ’المنجنيز ،الحمضية ، النترات ، والنتريت ، البكتريا)

وبناء علي النتائج والتحاليل تم معرفة المشاكل وتمثلت وجدت نسبة العكارة الزيادة تتمثل في عدم النظافة الدورية للفلاتر الموجودة بالمحطة وايضا عدم اضافه الكلوريد بالمحطة ومراجعة اجزاء الشبكة المرتبطة بالتوزيع .

index

Chapter 1 :Introduction

Chapter 2 : literature review

Chapter 3: Methodology and materials

Chapter4: Result and discussion

Chapter 5: conclusion and recommendations

List of figures

List of table

Chapter one

Introduction

Chapter one

Introduction

1.1 Introduction:

Water is a common substance, but life cannot exist without it. Water is a major component of living things. Humans are about two-thirds water, and most other animals contain equal or even greater proportions. Woody plants are at least 50% water, and the water content of herbaceous is 80 to 90%. Bacteria and other microorganisms normally contain 90 to 95% water. Water is important physiologically. It plays an essential role in temperature control of organisms. It is a solvent in which gases, minerals, organic nutrients, and metabolic wastes dissolve. Substances move between cells and within the bodies of organisms via fluids comprised mostly of water. Water is a reactant in biochemical reactions ,the turgidity of cells depends upon water, and water is essential in excretory functions.

Water is important ecologically for it is the medium in which many organisms live. The distribution of vegetation over the earth's surface is controlled more by the availability of water than by any other factor. Well watere dareas have abundant vegetation, while vegetation is scarce in arid regions. Water plays a major role in shaping the earth's surface through the processes of dissolution, erosion, and deposition. Large water bodies exert considerable control over air temperature of surrounding land masses.(Adams, F. 1971)

Thus, ecosystems have a great dependence upon water.

In addition to requiring water to maintain bodily functions, humans use water for domestic purposes such as food preparation, washing clothes, and sanitation. Many aquatic animals and some aquatic plants have long been an essential part of mankind's food supply. Water bodies afford a convenient means of transportation. Humans find water bodies to be aesthetically pleasing, and many recreational activities are conducted in and around them.

Early human settlements developed in areas with dependable supplies of water from lakes or streams. Gradually, humans learned to tap underground water supplies, store water, convey water, and irrigate crops.(Adams, F. 1971)

This permitted humans to spread into previously dry and uninhabitable areas. Even today, population growth in a region depends upon water availability.

Water is a key ingredient of industry for power generation through direct use of the energy of flowing water to turn water wheels or turbines, steam generation, cooling, and processing. In processing, water may be used as an ingredient, solvent, or reagent. It also may be used for washing or conveying substances, and wastes from processing often are disposed of in water.(Adams, F. 1971)

1.2. Research problem:

To assess the drinking water quality through the proper management and protection of water resources access to improve the drinking water quality among the water treatment plant, the network system which carry water, and until it reaches homes.

1.3. Objectives:

1.3.1. General objective:

The main objective is to assess the quality of drinking water in Al-Rahad town .

1.3.2. Specific objectives:

* To analyze the drinking water by laboratories tests.

* To determine the chemical, physical, and biological characteristics of water.

* To compare the result with Sudanese Standard of drinking water.

1.4. study area :..

1.4.1. Location and accessibility

Al-Rahadcity is located between long lines 30, 18 and 31.21 and latitudes 12.45 and 13.42 in the southern part of North Kordofan It is bordered to the south by South Kordofan State, to the east and north by Umm Rawaba and to the west by Shikan..located in the North Kordofan State, Sudan, on an altitude of 490 meters (1,610 feet) above sea level. It is about 379 kilometers (235 miles) away from the capital, Khartoum. It is a major railway station linking East and Central Sudan and the West, which is also a market for crops, especially hibiscus as well as livestock and also urban centers for nomadic shepherds in the region. It is the second largest in North Kordofan after the Shikan locality.

1.4.2. Physiographical description of Al Rahad water body :

Al-Rahad name and established

is a word that refers to Rahad, and it is one of the common mistakes that it is called a canal instead of its response and this alters the meaning completely) It is a lake and means the natural low ground in which water accumulates and often is rain water and this lake is that natural low between the two corners of sand From the eastern and western sides, it represents the natural crossing of the water that falls in the autumn from the northern and western sides, which descends from the south through the monsoon creek, such as OdeibehKhor, Khor Al Sawani, KhorBeqra and KhorAtaqqar to receive the waters descending from the southwest and the south, i.e. the waters from the mountains of Al South and has made up of Khor Abu habil Kordofan, which is heading east in Umm Ruwaba and Tandalti down to the White Nile at Alvhchou area for the slow rate of entry into force of the water through this corridor keep some water for some time in this area so the name came Rahad.

In the year 1957, the region was exposed to a shortage of drinking water due to the scarcity of rains where people after the end of autumn were consuming the water they needed from the struck wells and there were several wells in the city of Al-Rahad and the people of the region depended on it in drinking water. In that period, a rural council in North Kordofan decided to problem of water scarcity in the city in the coming seasons by taking advantage of the contour map of the area by doing a canal that supplies this depletion with additional water at the end of the autumn depending on the khor of Abu Habel, which continues to run until the end of October and the level of storage in that area has been increased. Work on the extension of the khor, which was completed at seven km, and this canal was designed to irrigate the corn production project in 1942 to supply the fighting armies in North Africa (the Quraysif project). This channel was extended in the western direction, i.e. the opposite of the contour where the difference was not so great as there was a difference One meter in the contour line and it was skipped by raising the edges of the canal in the low and deepening it a meter in the entire altitude, thus the scheme was built a semi-permanent lake and the problem of water scarcity was treated after the season, which did not happen until 1967 and the storage level was raised to the highest level of up to 65 million Cubic meters of water to take advantage of Water and irrigation more than three thousand acres are always irrigated and called the development project, which is located on the east of the reservoir, and a gate was created at the entrance to the Abu Habbel Creek to control the amount of water and increase the amount stored inside the canal. This is considered to be the first birth of the semi-permanent canal and to become a natural lake as it is now and extends On a scale of about 14 km long and two kilometers in width and at a depth of 5 meters in the middle to become in an area of 28 square kilometers and nine storage capacity estimated at about 50 million cubic meters and more water throughout the year and there was an optional study to extend the white city with a drinking water line from Turda Rahad was a choice . (https://en.wikipedia.)

1.4.3. Climate:

Al-Rahad has a tropical climate characterized by warm summers and mild winters, with a peak temperature from April to June, averaging 36 °C (97 °F), while the temperature drops significantly in November and December to record 15 and 19 °C (59 and 66 °F), respectively. Rain falls in the summer, with the highest in June, 134 mm (5.3 in) on average, July 128 mm (5.0 in) in August and an average of 67 mm (2.6 in) . (https://en.wikipedia.)

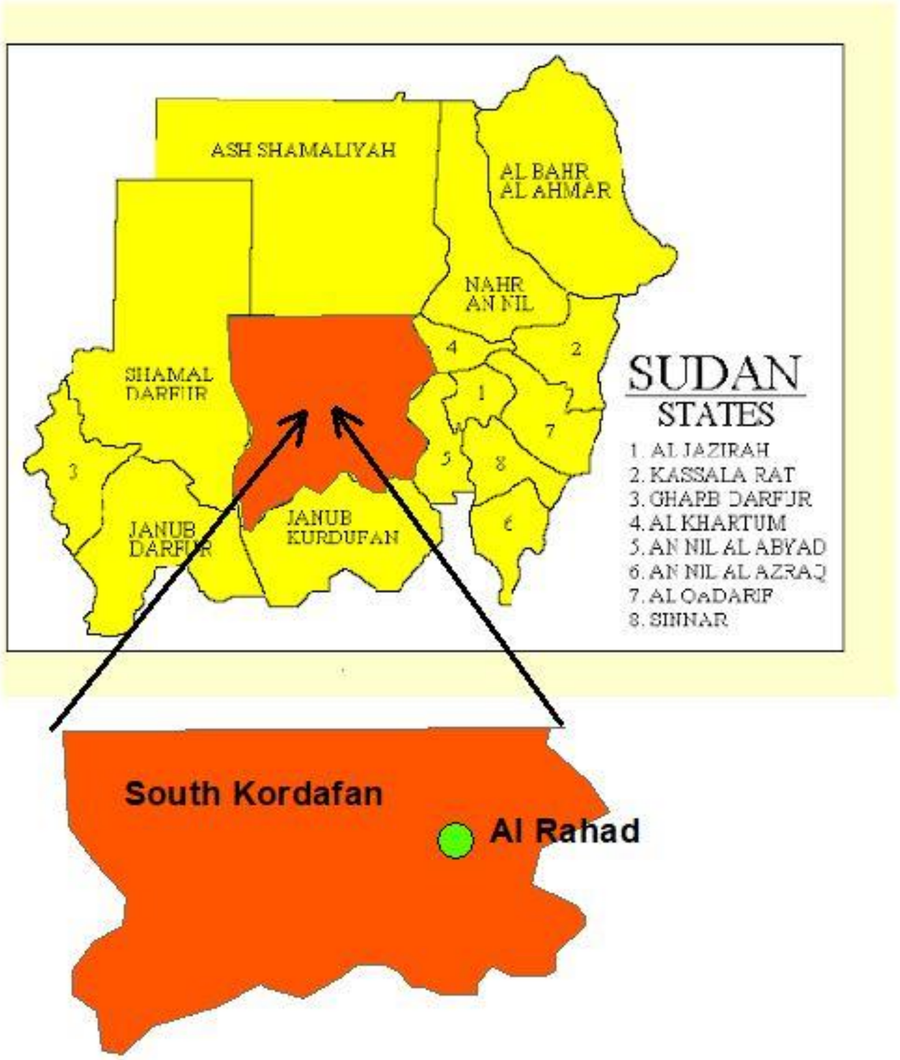


Fig no (1.1) location to area study

Chapter Two

Literature review

Chapter Two

Literature review

2.1. Introduction:

Students of water quality benefit from a knowledge of hydrology. The basic composition of water differs among components of the hydrosphere, rain water is less concentrated in minerals than runoff, and runoff usually does not contain as much dissolved mineral matter as groundwater.

One needs to know about the movement of water through the hydrologic cycle to appreciate why such differences occur. In most discussions, water quality cannot be separated entirely from water quantity. For example, the amount of nutrient entering a water body in an industrial effluent depends on the volume or flow rate of the effluent in addition to its nutrient concentration. This chapter provides a brief discussion of the hydrologiccycle and some simple methods of water measurement.

2.1.1The hydrosphere:

The hydrosphere is the gaseous, liquid, and solid water of the earth.The oceans have a volume of 1,348,000,000 km3 and comprise 97.40% of the earth's water. The remaining 36,020,000 km3 (2.60%) of water is contained in several freshwater compartments of the hydrosphere (Table 2.1). The largest proportion of freshwater is unavailable for direct use by mankind because it is either bound in ice or occurs as deep groundwater. (Boyd, C. E. (2019).

Nevertheless, the residence time of water in freshwater compartments(Table 2.1) is shorter than the average residence time of 37,000 years for water in the ocean. For example, the volume of water in the atmosphere is only 14,400 km3 at a particular time. Because the residence time is only 9 days, water vapor of the atmosphere can be recycled 1,500,000 times during the 37,000 years necessary to recycle the ocean water. The amount of water cycling through the atmosphere is 21,600,000,000 km3 in 37,000 years, or roughly 16 times the volume of the ocean. Thus, the volumes of water in the different compartments of the hydrosphere are not directly related to their comparative importance as sources of water for ecological systems or humans. (Boyd, C. E. (2019).

Table 2.1: Volumes of ocean water and different compartments of freshwater.Renewaltimes are provided for selected compartments. Source: (Boyd, C. E. (2019).

Compartment	Volume (Km^3)	Proportion of total(%)	Renewal time
Oceans FreshwaterPolar ice, icebergs, and	1,348,000,000	97.40 0.00008	37,000 years
glaciers	27,818,000	2.01	16,000 years
Groundwater (800 to	4,447,000	0.32	300 years
4,000 m depth)	3,551,000	0.26	
Groundwater (to 800 m	126,000	0.009	
depth)	61,100	0.004	
Lakes	12600	0.001	1-100 years
Soil moisture Atmosphere (water vapor)	14400	0.00008	280 days
Rivers	1070	0.00008	9 days
Plants, animals, humans	1070	0.00002	12-20 days
Hydrated minerals	360	(2.60)	
Total freshwater	36020000		

2.2. The hydrologic cycle:

The hydrologic or water cycle is the processes whereby water moves among the different compartments of the hydrosphere. The familiar and continuous motion of water in the hydrologic cycle is depicted in Water evaporates from oceans, lakes, ponds, and streams and from moist soil; water also is transpired by plants. The sun provides energy to change liquid water to water vapor, so solar radiation is the engine that drives the hydrologic cycle. Water vapor is condensed to solid or liquid water and is returned to the earth's surface as dew, frost, sleet, snow, hail, or rain. A portion of the water reaching the earth's surface evaporates back into the atmosphere almost immediately, but another part runs over the land surface as storm runoff, collects in streams, rivers, and lakes, and finally enters the oceans. Water is continually evaporating as the runoff flows toward the oceans, and it continually evaporates from the oceans. Some water infiltrates into the ground and becomes soil water or reaches saturated strata to enter groundwater aquifers. Soil water can be returned to the atmosphere by transpiration of plants. Groundwater seeps into streams, lakes, and oceans and it may be removed by wells for use by mankind. (Boyd, C. E. (2019).

2.3. Evaporation:

Air holds water vapor in relation to temperature The maximum amount of moisture that air can hold for its temperature is the saturation vapor pressure. If unsaturated air is brought in contact with a water surface, molecules of water bounce from the surface into the air until the vapor pressure is equal to the pressure of water molecules escaping the surface, and evaporation ceases. Water molecules continue to move back and forth across the surface, but there is no net movement in either direction. The driving force for evaporation is the vapor pressure deficit(VPD):

$$\mathbf{VPD = e_s - e_a}$$

Where es = saturation vapor pressure and ea = actual vapor pressure. The greater the vapor pressure deficit, the greater is the potential for evaporation. When es - ea = 0, evaporation stops.To change water from the liquid phase to the gaseous phase at 100°C requires considerable energy. Some may have difficulty reconciling this fact with the observation that water evaporates readily below 100°C.

Molecules in a mass of water are in constant motion, and molecular motion(Boyd, C. E. (2019)..

2.4 Rain fall:

Water vapor from evaporation enters the atmospheric circulation, but it will eventually return to the earth in precipitation. Rising air is necessary for precipitation. As air rises, the pressure on it decreases, because atmospheric pressure declines with increasing elevation. The temperature of an air parcel, like the temperature of any substance, results from the thermal energy of its molecules. Under reduced pressure the air parcel contains the same number of molecules as before expansion, but after expansion, its molecules occupy a larger volume. Thus, the temperature of an air parcel decreases upon expansion. The rate of cooling or adiabatic lapse rate is 1 °*CIl*00 m for air at less than 100% relative humidity. The word adiabatic implies that no energy is gained or lost by the rising air mass. If air rises high enough, it will cool until 100% relative humidity is reached and moisture will condense to form water droplets. The elevation at which air reaches the dew point and begins to condense moisture is called the lifting condensation level. Once rising air

begins to condense moisture, it gains heat, for water vapor must release latent heat to condense. The heat from condensation counteracts some of the cooling from expansion, and the adiabatic lapse rate for rising air with 100% relative humidity is *0.6°CIl* 00
m. This is the wet adiabatic lapse rate as opposed to the dry adiabatic lapse rate for rising air that is not condensing moisture as it rises.

Clouds form when air cools to 100% humidity and moisture condenses around hydro scopic particles of dust, salts, and acids to form tiny droplets or particles of ice. Droplets grow because they bump together and coalesce when the temperature is above freezing. At freezing temperatures, super cooled water and ice crystals exist in clouds. The vapor pressure of super cooled water is greater than that of ice. Ice particles grow at the expense of water droplets because of their lower vapor pressure. (Boyd, C. E. (2019).

Precipitation occurs when water droplets or ice particles grow too large to remain suspended by turbulence of moving air. The size of droplets or particles at the initiation of precipitation depends on the degree of air turbulence. In the tops of some thunderheads, turbulence and freezing temperature can lead to ice particles several centimeters in diameter knownas hail. Precipitation may begin its descent as sleet, snow, or hail, only to melt while falling through warm air. Sometimes ice particles may be so large that they reach the ground as hail even in summer.

The major factors causing air to rise are topographic barriers such as mountain ranges, warm air masses rising above heavier, cold air masses, and convectional heating of air masses. Several facts may be combined to provide some basic rules for the amounts of precipitation at a location:

- Precipitation is normally greater in areas where air tends to rise than in areas where air tends to fall.

- Amounts of precipitation generally decrease with increasing latitude.
- The amount of precipitation usually declines from the coast to the interior of a large land mass.
- A warm ocean offshore favors high precipitation and a cold ocean favors low precipitation(Boyd, C. E. (2019)..

2.5. Soil water:

Some of the water falling on the ground enters the soil. Water contained in pore spaces of soil or adsorbed to the surface of soil particles is known as soil water. Soil water may be divided into several categories. A soil completely saturated with water is said to be at its maximum retentive capacity. If such a soil is permitted to completely drain, it is said to be at field capacity. Soil water can be removed by plants and lost to the air as water vapor through transpiration or direct evaporation from soil surfaces. (Boyd, C. E. (2019).

When the water content of a soil drops so low that plants remain wilted at night, the soil is at its permanent wilting percentage. The water remaining at the permanent wilting percentage is held in very small pores and around the particles. If soil at the permanent wilting percentage is held in unsaturated air, further water is lost by evaporation. The moisture status at this point is known as the hydroscopic coefficient. Water remaining at the hydro scope coefficient is tightly attached to colloidal soil particles and notbiologically available. (Boyd, C. E. (2019).

2.6. Run off:

2.6.1. Storm Flow:

Storm flow is the portion of rain falling on a watershed that is not retained on or beneath the watershed surface or.lost from the watershed by evapotranspiration. It is the water that is ultimately transported from the watershed to streams of other water bodies by flow over the land surface after rainstorms.

Gravity causes storm flow. Storm flow begins after sufficient rainfall to exceed the capacity of watershed surfaces to detain water by absorption or in depressions and the rate of rainfall exceeds the rate of infiltration of water into the soil. Evaporation occurs as water flows over the land surface. Features of the watershed, rainfall characteristics, season, and climate influence the amount of runoff generated by a watershed. Factors favoring large amounts of storm flow are intense rainfall, prolonged rainfall, impervious soil, frozen or moist soil, high proportion of paved surface, steep slope, little surface storage, sparse vegetative cover, soils with a low moisture-holding capacity, and a shallow water table. As storm flow moves downslope in response to gravity, it collects into increasinglylarger rivulets and forms streams.(Boyd, C. E. (2019).

2.6.2. Stream:

A perennial stream normally flows year-round and has a well-defined channel. An intermittent stream flows only during wet seasons and after heavy rains and has a well-defined channel. An ephemeral stream only flows after rains and does not have a well-defined channel. (Boyd, C. E. (2019).

Streams in an area form a drainage pattern that can be seen on a topographic map. A tree-shaped pattern, called a dendritic pattern, forms where the land erodes uniformly and streams randomly branch and advance upslope. Where faulting is prevalent, streams follow the faults to form a rectangular pattern. Where the land surface is folded or is a broad, gently sloping plane, streams form a trellis or lattice pattern.(Boyd, C. E. (2019).

2.7.physical properties of water :

2.7.1. Introduction:

Water is a simple molecule with two hydrogen atoms and an oxygen atom. Its molecular weight is 18. Water has unique features that cause it to behave differently than other compounds of similar molecular weight. The water molecule is dipolar because it has a negatively charged side and positively charged one. Polarity leads to water having high freezing and boiling points, large latent heat requirements for phase changes between ice and liquid and between liquid and vapor, temperature dependent density, a large capacity to hold heat, and good solvent action. The physica
properties of water influence water quality. (Boyd, C. E. (2019).

2.7.2. Thermal characteristics:

Water is a liquid between 0 and lOOC^0 at standard atmospheric pressure (760 mm of mercury). Freezing and boiling points of water, 0 and lOOC^0, respectively, are much higher than those of other hydrogen compounds of low molecular weight, e.g., methane (CH4), ammonia (NH3) , phosgene (PH3), and hydrogen sulfide (H2S), that are gases at ordinary temperatures on the earth's surface. The aberrant behavior of water results from hydrogen bonding. Molecules of other common hydrogen compounds do not form hydrogen bonds and are joined only by van der Waals attractions. Considerable thermal energy is required to break hydrogen bonds and

convert ice to liquid water or to change liquid water to vapor.
Depending on its internal energy content, water exists in solid, liquid, or gaseous phase. In ice, all hydrogen atoms are bonded; in liquid phase, a(Boyd, C. E. (2019).
portion of the hydrogen atoms is bonded; in vapor, there are no hydrogen bonds. An increase in the internal energy content of water agitates .

2.7.3. Vapor pressure

Vapor pressure is the pressure exerted by a substance in equilibrium with its own vapor. In a beaker of water inside a sealed chamber filled with dry air, water molecules enter the air until equilibrium is reached. At equilibrium, the same number of water molecules enters the air from the water as enters the water from the air, and there is no net movement of water molecules. The pressure of the water molecules in the air (water vapor) acting down on the water surface in the beaker is the vapor pressure of water. Vapor pressure increases as temperature rises The vapor pressure of pure water reaches atmospheric pressure (760 mm mercury) at 100°C. Bubbles then form and push back the atmosphere to break the water surface. This is the boiling point. Atmospheric pressure varies with altitude and weather conditions, so the boiling point of water is not always exactly 100°C. At low enough pressure, water will boil at room temperature. (Boyd, C. E. (2019).

2.7.4. Density:

Ice molecules form a tetrahedral lattice through hydrogen bonding. Spacing of molecules in the lattice creates a void, so a volume of ice weighs less than the same volume of liquid water. Thus, ice is lighter than water and floats. The density of water increases as temperature rises until maximum density is attained at about 4°e. Further warming decreases its density. Two processes influence density as water warms above oDe. Remnants of the crystalline lattice of ice break up and increase density, and bonds stretch to decrease density. From 0 to 4°e, destruction of the remnants of the lattice has the greatest influence on density, but further warming causes density to decrease through bond stretching. Densities of water at different temperatures are given in Table 1.2. A cubic meter of water at 100e will weigh 999.70 kg, but at 30oe, a cubic meter of water only weighs 995.65 kg.(Boyd, C. E. (2019).

***Table* 2.2.Density of freshwater (g/cm3) at different temperatures betweeno and 40°C.**

C^{O}	g\cm^{3}	C^{O}	g\cm^{3}	C^{O}	g\cm^{3}
1	0.99984	14	0.99925	27	**0.99652**
2	0 .99994	15	0.99910	28	**0.99624**
3	0.99997	16	0.99895	29	**0.99595**
4	0.99998	17	0.99878	30	**0.99565**
5	0.99997	18	0.99860	31	**0.99534**
6	0.99994	19	0.99841	32	**0.99503**
7	0.99990	20	0.99821	33	**0.99471**
8	0.99985	21	0.99800	34	**0.99437**
9	0.99978	22	0.99777	35	**0.99403**
10	0.99970	23	0.99754	36	**0.99309**
11	0.99961	24	0.99730	37	**0.99333**
12	0.99950	25	0.99705	38	**0.99297**
13	0.99938	26	0.99678	39	**0.99260**
				40	**0.99222**

2.7.5.Viscosity:..

Fluids have an internal resistance to flow. Resistance to shear or angular deformation is viscosity, and it represents the capacity of a fluid to convert kinetic energy to heat energy. Viscosity results from cohesion between fluid particles, interchange of particles between layers of different velocities, and friction between the fluid and the walls of the conduit. In laminar flow, water moves in layers with little exchange of molecules among layers. During laminar flow in a pipe, the water molecules in the layer in contact with the pipe often adhere to the wall and do not flow. There is friction between the pipe wall and those molecules that do flow. The influence of the pipe wall on the flow of molecules declines with distance from the wall. Nevertheless, there is still friction between the layers of the flowing water. When flow becomes turbulent, the molecules no longer flow in layers and the movement of water becomes more complex.

Viscosity often is reported in centipoise (cp). In terms of force, 100 cp is equivalent to 1 g/cm·sec or 0.1 *Newton·sec/m2*• Viscosity decreases as(Boyd, C. E. (2019).

temperature rises, and the absolute viscosity of water at 0, 20, and 50°C is 1.78, 1.00, and 0.547 cp, respectively. Water flow in pipes and channels and seepage through soil are favored slightly by warmth, because viscous shear losses decrease with decreasing viscosity.

2 .7.6. Pressure:

A fluid has little or no elasticity of shape and conforms to the shape of its container. Fluids are liquids, and the ideal liquid offers no resistance to shearing forces. Unless completely confined, a liquid has a free surface that is always horizontal except at the edges. Liquids are considered to be essentially incompressible. Water can be treated as a fluid.(Boyd, C. E. (2019).

2.7.7. Turbidity:

Chemical Symbol or Formula: Not applicable [Bulk physical parameter].

Units Used for Analytical Results :Formazin Turbidity Units [FTU]; Jackson Turbidity Unit ;Nephelometric Turbidity Units [NTU]; Silica Units [SiO2]

Normal Method(s) of Analysis: Turbidimeter or Nephelometer

Occurrence/Origin: Clay particles, sewage solids, silt and sand washings, organic and biological
sludges etc.

Health/Sanitary Significance**:**

Direct health effects depend on the precise composition of the turbidity-causing materials, but there are other implications, as discussed below.

Background Information**:** Turbidity in water arises from the presence of very finely divided solids (which are not filtrable by routine methods). The existence of turbidity in water will affect its acceptability to consumers and it will also affect markedly its utility in certain industries. The particles forming the turbidity may also interfere with the treatability of waters and in the case of the disinfection process the consequences could be grave. As turbidity can be caused by sewage matter in a water there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant.

Comments:

As indicated above, there is a relative multiplicity of units for turbidity in water, a fact which has caused a marked degree of confusion at times. However, the position is rather simpler than at first appears, as FTU (formazin), JTU (Jackson) and NTU (nephelometric) are virtually equivalent and are used interchangeably. Silica units differ. The 1980 Drinking Water Directive showed the following "parallel" MAC values for turbidity (from which the relationship may be inferred): Jackson units [JTU/FTU/NTU] - MAC 4; Silica units - MAC 10 mg/l SiO_2. It will be noted below that Drinking Water Directive adverts to nephelometric units [NTU].(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

Turbidity guidelines for drinking water

For drinking water supplies, the following guidelines should be taken into consideration :

- Drinking water should have a turbidity of 5 NTU/JTU or less. Turbidity of more than 5 NTU/JTU would be noticed by users and may cause rejection of the supply.

- Where water is chlorinated, turbidity should be less than 5 NTU/JTU and

preferably less than 1 NTU/JTU for chlorination to be effective.(Grobbelaar, J.U., 1985.)

2.7.8 Total Dissolved Solids:

Background

Total Dissolved Solids (TDS) is a measure of all constituents dissolved in water. The

inorganic anions dissolved in water include carbonates, chlorides, sulfates and nitrates.

The inorganic cations include sodium, potassium, calcium and magnesium.(Iowa, D.N.R., 2009.)

Chemical Symbol or Formula: Not applicable [Bulk parameter].

Units Used for Analytical Results**:** mg/l solids (Dried at stated temperature).

Normal Method (s) of Analysis: Gravimetric (Dried at stated temperature after filtration)

Occurrence/Origin: Natural or added solutes present in a water.

Health/Sanitary Significance**:** Principally organoleptic implications.

Background Information**:** The parameter is determined as for total solids except that the sample is filtered through a defined medium (membrane or glass fiber paper; cf. "Solids, Suspended") beforehand. The term *Total Filterable Solids* is also used. It is often convenient and acceptable to use the very rapid determination of conductivity (q.v.) to give an estimation of the total dissolved solids.(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

Comments**:** As discussed earlier, the *total dissolved solids*, or *TDS*,includes ionized and non ionisedmatter but only the former is reflected in the conductivity. Where TDS are high the water may be "saline" and the applicable parameter "Salinity."

2.8 Chemical PROPERTIES OF WATER

2.8.1 PH:

Definition of pH:
pH is an abbreviation of "pondushydrogenii" and was proposed by the Danish scientist S.P.L. Sørensen in 1909 in order to express the very small concentrations of hydrogen ions.
In 1909, pH was defined as the negative base 10 logarithm of the hydrogen *ion concentration*. However, as most chemical and biological reactions are governed by the hydrogen *ion activity*, the definition was quickly changed. As a matter of fact, the first potentiometric methods used actually resulted in measurements of ion activity(Bates, R.G., 1964).

Chemical Symbol: Not applicable [Physical parameter].

Units Used for Analytical Results: pH units.

Normal Method(s) of Analysis :Electrometry [pH electrode] [A/B]

Occurrence/Origin: Physical characteristic of all waters/solutions.

Health/Sanitary Significance: None - except that extreme values will show excessive Acidity/alkalinity, with organoleptic consequences.

Background Information: By definition pH is the negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline. The pH scale (derived from the ionisation constant of water) ranges from 0 (very acid) to 14 (very alkaline). The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0. In waters with low dissolved solids, which consequently have a low buffering capacity (i.e. low internal resistance to pH change), changes in pH induced by external causes may be quite dramatic. Extremes of pH can affect the palatability of water but the corrosive effect on distribution systems is a more urgent problem. .(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

The effect of pH on fish is also an important consideration and values which depart increasingly from the normally found levels will have a more and more marked effect on fish, leading ultimately to mortality. The range of pH suitable for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable.(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

Comments**:** Apart from the aspects just mentioned, pH values govern the behavior of several other important parameters of water quality. Ammonia toxicity, chlorine disinfection efficiency, and metal solubility are all influenced by pH, for example. .(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.8.2 Total hardness:

Chemical Symbol or Formula: Not Applicable [Bulk parameter].

Units Used for Analytical Results: mg/l CaCO3.

Normal Method(s) of Analysis: Titration with EDTA [A].

Occurrence/Origin: Rock formations - limestone etc.

Health/Sanitary Significance**:** Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Health studies in several countries in recent years indicate that mortality rates from heart diseases are lower in areas with hard water.

Background Information:

Originally taken to be the capacity of water to destroy the lather of soap, hardness was determined formerly by titration with soap solution. Nowadays, the analysis comprises the determination of calcium and magnesium which are the main constituents of hardness. Although barium, strontium and iron can also contribute to hardness, their concentrations are normally so low in this context that they can be ignored. Thus, *total hardness* is taken to comprise the calcium and magnesium concentrations expressed as mg/l CaCO3. The widespread abundance of these metals in rock formations leads often to very considerable hardness levels in surface and ground waters. (McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

The following is one of several such arbitrary classifications of waters by hardness7:

Soft up to 50 mg/l CaCO3 Moderately Hard 151-250 mg/l CaCO3
Moderately Soft 51-100 mg/l CaCO3 Hard 251-350 mg/l CaCO3
Slightly Hard 101 - 150 mg/l CaCO3 Excessively Hard over 350 mg/l CaCO3.

A variety of additional terms is used to describe different aspects of hardness. These are frequently encountered and are summarized briefly below:

Calcium Hardness is the expression of the results of the measurement of calcium only, as mg/l CaCO3.

Carbonate Hardness is the hardness derived from the solubilisation of calcium or magnesium carbonate (by conversion of the carbonate to bicarbonate). This hardness is removed by heating (see below).

Magnesium Hardness The difference between total hardness and calcium hardness is taken as the magnesium(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

hardness (all figures as mg/l CaCO3.).

Non-carbonate Hardness is the hardness due to the solution of calcium chloride or magnesium sulphate, for example.

Permanent Hardness this is equivalent to non-carbonate hardness in that it cannot be reduced or removed by heating.

Temporary Hardness The same as carbonate hardness, this form may be removed by heating the waters, when chemical reactions occur as follows:

$2HCO3 - \rightarrow H2O + CO2 + CO3 - -$

$CO3 - - + Ca{+}{+} \rightarrow CaCO3$

Calcium Carbonate (insoluble)

This is in fact what happens in most cases when the temporary hardness is deposited as scale in boilers, etc. (McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.8.3.Total Alkalinity:

Chemical Symbol or Formula**:** Not Applicable [Bulk parameter]

Units Used for Analytical Results: mg/l CaCO3.

Normal Method(s) of Analysis: Titration with Sulphuric Acid [A]

Occurrence/Origin:

The alkalinity of a natural water is generally due to the presence of bicarbonates formed in reactions in the soils through which the water percolates. It is a measure of the capacity of the water to neutralise acids and it reflects its so-called *buffer capacity* (its inherent resistance to pH change). A poorly-buffered water will have a low or very low alkalinity and will be susceptible to pH reduction by, for example, "acid rain." At times, however, river alkalinity values of up to 400 mg/l $CaCO_3$ may be found; they are without significance in the context of the quality of the water.

Health/Sanitary Significance:

There is little known sanitary significance attaching to alkalinity (even up to 400 mg/l $CaCO_3$), though unpalatability may result in highly alkaline waters.

Background Information:

Alkalinity in natural waters may also be attributable to carbonates and hydroxides. Sometimes analysis is carried out to distinguish between the alkalinity elements and this is done by using different indicators in the titration procedure and by making appropriate calculations. The indicators most commonly employed are phenolphthalein (colour change around pH8.3) and methyl orange (colour change around pH4.5), resulting in the additional terms *phenolphthalein alkalinity* and *methyl orange alkalinity*; the latter is synonymous with *total alkalinity*(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.).

Alkalinity is involved in the consequential effects of eutrophication [over-enrichment] of waters. Where a high degree of photosynthesis occurs, as discussed below under "Oxygen, Dissolved" (q.v.), there is a high consumption of carbon dioxide by algae. As any free carbon dioxide initially available is consumed, more is produced in a series of related chemical equilibrium reactions, as follows:

1. $H^+ + HCO_3^- \Leftrightarrow H_2CO_3\ [H_2O + CO_2]$
2. $H^+ + CO_3^{--} \Leftrightarrow HCO_3^-$
3. $H_2O \Leftrightarrow H^+ + OH^-$.

As the carbon dioxide is consumed by photosynthesis, more is produced (reaction 1, left to right) by the action of bicarbonate ions, present as alkalinity and hydrogen ions to give undissociated carbonic acid (carbon dioxide and water). Any carbonate ions present will then react with more hydrogen ions to replace the bicarbonate consumed (reaction 2, again left to right). Both these reactions consume hydrogen ions, more of which are produced as in reaction 3 (equilibrium again to the right). A net overall effect is the production of hydroxyl ions and an increase in the pH. It is not uncommon for extreme photosynthetic activity to produce pH levels high enough tocause serious damage (even death) to fish. (McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.8.4. Chloride:

Chemical Symbol or Formula: Cl^-

Units Used for Analytical Results: mg/l Cl.

Normal Method (s) of Analysis: Titration (Mohr Method: Silver Nitrate)

Occurrence/Origin:

Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl). In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents.

Health/Sanitary Significance:

Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability

Background Information:

At levels above 250 mg/l Cl water will begin to taste salty and will become increasingly objectionable as the concentration rises further. However, external circumstances govern acceptability and in some arid areas waters containing up to 2,000 mg/l Clare consumed, though not by people unfamiliar with such concentrations. High chloride levels may similarly render freshwater unsuitable for agricultural irrigation.(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

Comments:

Because sewage is such a rich source of chloride, a high result may indicate pollution of a water by a sewage effluent. Natural levels in rivers and other fresh waters are usually in the range 15-35 mg/l Cl - much below drinking water standards. What is normally important to note in a series of results from a river, for example, is not the absolute level, but rather the relative levels from one sampling point to another.

An increase of even 5 mg/l at one station may give rise to suspicions of a sewage discharge, especially if the free ammonia levels (q.v.) are also elevated. In coastal areas, however, elevated chloride values may be due to sea spray, or sea water infiltration, and not necessarily to discharges. Normal raw water treatment processes do not remove chloride. (McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2 .8.5 Manganese:

Chemical Symbol or Formula: Mn.

Units Used for Analytical Results: mg/l Mn.

Normal Method(s) of Analysis: Colorimetric (Persulphate) [B]; Atomic Absorption Spectrometry [B/C].

Occurrence/Origin: Widely distributed constituent of ores and rocks.

Health/Sanitary Significance: No particular toxicological connotations; the objections to manganese - like iron - are aesthetic.

Background Information: As with iron, manganese is found widely in soils and is a constituent of many ground waters. It, too, may be brought into solution in reducing conditions and the excess metal will be later deposited as the water is reaerated. The general remarks for iron (q.v.) apply to manganese but the staining problems with this metal may be even more severe, hence the quite stringent limits. A second effect of the presence of manganese much above the limits is an unacceptable taste problem. (McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

Comments: Toxicity is not a factor, as waters with high levels of manganese will be rejected by the consumer long before any danger threshold is reached. (McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.8.6 Calcium:

Chemical Symbol or Formula: Ca.

Units Used for Analytical Results: mg/l Ca.

Over 99% of total body calcium is found in bones and teeth, where it functions as a key structural element. The remaining body calcium functions in metabolism, serving as a signal for vital physiological processes, including vascular contraction, blood clotting, muscle contraction and nerve transmission.

Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Most of these disorders have treatments but no cures. Owing to a lack of compelling evidence for the role of calcium as a single contributory element in relation to these diseases, estimates of calcium requirement have been made on the basis of bone health outcomes, with the goal of optimizing bone mineral density. Calcium is unique among nutrients, in that the body's reserve is also functional: increasing bone mass is linearly related to reduction in fracture risk.(Cotruvo, J.A. and Bartram, J. eds., 2009.)

Normal Method(s) of Analysis: Titration (Calcium Hardness) Atomic Absorption Spectrometry. .(Cotruvo, J.A. and Bartram, J. eds., 2009.)

Occurrence/Origin: Occurs in rocks, bones, shells etc. Very abundantHealth/Sanitary Significance: High levels may be beneficial (see below) and waters which are rich in calcium (and hence are very hard) are very palatable.

Background Information: This element is the most important and abundant in the human body and an adequate intake is essential for normal growth and health. The maximum daily requirement is of the order of 1 - 2 grams and comes especially from dairy products. There is some evidence to show that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the.(Cotruvo, J.A. and Bartram, J. eds., 2009.)

primary constituent of which is calcium, so that the presence of the element in a water supply is beneficial to health.

Comments: Despite the potential health benefits of calcium abundance there are problemsassociated with hardness, as discussed.(Cotruvo, J.A. and Bartram, J. eds., 2009.)

2.8.7. Potassium:

Chemical Symbol or Formula: K.

Units Used for Analytical Results: mg/l K.

Normal Method(s) of Analysis: Flame Photometry Atomic Absorption Spectrometry .

Occurrence/Origin: Geological formations.

Health/Sanitary Significance: None, except at gross levels

Background Information:(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

Potassium is an essential constituent of many artificial fertilizer formulations, and hence its determination is often carried out on lake waters when an assessment is being made of nutrient input. However, potassium tends to be "fixed" in soils and is not that easily leached out. There are no implications of toxicity.

Comments: Very often potassium is measured on samples solely to permmit the calculation of an"ion balance" for the verification of the analysis. :(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.8.8Nitrate:.

Chemical Symbol or Formula: $NO_3^–$

Units Used for Analytical Results: mg/l N or mg/l $NO_3^–$.

Normal Methods of Analysis: Manual/Automated Colorimetry Specific Ion Electrode

Occurrence/Origin: Oxidation of ammonia: agricultural fertiliser run-off.

Health/Sanitary Significance: Hazard to infants above 11 mg/l N [50 mg/l NO_3].

Background Information: Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former :(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

including waste discharges and the latter comprising chiefly artificial fertilisers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrate. Interest is centred on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite [see also below] which reacts with blood haemoglobin to cause methaemoglobinaemiOf increasing importance is the degree to which fertiliser run-off can contribute toeutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterialaction may ultimately appear in the aquatic environment as nitrate. Hence, the presence of nitratein ground waters, for example, is cause for suspicion of past sewage pollution or of excess levels offertilisers or manure slurries spread on land. (High nitrite levels would indicate more recentpollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation). In rivers highlevels of nitrate are more likely to indicate significant run-off from agricultural land than anythingelse and the parameter is not of primary importance per se. However, it should be noted that there is a general tendency for nitrate concentrations in rivers to increase as a result of enhanced nutrient run-off; this may ultimately lessen their utility as potential sources of public water supply. Nitrite concentrations in rivers are rarely more than 1 - 2 per cent of the nitrate level so that it may therefore be acceptable to carry out the analytically convenient determination of nitrate + nitrite at the same time. This determination is correctly referred to as *total oxidized nitrogen* (McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.).

Comments: Although the topic of the units in which analytical results are expressed is dealtwith in detail in Appendix 2, it should be noted here that very often nitrate results as expressed as NO3 rather than as N and that there is over a four-fold difference between the applicable limit values, the former being:(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.8.9Nitrite:

Chemical Symbol or Formula: NO_2^-

Units Used for Analytical Results: mg/l NO_2^-.

Normal Methods of Analysis: Manual or Automated Colorimetric [A/B]

Occurrence/Origin: Generally from untreated or partially treated wastes.

Health/Sanitary Significance: Methaemoglobinaemia-causing agent [cf. Nitrate].

Background Information:

Nitrite exists normally in very low concentrations and even in waste treatment plant effluents levels are relatively low, principally because the nitrogen will tend toexist in the more reduced (ammonia; NH3) or moreoxidized (nitrate; NO3) forms.

Because nitrite is an intermediate in the oxidization of ammonia to nitrate, because such oxidation can proceed in soil, and because sewage is a rich source of ammonia nitrogen, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.03 mg/l NC)2. Values greater than this may indicate sewage pollution.

Comments: The significance of nitrite (at the low levels often found in surface waters) is mainly as an indicator of possible sewage pollution rather than as a hazard itself although, as mentioned above under "Nitrate" (q.v.), it is nitrite rather than nitrate which is the direct toxicant. There is, accordingly, a stricter limit for nitrite in drinking waters. In addition, nitrites can give rise to the presence of nitrosamines by reaction with organic compounds and there may be carcinogenic effects.(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

HEALTH EFFECTS 0f Nitrate

Nitrate in drinking water can be responsible for a temporary blood disorder in infants called methemoglobinemia (blue baby syndrome). In infants less than six months old, a condition exists in their digestive systems which allows for the chemical reduction of nitrate to nitrite. The nitrite absorbs through the stomach and reacts with hemoglobin to form met hemoglobin, which does not have the oxygen carrying capacity of hemoglobin.(Bondonno, C.P., Liu, A.H., Croft, K.D., Considine, M.J., Puddey, I.B., Woodman, R.J. and Hodgson, J.M., 2015)

2.8.10. Sulphate:

Chemical Symbol or Formula: SO_4

Units Used for Analytical Results: mg/l SO_4

Normal Method(s) of Analysis: Turbidimetric (Barium Sulphate) Ion ChromatographyOccurrence/Origin: Rocks, geological formations, discharges and so on .

Health/Sanitary Significance: Excess sulphate has a laxative effect, especially in combination with magnesium and/or sodium.

Background Information**:**

Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They are often derivedfrom the sulphides of heavy metals (iron, nickel, copper and lead). Iron sulphides are present in sedimentary rocks from which they can be oxidised to sulphate in humid climates; the latter may then leach into watercourses so that ground waters are often excessively high in sulphates. As magnesium and sodium are present in many waters :(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

their combination with sulphate will have an enhanced laxative effect of greater or lesser magnitude depending on concentration. The utility of awater for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 250 mg/l SO_4.

Comments: Other problems are associated with sulphate. In polluted waters in which the dissolved oxygen i.e. zero, sulphate is very readily reduced to sulphide causing noxious odors.

Waters containing sulphates in excess will also attack the fabric of concrete sewer

pipes. :(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.8.10. Iron:

Chemical Symbol or Formula: Fe.

Units Used for Analytical Results: mg/l Fe.

Normal Method(s) of Analysis: Colorimetric (o-PhenanthroIine) Atomic Absorption Spectrometry.

Occurrence/Origin: Geological formations (especially under reducing conditions); acid drainage; effluent discharges.

Health/Sanitary Significance: The objections to iron are primarily organoleptic, but there has been recent medical concern about high levels in drinking water.

Background Information:

Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. Appreciable amounts of iron may therefore be present in ground waters. Severe problems can be caused in drinking water supplies by the presence of iron although there is normally no harmful effect on persons consuming waters with significant amounts of iron. Rather, the problems are primarily aesthetic, as the soluble (reduced) ferrous (Fe++) iron is oxidised in air to the insoluble ferric (Fei+++) form, resulting in colour or turbidity (or, in severe cases, precipitate formation). Laundry becomes stained if washed in water with excessive iron, and vegetables likewise become discoloured on cooking.

Taste problems may also occur. When waters rich in iron are used to make tea (in which tannins are present) there may be a reaction giving rise to offcolours which may in severe cases resemble that of ink. Problems have been reported also with the addition of such waters to whiskey.

Comments: The metal is quite harmful to aquatic life, as evidenced by laboratory studies, but in nature the degree of toxicity may be lessened by the interaction of the iron with other constituents of a water. Should the metal be converted to an insoluble form then the iron deposits will interfere with fish food and with spawning.(McNeely, R.N., Neimanis, V.P. and Dwyer, L., 1979.)

2.9. Microbiology:

Things aren't always the way they seem. On the face of it, 'microbiology' should be an easy word to define: the science (*logos*) of small (*micro*) life (*bios*), or to put it another way, the study of living things so small that they cannot be seen with the naked eye.

Bacteria neatly fit this definition, but what about fungi and algae? These two groups each contain members that are far from microscopic. On the other hand, certain animals, such as nematode worms, can be microscopic, yet are not considered to be the domain of the microbiologist. Viruses represent another special case; they are most certainly microscopic (indeed, most are submicroscopic), but by most accepted definitions they are not living. Nevertheless, these too fall within the remit of the microbiologist.

In the central section of this book you can read about the thorny issue of microbial classification and gain some understanding of just what is and what is not regarded as a microorganism.

To the lay person, microbiology means the study of sinister, invisible 'bugs' that cause disease. As a subject, it generally only impinges on the popular consciousness in newscoverage of the latest 'health scare'. It may come as something of a surprise therefore to learn that the vast majority of microorganisms coexist alongside us without causing any harm. Indeed, many perform vital tasks such as the recycling of essential elements, without which life on our planet could not continue, as we will examine in. .(Hogg, S., 2013)

Other microorganisms have been exploited by humans for our own benefit, for instance in the manufacture of antibiotics and foodstuffs To get some idea of the importance of microbiology in the world today, just consider the following list of some of the general areas in which the expertise of a microbiologist might be used:
_   medicine
_   environmental science
_ food and drink production
_ fundamental research
_ agriculture
_ pharmaceutical industry
_ genetic engineering.

The popular perception among the general public, however, remains one of infections and plagues. Think back to the first time you ever heard about microorganisms; almost certainly, it was when you were a child and your parents impressed on you the dangers of 'germs' from dirty hands or eating things after they'had been on the floor. In reality, only a couple of hundred out of the half million or so known bacterial species give rise to infections in humans; these are termed *pathogens*, and have tended to dominate our view of the microbial world.

In the next few pages we shall review some of the landmark developments in the history of microbiology, and see how the main driving force throughout this time, but particularly in the early days, has been the desire to understand the nature and cause of infectious diseases in humans.(Hogg, S., 2013)

Chapter three

Methodology and materials

Chapter three

Methodology and materials

3.1 Introduction:

In the Water Quality Standardization, it was recommended that a user friendly Standard Analytical Procedure (SAP) Manual for analysis of water samples should be prepared for use in chemical laboratories under high peruse (HP). The present SAP manual comprising 38 procedures is based on 'Standard Methods for the Examination of Water (Standard Methods), 19th edition, APHA, AWWA, WEF, 1995, with one exception as noted below. The reasons for using Standard Methods as a reference are:

- Almost all chemical laboratories under high peruse (HP) are using procedures adopted from older editions of Standard Methods. Only a few are using the 19th edition.
- Standard Methods is also used by other agencies, such as State and Central Pollution Control Board Laboratories, State Public Health Laboratories, Water and Sewage Boards, etc. the manual. These could not be included since the purpose of this manual is to give procedures which can easily be followed without increasing its complexity and volume.

The procedures given in the SAP manual can be used for analysis of commonly encountered environmental water samples. The user should refer to the original text for unusual cases, details of interference, precautions, chemistry of reactions and precision and accuracy of the tests

3.2. Analytical Procedures:..

3.2.1.PH:

Method: PH meter

Apparatus

a. pH meter with temperature compensating device, accurate and reproducible to 0.1 Ph unit with a range of 0 to 14.

b. Reference electrode preferably with quartz liquid junction. Follow manufacturer's instructions on use and care of the reference electrode. Refill non-sealed electrodes with correct electrolyte to proper level and make sure junction is properly wetted.

c. Glass electrode. Follow manufacturer's instructions on use and care of electrode.

Reagents

a. Potassium hydrogen phthalate buffer, 0.05M, pH 4.00. Dissolve 10.12 g KHC8H4O4 (potassium hydrogen phthalate) in 1000 mL freshly boiled and cooled distilled water *b. 0.025M Potassium dihydrogen phosphate + 0.025M disodium hydrogen phosphatebuffer, pH 6.86*. Dissolve 3.387 g KH2PO4 + 3.533 g Na2HPO4 in 1000 mL freshly boiled and cooled distilled water *c. 0.01M sodium borate decahydrate (borax buffer), pH = 9.18*. Dissolve 3.80 g

Na2B4O7.10H2O in 1000 mL freshly boiled and cooled distilled water.

d. Store buffer solutions in polyethylene bottles. Replace buffer solutions every 4 weeks.

Procedure:..

a. Remove electrodes from storage solution, rinse, blot dry with soft tissue, place in initial buffer solution and standardise pH meter according to manufacturer's instructions.

b. Remove electrodes from the first buffer, rinse thoroughly with distilled water, blot dry and immerse in second buffer preferably of pH within 2 pH units of the pH of the sample.

Read pH, which should be within 0.1 unit of the pH of the second buffer.

c. Determine pH of the sample using the same procedure as in (b) after establishing equilibrium between electrodes and sample. For buffered samples this can be done by dipping the electrode into a portion of the sample for 1 min. Blot dry, immerse in a fresh portion of the same sample, and read pH.

d. With dilute poorly buffered solutions, equilibrate electrodes by immersing in three or four successive portions of the sample. Take a fresh sample to measure pH.

e. Stir the sample gently while measuring pH to insure homogeneity.

3.2.2. T alkalinity:

Method: titrimetric (Methyl orange)

Apparatus:.

a. Standard laboratory glassware such as burettes, volumetric flasks and beakers.

Reagents:..

a. Standard sodium carbonate, approximately 0.05N. Dry 3 to 5g sodium carbonate, Na2CO3, at 250°C for 4h and cool in a desiccators. Accurately weigh 2.5±0.2g to the nearest mg, dissolve in distilled water and make to 1L.

b. Standard H2SO4, approximately 0.1N. Dilute 2.8 mL conc. sulphuric acid to 1L.

Standardize against 40.00 mL 0.05*N* Na2CO3 with about 60 mL distilled water, in a beaker by titrating potential metrically to pH 5. Lift out electrodes, rinse into the same beaker and boil gently for 3 to 5 min under a watch glass cover. Cool to room temperature, rinse cover glass into beaker and finish titration to pH 4.3. Calculate normality of sulphuric acid:

$$\textbf{Normality, N} = \frac{A*B}{53*C}$$

Where:

A = g Na2CO3 weighed into the 1L-flask for the Na2CO3 standard (see *a*.)

B = mL Na2CO3 solution taken for standardization titration

C = mL acid used in standardization titration

c. In case potentiometric titration is not possible use bromcresol green indicator to complete the titration.

d. Standard sulphuric acid, 0.02N. Dilute the approximate 0.1*N* solution to 1L. Calculate volume to be diluted as:

$$\textbf{mL volume} = \frac{20}{N}$$

where:

N = exact normality of the approximate 0.1*N* solution.

e. Bromcresol green indicator, pH 4.5: Dissolve 100mg bromcresol green sodium salt in 100 mL distilled water

Procedure

a. Add 2 to 3 drops of bromcresol green indicator. Titrate until change in colour (blue to yellow, pH 4.9 to 4.3) is observed. Record total mL titrant used.

Calculation

$$\textbf{Total alkalinity, mgCaCO /L 3} = \frac{B*N*50000}{MLSamle}$$

where:

B = total mL of titrant used to bromcresol green end point

N = normality of titrant(Snyder, S.A., Keith, T.L., Verbrugge, D.A., Snyder, E.M., Gross, T.S., Kannan, K. and Giesy, J.P., 1999)

Note:

For turbid/coloured samples, titration can be performed using a pH meter to end point pH(Snyder,., 1999)

3.2.3. Ca Calcium

Method: edta titrimetric

Reagents

a. Sodium hydroxide, NaOH, 1N.

b. Murexide (ammonium purpurate) indicator: Mix 200 mg dye with100 g solid NaCl. Grind to 40 to 50 mesh size.

c. Standard EDTA titrant, 0.01M: Weigh 3.723 g di-sodium salt of EDTA, EDTA dihydrate, dissolve in distilled water and dilute to 1000 mL. Store in polyethylene bottle, 1 mL = 400.8 µg Ca. Standardise EDTA against standard calcium solution periodically following the method described below.

d. Standard calcium solution: Weigh 1.000 g anhydrous CaCO3 in 500 mL flask (primary standard). Add 1 + 1 HCl in small amounts through a small funnel till all CaCO3 is dissolved. Add 200 mL distilled water and boil for a few minutes to expel CO2. Cool and add a few drops of methyl red indicator and adjust to intermediate orange colour by adding 3*N* NH4OH or 1 + 1 HCl, as required. Transfer quantitatively and dilute to 1000 mL with distilled water, 1 mL = 400.8 µg Ca.

Procedure

a. Take 50 mL sample or an aliquot diluted to 50 mL such that the calcium content is not more than 10 mg. Samples which contain alkalinity greater than 300 mg/L should be

neutralised with acid, boiled for 1 min and cooled before titration.

b. Add 2 mL NaOH solution or a volume sufficient to produce a pH of 12 to 13. Start titration immediately after addition of the alkali. Add 0.1 to 0.2 g indicator mixture. Titrate with EDTA solution, with continuous mixing, till the colour changes from pink to purple.

Check end point by adding 1 to 2 drops excess titrant to make certain that no further colour change occurs.

Calculation

$$\mathbf{mgCa/L} = \frac{A * B * 400.8}{MLsample}$$

where:

A = mL titrant for sample

$$B = \frac{\text{mL of standard calcium solution taken for titration}}{\text{mL EDTA titrant}}$$

3.2.4. Cl Chloride

Method: Argentometric titration

Reagents

a. Potassium chromate indicator solution: Dissolve 50 g K_2CrO_4 in a little distilled water.

Add $AgNO_3$ solution until a definite red precipitate is formed. Let stand 12 h, filter, and dilute to 1 L with distilled water.

b. Standard silver nitrate titrant, 0.0141M (0.0141N): Dissolve 2.395 g $AgNO_3$ in distilled water and dilute to 1000 mL; 1 mL = 500 µgCl-. Store in brown bottle(Snyder, 1999).

Standardise against 10 mL standard NaCl diluted to 100 mL, following the procedure described for the samples.

$$\mathbf{N = 0.0141 * \frac{mL\ s\ tan\ dard\ NaCl}{V-B}}$$

where:

N = normality of $AgNO_3$

V = mL $AgNO_3$ titrant

B = mL titration for blank

c. Standard sodium chloride, 0.0141M (0.0141N): Dissolve 824.0 mg NaCl (dried at 140 oC) in distilled water and dilute to 1000 mL; 1mL = 500 µg Cl*d.*

Aluminium hydroxide suspension: Dissolve 125 g aluminium potassium sulphate or

aluminium ammonium sulphate, $AlK(SO_4)_2.12H_2O$ or $AlNH_4(SO_4)_2.12H_2O$, in 1L distilledwater. Warm to 60oC and add 55mL concentrated ammonium hydroxide slowly with stirring. Let stand for about 1h, transfer to a large bottle. Wash precipitate two times or till free of chloride, by successive addition of distilled water, settling and decanting

Procedure

a. Use a 100 mL sample or a suitable portion diluted to 100 mL. If the sample is coloured or

turbid, add 3 mL $Al(OH)_3$ suspension, mix, let settle and filter.

b. Add 1 mL K_2CrO_4 indicator solution, titrate with $AgNO_3$ titrant to a pinkish yellow end point.

c. Repeat the titration with distilled water blank. A blank of 0.2 to 0.3 mL is usual.

Calculation:..

$$\mathbf{mgCl\ /L} = \frac{(A-B)*N*35450}{MLsample}$$

where:
A = mL titration for sample
B = mL titration for blank
N = normality of AgNO3

3.2.5. Total hardness

Method: edta titrimetric

Reagents

a. Buffer solution1: Dissolve 16.9g NH4Cl in 143 mL conc. NH4OH. Add 1.25g magnesium salt of ethylenediaminetetraacetate (EDTA) and dilute to 250 mL with distilled water. Store in a plastic bottle stoppered tightly for no longer than one month.

b. Completing agent: Magnesium salt of 1,2cyclohexanediaminetetraacetic acid. Add 250mg per 100 mL sample only if interfering ions are present and sharp end point is not obtained.

c. Indicator: Eriochrome Black T sodium salt. Dissolve 0.5g dye in 100 mL triethanolamine or 2 ethylene glycol monomethyl ether. The salt can also be used in dry powder form by grinding 0.5g dye with 100g NaCl.

d. Standard EDTA tartan, 0.01M: Weigh 3.723g di-sodium salt of EDTA, dihydrate, dissolve in distilled water and dilute to 1000 mL.Store in polyethylene bottle.(Snyder, 1999).

e. Standard Calcium Solution: Weigh 1.000g anhydrous CaCO3 in a 500 mL flask. Add 1 +

1 HCl slowly through a funnel till all CaCO3 is dissolved. Add 200 mL distilled water and boil for a few minutes to expel CO2. Cool and add a few drops of methyl red indicator and adjust to the intermediate orange colour by adding 3*N* NH4OH or 1 + 1 HCl, as required. Transfer quantitatively and dilute to 1000 mL with distilled water, 1 mL = 1mg CaCO3.

Procedure

a. Dilute 25 mL sample to 50 mL with distilled water. Add 1 to 2 mL buffer to give a pH of

10.0 to 10.1. Add 1 to 2 drops of indicator solution and titrate with EDTA titrant to change in colour from reddish tinge to blue. Select a sample volume that requires less then 15 mL EDTA titrant and complete titration within 5 min after buffer addition.

b. Standardise the EDTA titrant against standard calcium solution using the above procedure.

Calculation

$$\textbf{Total Hardness (EDTA),mgCaCO /L} = \frac{A*B*1000}{\text{mL sample}}$$

where:

A = mL EDTA titrated for sample

B = mg CaCO3 equivalent to 1.00 mL EDTA titrant

Note

1) If the Mg salt of EDTA is unavailable (or too expensive) dissolve 1.179 g disodium salt of

ethylenediaminetetraacetic acid dihydrate (anlaytical reagent grade) and 780 mg magnesium sulfate (MgSO4.7H2O) or 644 mg magnesium chloride (MgCl2.6H2O) in 50Ml distilled water. Add this solution to 16.9 g NH4Cl and 143 mL conc. NH4OH with mixing and dilute to 250 mL with distilled water. To attain the highest accuracy, adjust to exact equivalence through appropriate addition of a small amount of EDTA or MgSO4 or MgCl2. .(Snyder, 1999).

3.2.6. Fe Iron

Method: phenantholine spectrophotometric

Apparatus

a. Spectrophotometer, for use at 510nm, providing a light path of 1cm or longer

b. Acid-washed glassware: use conc. HCl for cleaning all the glassware, rinse with distilled water before use.

c. Separator funnels: 125 mL ground-glass or TFE stopcocks and stoppers

Reagents

a. Hydrochloric acid, HClconc, with less than 0.00005% iron.

b. Hydroxylamine solution; dissolve 10g NH2OH.HCl in 100 mL distilled water.

c. Ammonium acetate buffer solution; dissolve 250g NH4C2H3O2 in 150 mL water, add

700 mL glacial acetic acid. Since ammonium acetate may contain a significant amount of iron, prepare new reference standards with each buffer preparation.

d. Sodium acetate solution; dissolve 200 g NaC2H3O2.3H2O in 800 mL water.

e. Phenanthroline solution; dissolve 100mg 1,10-Phenanthroline monohydrate,(Snyder, , 1999).

$C_{12}H_8N_2.H_2O$, in 100 mL water by stirring and heating to 80°C, without boiling, discard if darkens or add 2 drops conc. HCl to avoid heating.

f. Stock iron solution; slowly add 20 mL conc H_2SO_4 to 50 mL water and dissolve 1.404g ferrous ammonium sulphate, $Fe(NH_4)_2(SO_4)_2.6H_2O$; add 0.1*N* $KMnO_4$ dropwise until a faint pink colour persists, dilute to 1 L with water and mix; 1 mL=200 µgFe.

g. Standard iron solutions: (i) Take 50 mL stock iron solution in volumetric flask and dilute to 1 L; 1 mL = 10.0 µgFe; (ii) Take 5 mL stock solution into a 1 L volumetric flask and dilute to the mark with distilled water: 1 mL = 1.0µg Fe.

Procedure

a. Total iron : Take 50 mL of mixed sample into a 125 mL conical flask. If this volume is expected to contain more than 200 µg iron use a smaller portion and dilute to 50 mL. Add 2 mL concHCl 1 mL NH_2OH. HCl solution, a few glass beads and heat to boiling till the volume is reduced to 15-20 mL, cool, and transfer to a 50 mL volumetric flask. Add 10 mL $NH_4C_2H_3O_2$ buffer solution and 4 mL phenanthroline solution, dilute to the mark with water. Mix and allow 10-15 min. for colour development. Take photometer readings at 510nm.

b. Dissolved iron : Filter sample through a 0.45 µm membrane filter into a vacuum flask containing 1 mL conc.HCl/100 mL sample. Analyse as above and express as total dissolved iron.

c. Ferrous iron : Acidify freshly collected sample with 2 mL conc. HCl/100 mL of sample, withdraw 50 mL portion, add 20 mL phenanthroline solution and 10 mL $NH_4C_2H_3O_2$solution, mix. Measure the colour after 15 minutes.

d. Calculate ferric iron by subtracting ferrous from total iron.

e. Colour measurement: Prepare a series of standards by accurately pipetting volumes of standard iron solution into 125 mL conical flask, dilute to 50 mL. Follow steps as in *a*andplot a calibration curve. Use weaker standard for measuring 1-10µg iron.

Calculation

Read from the calibration curve and calculate the iron content

$\mathbf{mg\ Fe/L} = \frac{\mathbf{Fe\ (in\ final\ volume)}}{\mathbf{mL\ sample}}$(Snyder, 1999).

3.2.7. Mg Magnesium

Method: Calculation from total hardness and calcium

Procedure

Get the values for Total Hardness and Ca Hardness determined by EDTA and calculate Mg

Calculation
mg Mg/L = (TH as mg $CaCO_3$/L - Calcium Hardness as mg $CaCO_3$/L) x 0.243
where
TH = Total Hardness, mg $CaCO_3$/L(Snyder, 1999).

3.2.8.TDS Total dissolved solid

*Method: Calculation*from TS and TSS

Procedure
Measure Total Solids, TS (method 1.25) and Total Suspended Solids, TSS (method 1.24) and obtain the data.
Calculation

TDS = TS –TSS

where:
TDS = Solids, Total Dissolved, mg/L
TS = Solids, Total, mg/L
TSS = Solids, Total Suspended, mg/L

Note
A laboratory should **not** report TDS values if these values are calculated from EC values!
The multiplication factor may not be valid for each sample since it may change over time. (Snyder, 1999).

3.2. 9. Turb turbidity

Method :.Nephelometric

Apparatus
a. Nephelometric turbidity meter with sample cells
Reagents
a. Solution I. Dissolve 1.000g hydrazine sulphate, $(NH_2)_2.H_2SO_4$ in distilled water and dilute to 100 mL in a volumetric flask.
b. Solution II. Dissolve 10.00g hexamethylenetetramine, $(CH_2)_6N_4$, in distilled water and dilute to 100 mL in a volumetric flask(Snyder, 1999)..
c. 4000 NTU suspension. In a flask mix 5.0 mL of Solution I and 5.0 mL of Solution II. Let stand for 24 h at 25 ±3°C. This results in a 4000 NTU

suspension. Store in an amber glass bottle. The suspension is stable for up to 1 year.

d. Dilute 4000 NTU stock solution with distilled water to prepare dilute standards just before use and discard after use.

Procedure

*a. Calibrate nephelometer*according to manufacturer's operating instructions. Run at least one standard in each instrument range to be used.

b. Gently agitate sample. Wait until air bubbles disappear and pour sample into cell. Read turbidity directly from instrument display. (Snyder, 1999).

3.2.10. K POTASSIUM

Method: Flame emission photometer

Apparatus

a. Flame photometer, direct reading type.

b. Glassware, rinse with 1 + 15 HNO3, followed by de-ionised distilled water.

c. Plastic bottles, to store all solutions

Reagents

a. Stock potassium solution, weigh 1.907g KCl, dried at 110oC and cooled in desiccator, transfer to 1L volumetric flask and make to 1L with water; 1mL = 1.00mg K.

b. Intermediate potassium solution, dilute 10mL stock potassium solution with water to 100mL; 1mL = 0.1mg K, prepare calibration curve in the range of 1 to 10mg/L

c. Standard potassium solution: Dilute 10mL intermediate solution with water to 100mL,

1mL = 10µg K, prepare calibration curve in the range of 0.1 to 1mg/L.(Snyder., 1999).

Procedure

a. Follow instructions of flame photometer manufacturer for selecting proper photocell, wavelength, slit width adjustments, fuel gas and air pressure, steps for warm up, correcting for interference and flame background, rinsing of burner, sample ignition and emission intensity measurements.

b. Prepare a blank and potassium calibration standards, in any of the applicable ranges, 0-

100, 0-10, or 0-1 mg K/L. Measure emission at 766.5 nm and prepare calibration curve.

Determine potassiumium concentration of the sample, or diluted sample, from the curve. (Snyder, 1999).

3.2.11. SO4*sulphate*

Method: Nephelometric

Apparatus

a. Nephelometric turbidity meter with sample cells. Alternatively a spectrophotometer for use at 420nm with a light path of 2.5 to 10 cm

b. Magnetic stirrer

c. Timer with indication of seconds

Reagents

a. Buffer solution A: Dissolve 30g magnesium chloride, $MgCl_2.6H_2O$, 5g sodium acetate,

$CH_3COONa.3H_2O$, 1g potassium nitrate, KNO_3, and 20 mL acetic acid CH_3COOH (99%) in

500 mL distilled water and make up to 1000 mL.

b. Buffer solution B: Only required if sample SO_4^{2-} concentration is less than 10 mg/L.

Prepare as buffer solution A and add 0.111g sodium sulphate, Na_2SO_4.

c. Barium chloride, $BaCl_2$, crystals, 20 to 30 mesh

d. Standard sulphate solution: Dilute 10.4 mL standard 0.02*N* H_2SO_4 in to 100 mL (1.00 mL

= 100µg SO_4^{2-}).

e. Standard sodium carbonate, approximately 0.05N. Dry 3 to 5g sodium carbonate, Na_2CO_3*, at 250°C for 4h and cool in a desiccator. Accurately weigh 2.5±0.2g to the nearest mg, dissolve in distilled water and make to 1L.*

f. Standard H_2SO_4*, approximately 0.1N*. Dilute 2.8 mL conc. s*ulphuric acid to* 1L.

Standardise against 40.00 mL 0.05*N* Na_2CO_3 with about 60 mL distilled water, in a beaker by titrating potentiometrically to pH 5. Lift out electrodes, rinse into the same beaker and boil gently for 3 to 5 min under a watch glass cover. Cool to room temperature, rinse cover glass into beaker and finish titration to pH 4.3. Calculate normality of sulphuric acid:

$$N = \frac{A * B}{53 * C}$$

where:

A = g Na_2CO_3 weighed into the 1-L flask for Na_2CO_3 standard (see e.)

B = mL Na_2CO_3 solution taken for standardisation titration

C = mL acid used in standardisation titration

g. In case potentiometric titration is not possible use bromcresol green indicator to complete the titration. The indicator is prepared by dissolving 100mg bromcresol green sodium salt in 100 mL distilled water.

h. Standard sulphuric acid, 0.02N. Dilute the approximate 0.1*N* solution to 1L. Calculate volume to be diluted as:

$$\textbf{mL volume} = \frac{\mathbf{20}}{\boldsymbol{N}}$$

where:
N = exact normality of the approximate 0.1*N* solution

Procedure

a. Standardisenephelometer following manufacturer's instructions.

b. Measure the turbidity of *sample-blank*, a sample in which no $BaCl_2$ is added.

c. Measure 100 mL sample, or a suitable portion made up to 100 mL, into a 250 mL conical flask. Add 20 mL buffer solution and mix. While stirring add a spoonful of $BaCl_2$ crystals. Stir for 60 ± 2 s.

d. Measure turbidity of the sample at 5±0.5 min after stirring ended

e. Prepare SO_4 standards at 5 mg/L increments in the range of 0- to 40 mg/L SO_4 according to the following protocol:

f. Develop $BaSO_4$ turbidity for the standards as above.

g. Determine turbidity of the standards using procedure as above and draw calibration curve between turbidity and SO_4^{2-} concentration, mg/L.

h. In case of buffer solution B is used for samples containing less than 10mg/L SO_4^{2-}, run a *reagent-blank* with distilled water in place of sample, developing turbidity and reading it as above.

Calculation

In case buffer solution A is used, read SO_4^{2-} concentration for the sample from the calibration curve after subtracting the turbidity of sample-blank from the turbidity of the treated sample. If less than 100 mL sample was used, multiply the result by 100/mLsample volume.

In case buffer solution B is used, for samples containing less than 10mg/L sulphate, calculate SO_4^{2-} as follows. Read SO_4^{2-} concentration in the treated sample from the calibration curve after subtracting the turbidity of sample-blank from the turbidity of the treated sample (same as in *i*). Subsequently read SO_4^{2-} concentration for the reagents from the turbidity value of the reagent-blank (see procedure '*h*') from the calibration curve. Report the corrected SO_4^{2-} concentration in the sample after subtracting the reagent-blank SO_4^{2-} concentration from the sample SO_4^{2-} concentration.

3.2. 12.NO3-N . *Nitrate*

Method: **UV** *Spectrophotometer*

Apparatus

a. Spectrophotometer, for use at 220nm and 275nm with matched Silica cells of 1 cm or longer light path.

Reagents

a. Nitrate free water: Use re-distilled or de-ionised water to prepare all solutions.

b. Stock Nitrate solution: Dissolve 0.7218g KNO3, earlier dried in hot air oven at 105oC overnight and cooled in desiccator, in distilled water and dilute to 1L. Preserve with 2 mL of CHCl3/L; 1 mL = 100 µg NO3 --N, stable for 6 months.

c. Standard Nitrate Solution: Dilute 100 mL of stock solution to 1000 mL with water, preserve with 2 mL CHCl3/l; 1 mL = 10 µg NO3 --N, stable for 6 months.

d. Hydrochloric acid solution, HCl, 1N: Cautiously add 83 mL conc. HCl to about 850 mL of distilled water while mixing, cool and dilute to 1L.

Procedure

a. Treatment of sample: Add 1 mL HCl to 50 mL clear/filtered sample, mix.

b. Preparation of standard curve: Prepare calibration standards in the range of 0-7mg NO3 --N/L, by diluting to 50 mL the following volumes of standard solutions, add 1 mL of HCl and mix.

c. Spectro photometric measurements: Read absorbance or transmittance against re-distilled water set at zero absorbance or 100 % transmittance. Use a wavelength of 220 _m to obtain NO3 - reading and a wavelength of 275nm to determine interference due to dissolved organic matter

d. If reading at 275 _m is more than10% of the reading at 220nm, do not use this method (use method 1.42 instead).

Calculation

For sample and standards, subtract 2 times the absorbance reading at 275nm, from them reading at 220nm to obtain absorbance due to NO3 -. Prepare a standard curve by plotting absorbance due to NO3 - against NO3

--N concentration of standards. Obtain sample concentrations directly from standard curve, by using corrected sample absorbance's (Snyder, 1999).

3.2.13. NO2- , NITRITE

Method: Sulphanilamide*Spectrophotometer*

Apparatus

a. Spectrophotometer for use at 543nm or filter photometer with green filter, maximum transmittance near 540nm, providing 1 cm light path or longer.

Reagents

a. Colour reagent: To 800 mL water add 100 mL 85% phosphoric acid and 10g Sulphanilamide. After dissolving add 1g N-(1-naphthyl)-ethylenediaminedihydrochloride.

Mix to dissolve, then dilute to 1L with water. Solution is stable for one month when stored in dark bottle in refrigerator.

b. Sodium oxalate, 0.025M (0.05N): Dissolve 3.350g $Na_2C_2O_4$ primary standard grade, in water and dilute to 1000 mL.

c. Stock nitrite: Dissolve 1.232g $NaNO_2$ in water and dilute to 1000 mL; 1.00 mL = 250 µgN.

Preserve with 1 mL $CHCl_3$. Standardise by pipetting, in order, 50 mL 0.01M $KMnO_4$, 5 mL

conc H_2SO_4 and 50.00 mL stock NO_2 - solution in to a glass stoppered flask. Shake gently and warm to 70-80oC. Discharge permanganate colour by adding 10 mL portions of 0.025M sodium oxalate. Titrate excess oxalate with 0.01M (0.05N) $KMnO_4$ to faint pink end point.

Calculate nitrite content of stock solution:

$$A = \frac{((B*C) - (D*E))*7}{F}$$

where:

A = mg NO_2

- - N/mL in stock solution

B = mL total $KMnO_4$ used

C = normality of $KMnO_4$

D = total mL oxalate added

E = normality of oxalate

F = mL stock nitrite taken for titration *d. Intermediate nitrite solution*: Calculate the volume, G, of stock nitrite solution required for the intermediate nitrite solution from G = 12.5/A. Dilute the volume G to 250 mL with water;

1 mL = 50.0µg NO2 --N. Prepare daily.

e. Standard nitrite solution: Dilute 10 mL intermediate NO2 - solution to 1000 mL with water; 1.00 mL = 0.500µg NO2 --N. Prepare daily.

f. Standard potassium permanganate titrant, 0.01M (0.05*N*): Dissolve 1.6g KMnO4 in 1L distilled water. Allow ageing for 1 week then decant supernatant. Standardise this solution frequently as follows:

Weigh to nearest 0.1mg several 100 to 200mg samples of anhydrous sodium oxalate in beakers. To each beaker add 100 mL distilled water, 10 mL 1 + 1 H2SO4 and heat rapidly to 90 to 95oC. Titrate with permanganate solution to a slight pink end point that persists to at least 1 min. Do not allow temperature to fall below 85oC. Run a blank on distilled water

+ H2SO4.

normality $KMnO_4$ $= \frac{g\ Na2\ C2O4}{(A-B)*0.33505}$(Snyder, 1999).

where:

A = mL titrant for sample

B = mL titrant for blank

Average the result of several titrations.

Procedure

a. Add 2 mL colour reagent to 50 mL sample, or to a portion diluted to 50 mL, and mix.

b. Measure absorbance at 543nm. Wait between 10 min and 2h after addition of colour reagent before measurement

c. Prepare standard curve by diluting 1, 2, 3, 4 and 5 mL of standard nitrite solution to 100 mL to give 5, 10, 15, 20 and 25 µg/L concentration, respectively.

Calculation

Compute sample concentration directly from the curve, taking in consideration dilution of the sample if applicable. (Snyder, 1999).

3.2.14 .TCOL-MPN COLIFORMS, TOTAL

Method: STANDARD MULTIPLE TUBE FERMENTATION

Apparatus

a. Autoclave, for operation at 121o C.

b. Sterilizer oven, to maintain 160 -170o C

c. Incubator, to maintain 35 ± 0.5o C

d. Glassware: fermentation tubes 30 - 40 mL capacity with aluminum caps, vials 0.25 - 0.5 mL capacity, pipettes 10 and 1 mL with 0.1 mL graduations.

e. Inoculating wire loop: 22 - 24 gauge nickel alloy wire loop 3 - 3.5 mm diameter for flame sterilization.

Reagents and Culture medium:

a. Dilution water: Dissolve 34.0 g potassium dehydrogenate phosphate, KH2PO4, in 500 mL distilled water and adjust to pH 7.2 ± 0.5 with 1N sodium hydroxide and dilute to 1L. Distribute at the rate of 9 mL/tube. Close tubes with caps and sterilize.

b. Lauryl tryptose broth:

Add ingredients to water, mix thoroughly and heat to dissolve. pH should be 6.8 + 0.2 after sterilization. Before sterilization, dispense sufficient medium (approximately 10 mL) in fermentation tubes, in which inverted vials are placed (to cover the vial at least two- thirds after sterilization, it may be completely submerged also). Close tubes with caps and sterilize.

b. Brilliant green lactose bile broth:

Prepare, dispense and sterilize as in b above

Note:

- Pre-formed dry powder medium available commercially for both b and c may be used.
- Double the strength of medium if 10 mL inoculum is used.

Procedure:…

a. Sterilisation: Sterilise culture broths and dilution water, in autoclave at 121o C for 15 min. and pipettes in metal containers in steriliser oven at 170o C for 2h.

b. Presumptive phase: •Aseptically transfer appropriate sample volumes of the sample to lauryl tryptose fermentation tubes. Sample volume and number of tubes to be inoculated will depend on the quality of water samples. Use the following table as a guide:

•For transferring volumes less than 0.1 mL, prepare serial dilutions. To prepare serial dilutions add one mL sample to a dilution tube containing 9 mL dilution water.

Mix and transfer one mL from the first dilution to second dilution tube to given second dilution and so on. Thus one mL each of the first dilution, second dilution etc., will represent 0.1 mL, 0.01 mL etc., of the original sample, respectively. Note that the volumes of inocula in a series always decrease by a factor of 10.

- Incubate the inoculated tubes at 35 ± 0.50 C. After 24 ± 2h swirl each tube and examine for gas production. If no gas is evident, re-incubate and re-examine at the end of total 48 ± 3h. Record presence or absence of growth and gas. Presence of both gas and growth constitutes a positive presumptive test.

c. Confirmed phase:

Subject all positive presumptive tubes to the confirmed phase. Gently shake the positive tubes to re-suspend growth and with a sterile loop, transfer one loopful to a fermentation tube containing brilliant green lactose bile broth.

Incubate the inoculated tubes at 35 ± 0.5o C. Formation of gas within 48 ± 3h constitutes a positive confirmed phase(Snyder, 1999).

Chapter four

Result and discussion

Chapter four

Result and discussion

4.1. PH meter :

Table No (4-1) amount of the result of ph values .

Number of sample	Name of sample	Result(Ph)
1	**Source**	**8.64**
2	**treatment Unit**	**7.76**
3	**House**	**8.08**

After analyzing the samples by comparing the pH values with an observation, there is an increase in the source and processing unit

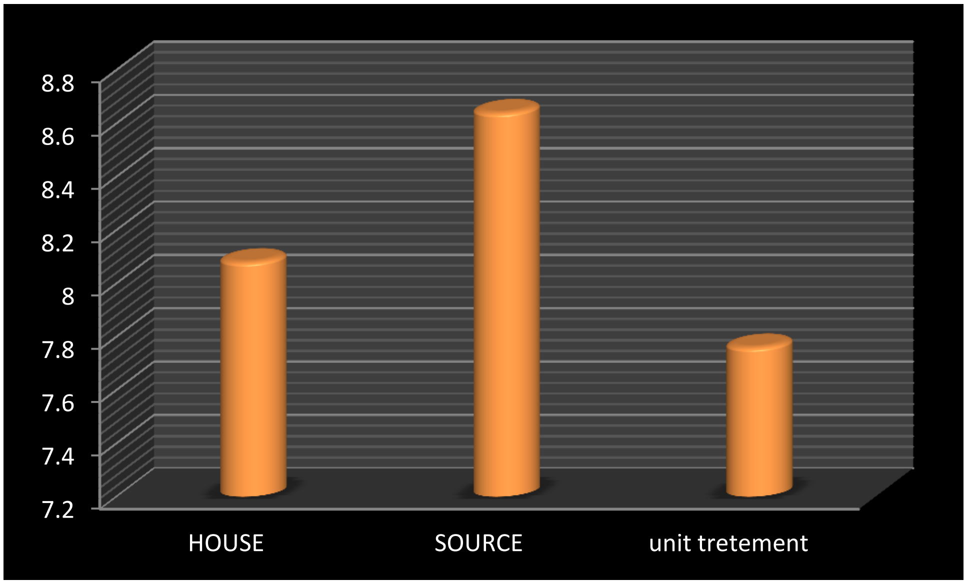


fig NO (4-1) compare o result of ph values

The figure shows the results and the pH value and comparing them together We find that increasing the pH in relation to the main water source is considered to be surface runoff and rain water, and the increase in the pH number in the house is due to the presence of some problems in the semi-distribution

4.2. total dissolved solid :.

Table No (4-2)amount of the result ofTDS

Number of sample	Name of sample	Result
1	**Source**	**150.7**
2	**Unit treatment**	**122.8**
3	**House**	**150.4**

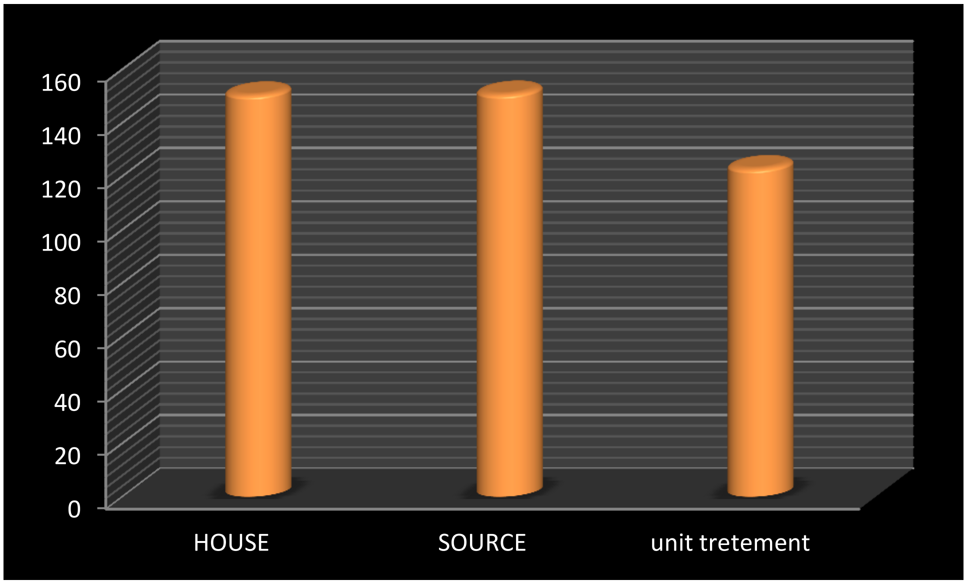


fig NO (4-2) compare of result of TDS

Comparing the results, it was found that there is an increase in salts in the house after treatment, due to the problems in the distribution network in the town .

4.3. Turbidity:….

Table No (4-3) amount of the result ofTurbidity

Number of sample	Name of sample	Result
1	**Source**	**26**
2	**Unit treatment**	**105**
3	**House**	**22**

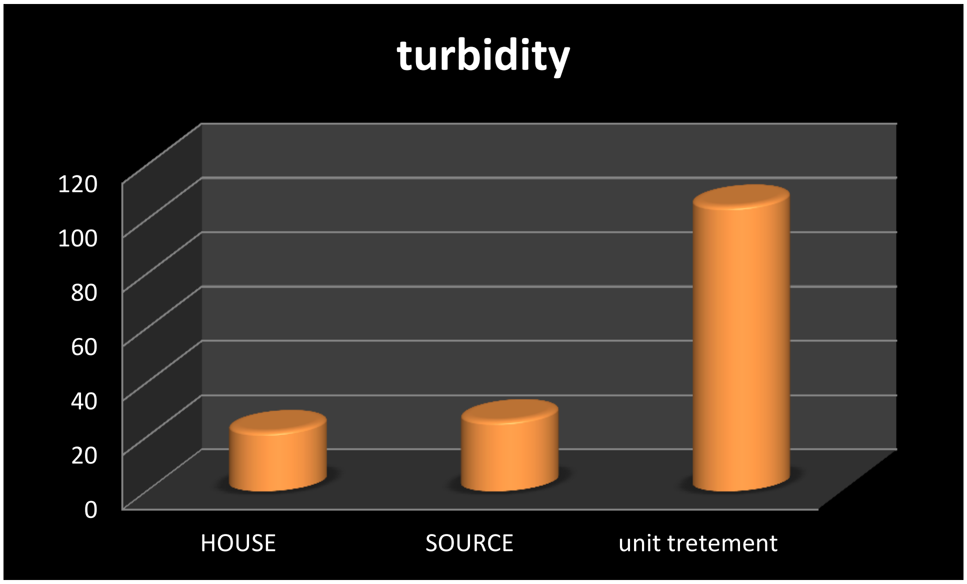


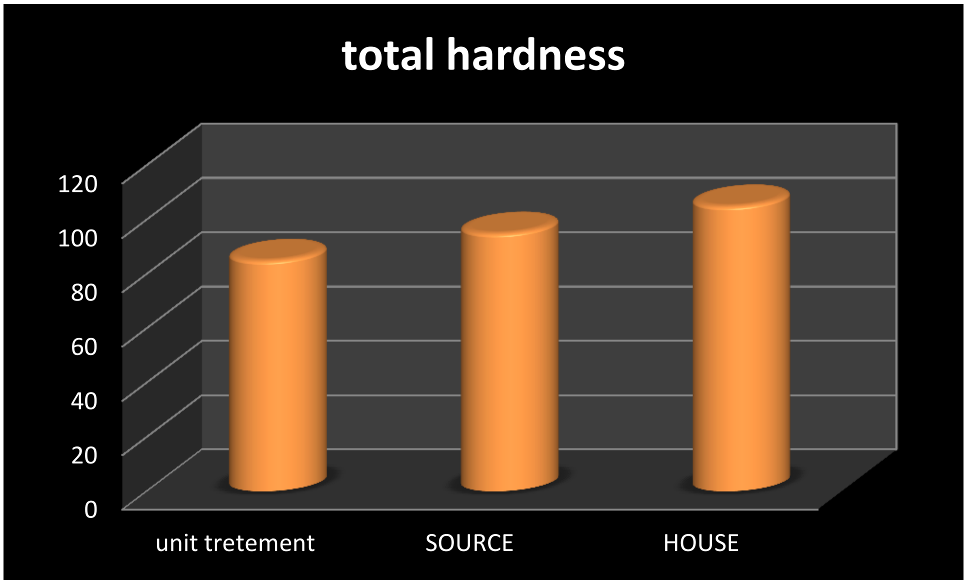
fig NO (4-3)compare of result of Turbidity

After analysis and comparison, it was found that there are problems in the filters in the treatment units due to the inefficiency of the filters and the lack of periodic maintenance

4.4. Total hardness:..

Table No (4-4) amount of the result ofTotal hardness

Number of sample	Name of sample	Result
1	**Source**	**95**
2	**Unit treatment**	**85**
3	**House**	**105**



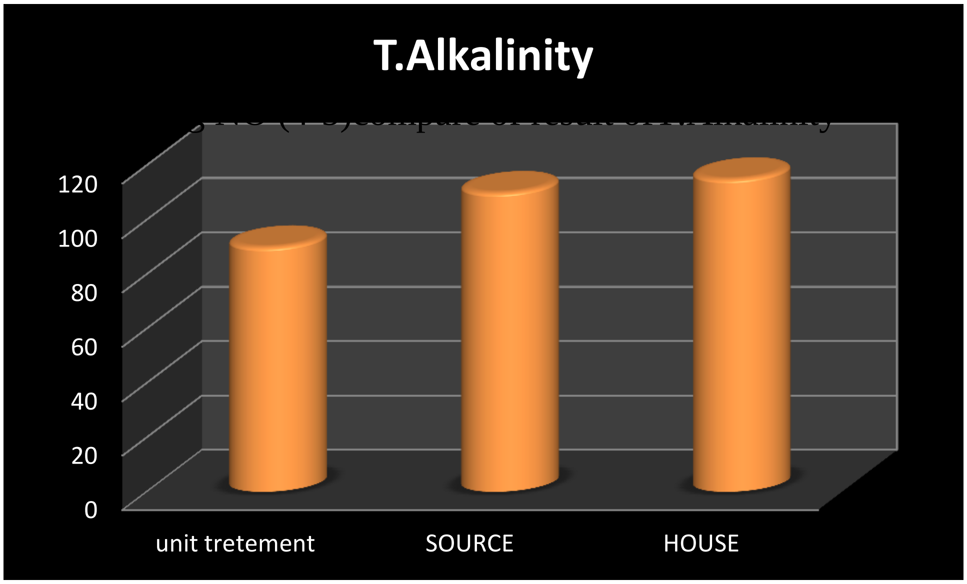
Total hardnesscompare of result of fig NO (4-4)

After comparing the results, it was found that there was an increased hardness at home, the percentage of dissolving salts accumulated on the distribution network

4.5. T.Alkalinity:..

Table No (4-5) amount of the result ofT.Alkalinity

Number of sample	Name of sample	Result
1	**Source**	**110**
2	**Unit treatment**	**90**
3	**House**	**115**



There is an increase in the base in the home due to the solubility of sediments in the distribution network

4.6. Chloride:…

Table No (4-6)amount of the result ofChloride

Number of sample	Name of sample	Result
1	**Source**	**1.2**
2	**Unit treatment**	**0**
3	**House**	**1.3**

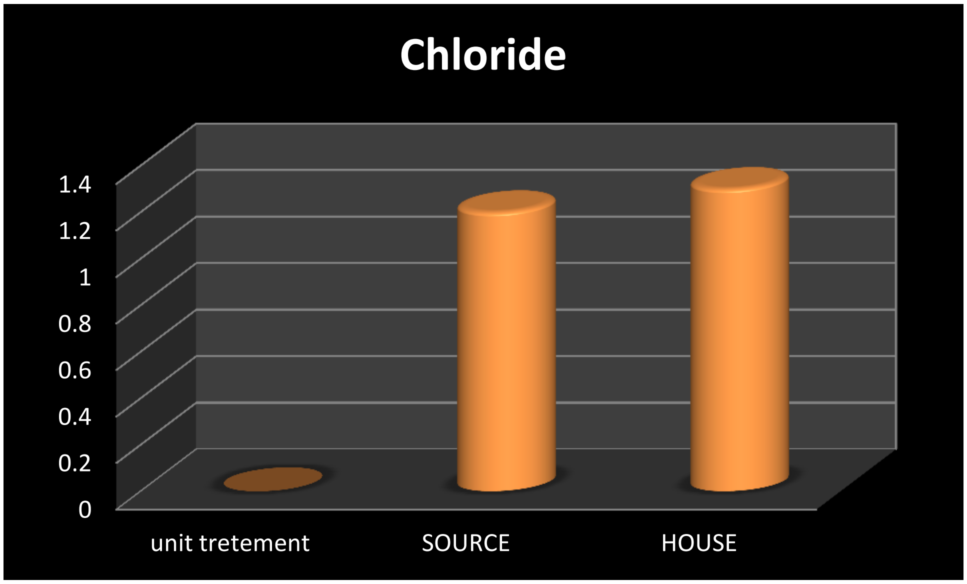


fig NO (4-6)compare of result of Chloride

After the analysis and comparison, we find that the acute shortage of chloride in the station is due to the presence of a defect in the addition that is not stable and there is an increase in the house due to the degradation of the salts in the network so negative ions are produced for the chloride so we find an increase in the house

4.7. Iron:

Table No (4-7)amount of the result of Iron

Number of sample	Name of sample	Result
1	**Source**	**0.02**
2	**Unit treatment**	**0.01**
3	**House**	**0.02**

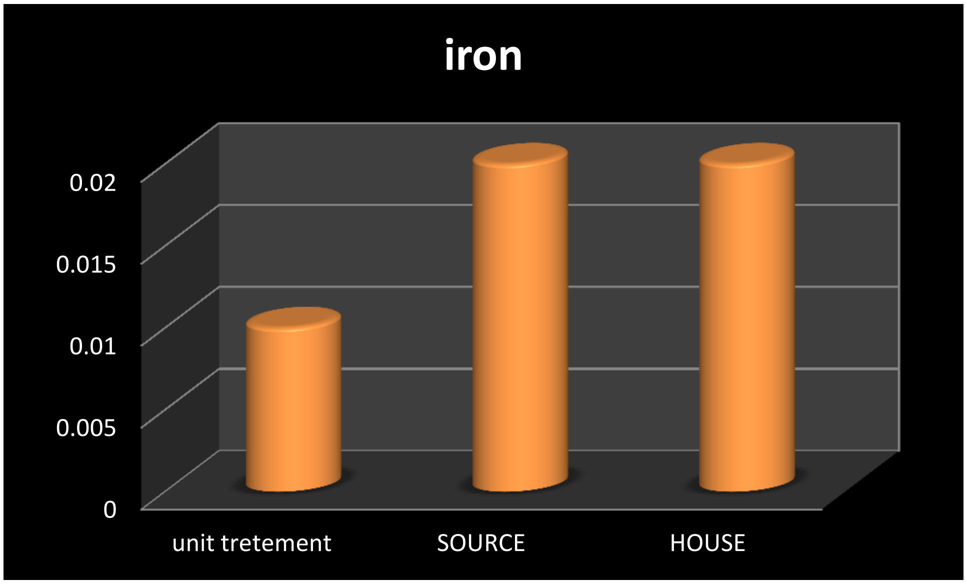


fig NO (4-7)compare of result ofIron

After analysis and comparison, it was found that the difference in iron is not significant, since the main source of water is rainwater and its lack of much movement, so there was no noticeable change.

4.8. Nitrate:

Table No (4-8)amount of the result ofNitrate

Number of sample	Name of sample	Result
1	Source	0.14
2	Unit treatment	0.8
3	House	0.48

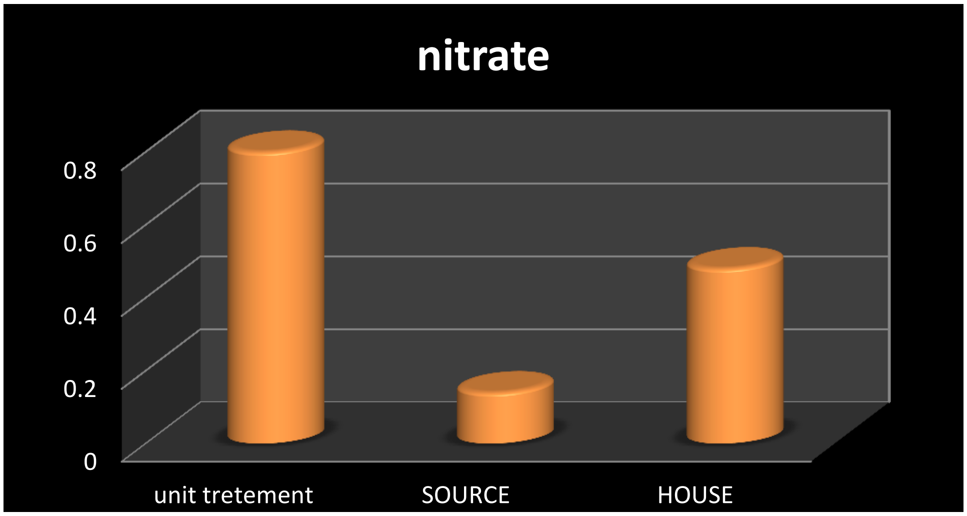


fig NO (4-8)compare of result ofNitrate

After analyzing and comparing the results, I found that there is an increase in the nitrate content due to the high turbidity resulting from the treatment units due to the failure of the filters to work with high efficiency, so there is an increase in the nitrate content at home

4.9. Nitrite:

Table No (4-9)amount of the result ofNitrite

Number of sample	Name of sample	Result
1	**Source**	**0**
2	**Unit treatment**	**0.01**
3	**House**	**0**

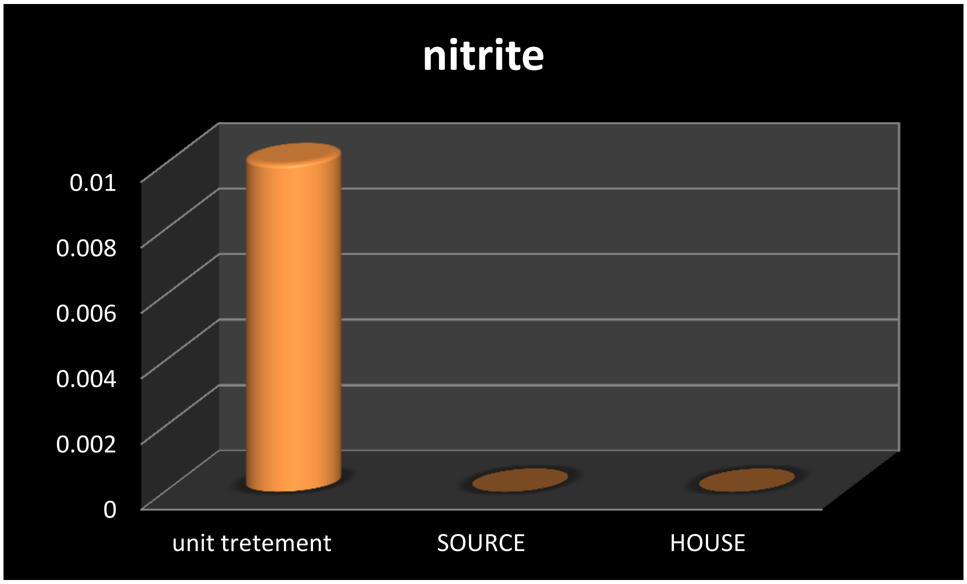


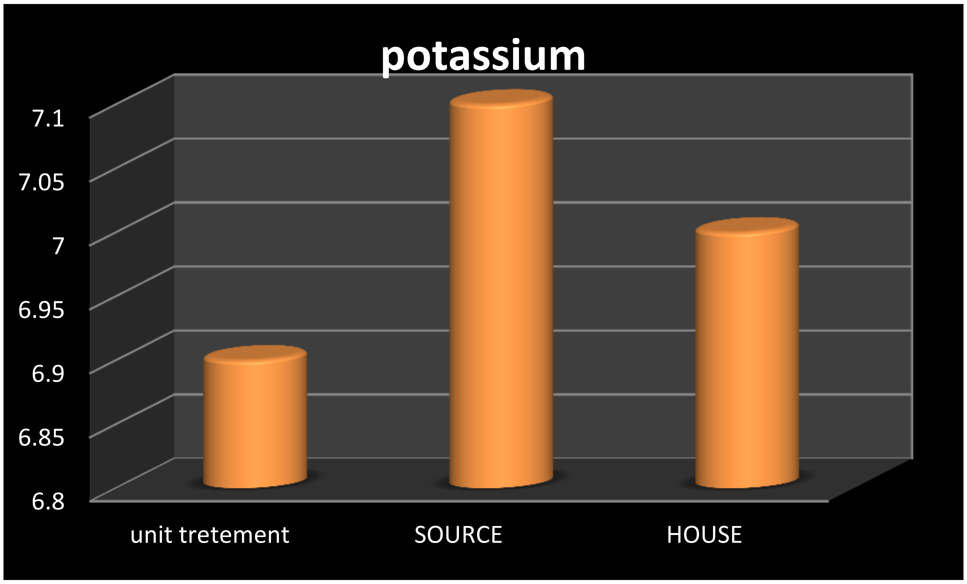
fig NO (4-9)compare of result ofNitrite

- After analyzing the samples, it was found that there is a correlation in the values of minerals in the samples within the existing specifications

4.10. Potassium:…

Table No (4-10) amount of the result ofPotassium

Number of sample	Name of sample	Result
1	Source	7.1
2	Unit treatment	6.9
3	House	7



figNO (4-10)compare of result of Potassium

After analyzing and comparing the results, it was found that there is an increase in the potassium content in the house due to the presence of salt deposits on the network, so there may be an increase in the concentration of potassium in the house due to the solubility of the sediment salts as the water passes through the distribution seam.

4.11. Calcium:

Table No (4-11) amount of the result of**.** calcium

Number of sample	Name of sample	Result
1	**Source**	**16**
2	**Unit treatment**	**11**
3	**House**	**18**

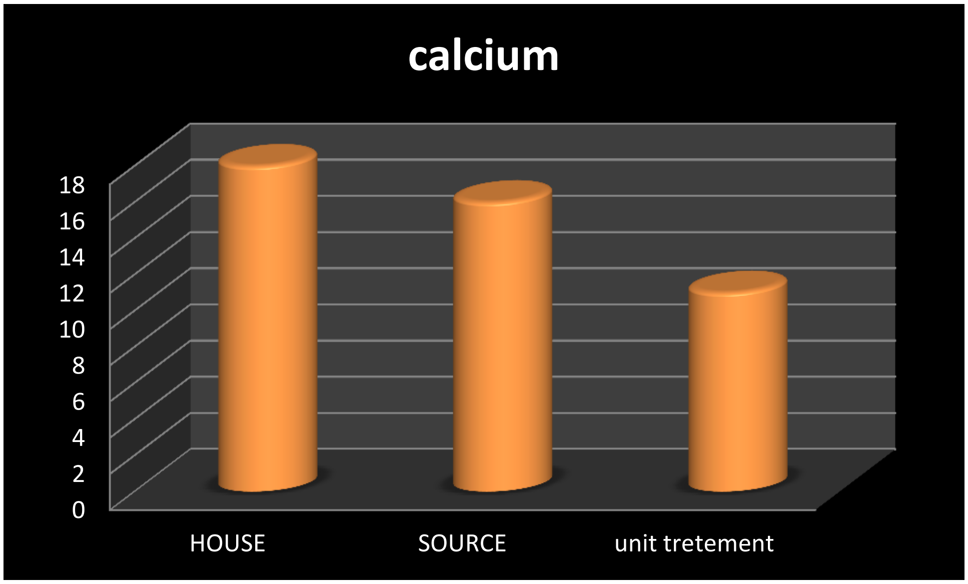


fig NO (4-11)compare of result ofcalcium

After analyzing and comparing the results, it was found that there was an

increase in the calcium content in the house due to the presence of solid salt deposits in the distribution network, so he worked to increase the calcium content at home.

4.12. Magnesium:

Table No (4-12) amount of the result ofMagnesium

Number of sample	Name of sample	Result
1	**Source**	**13**
2	**Unit treatment**	**6.5**
3	**House**	**14**

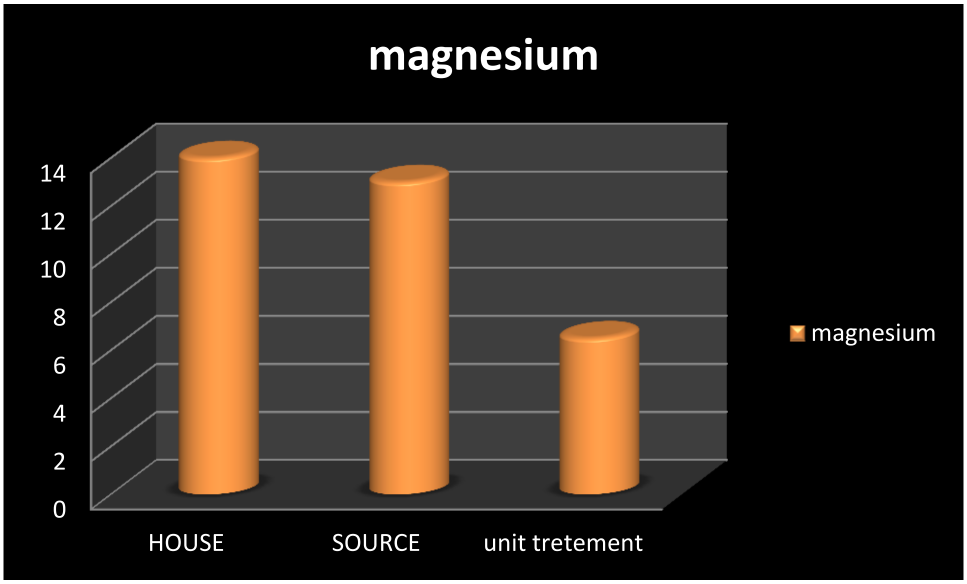


fig NO (4-12)compare of result of Magnesium

After analyzing and comparing the results, it was found that there was an increase in the magnesium content at home due to the presence of solid salt deposits in the distribution network, so he worked to increase the magnesium content at home

Chapter five

Conclusion and Recommendations

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Conclusion and Recommendations

5.1. Conclusion:.

Water is considered an important thing in a person's life, so he must be concerned with all quality standards in water purification and maintaining this basic resource and with an effective impact on human and animal health. In this research, we examined and evaluated the quality of water in Al-Rahad town , which dealt with all stages of purification and treatment and taking samples with an effect to control all standards and their conformity to all scientific and international standards in water quality, knowledge of all weaknesses and treatment of all problems represented in increasing the proportion of turbidity in the rain fall and summer seasons and color change. Samples were taken, analyzed and access to appropriate solutions represented in review all the existing filters in the station and maintain its periodic cleanliness, and review the distribution network of water entering the residential town and increase the proportion of chloride in the treatment stages until the harmful effects in the bacteria are reduced, the color changes, and the recommendations are made and submitted for discussion.

5.2. Recommendations:

- Check the filters in the station due to the increase in the degree of turbidity between the source, the station and the house termination
- Check the water supply system networks working in distributing water from the station to the residential neighbour hoods
- Increase the chloride addition rate in the plant to treat all biological effects

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Appendixes