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Characterization and Treatment of Groundwater in Khartoum State

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Abstract

The increase of the population density and the intensified water and on-site sanitation facilitates in the Khartoum state without appropriate sewage disposal facilitates have put water sources in general. The objective of this study is to assess and reduce the Vulnerability of groundwater. Water samples were collected from Thirty nine (39) water supply wells of the Khartoum state during the summer season of the year 2019. Chemical analyses were carried out for the water samples before and after passing into activated carbon and ion exchange columns. The PHREEQC index concept was adopted for the design of a system of activated carbon and ion exchange columns for groundwater treatment. According to the statistical analyzes there was a significant positive correlation coefficients between HCO_3^- with Na^+ (r= 0.862), Na^+ with K^+ (r = 0.503) and between Na^+ with TDS (r = 0.565).Such correlation shows that the dissolution and precipitation reactions are active and occur in the groundwater of the studied samples. The results were also analyzed and interpreted using a modern computerized simulation model (PHREEQC) which indicated that the treated samples became significantly under saturation with minerals after treatment. There was a significant reduction in cations {Na^+, K^+, Ca^{2+} and Mg^{2+}}, anions {(SO_4^{2-}), F,(NO^{3-}), (NO^{2-}), CL^-} and TDS after treatment. The efficiencies of the treatment with activated carbon and ion exchange columns were for {NO^{3-} (93%), NO^{2-} (67%), Na^+ (70%), Fe^{+3} (87%), F^- (78%), NH_3 (93%), SO_4^{2-} (76%), TDS (69%) and Color (46%).

Keywords: Treatment, Groundwater, PHREEQC, Activated carbon, Ion exchange.

1. INTRODUCTION

Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells.

The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology. Typically, groundwater is thought of as water flowing through shallow aquifers, but, in the technical sense, it can also contain soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults. It is likely that much of Earth's subsurface contain some water, which may be mixed with other fluids in some instances. Groundwater may not be confined only to Earth. The formation of some of the landforms observed on Mars may have been influenced by groundwater. There is also evidence that liquid water may also exist in the subsurface of Jupiter's moon Europe.

Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water. Therefore, it is commonly used for public water supplies. For example, groundwater provides the largest source of usable water storage in the United States, and California annually withdraws the largest amount of groundwater of all the states. Underground reservoirs contain far more water than the capacity of all surface reservoirs and lakes in the US, including the Great Lakes. Many municipal water supplies are derived solely from groundwater. Groundwater is fresh water that soaks into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. Groundwater accounts for nearly 95 percent of the nation's fresh water resources. It can stay underground for hundreds of thousands of years, or it can come to the surface and help Fill Rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring or be pumped from a well. Both of these are common ways we get groundwater to drink. About 50 percent of our municipal, domestic, and agricultural water supply is groundwater.

1.1 Literature review of Groundwater

Groundwater is a valuable water resource on earth and thus, groundwater contamination warrants much more attention. Currently, groundwater contamination is a widespread environmental problem and high concentrations of various organic/inorganic contaminants have been detected in groundwater at many locations in developing and developed countries worldwide. From a practical and engineering point of view, contaminated groundwater remediation needs to be focused on the prevention of dissolved contaminants migration because it is usually time-consuming and costly for residual no aqueous-phase liquid delineation and removal [**1**].

Sudan is one of the biggest countries in Africa. The Nile crosses the country from the south to the north and its water resources are not available to a large part of the country. Mast population for from Nile depends on groundwater. Major groundwater aquifers in Sudan cover about 50% of the surface area of the country. The estimated probable strategic potential of these aquifers is rather huge, amounting to some hundred milliards cubic meters according to some estimates [**2**].

1.2 Process Pollution of Groundwater from the Anthropogenic Activities

Sewage comprises a complex mixture of natural inorganic and organic matter with a small proportion of man-made substances. It originates from domestic, commercial and industrial sources, and is transported within a system of pipes to outlets such as septic tanks, wastewater treatment plants, or natural watercourses. In certain developing countries, sewage is discharged directly into soak pits [**3**]. In a septic tank system, the sewage flow is slowed in the tank to allow solids to settle to the bottom. Liquid from the middle of the tank passes out of the tank to a subsurface pit or drain field for infiltration into soil. The percolation of septic wastes through soil is required for the purification of the effluent before it replenishes groundwater. In the United States, 3 billion m^3 of wastewater per year are discharged into the soil via individual on-site disposal units, which include septic tanks and cesspools [**4**].Solid waste is one of the main sources of potential contamination of groundwater in urban areas and surroundings. Pollutants can be leached from solid waste on manufacturing sites and others, penetrating through the topsoil and through to groundwater. Urbanized areas throughout the world are characterized by a high production of solid waste. Waste generation rates have been estimated to vary between 0.3~0.6 kg/person/day in some cities of developing countries and 0.7~1.8 kg/person/day for developed cities [**5**].

Nitrogen fertilizers supply plants with forms of nitrogen that are biologically available for plant uptake; namely NO^{3-} (nitrate) and NH_4^+ (ammonium). This increases crop yield and agricultural productivity, but it also negatively affects groundwater and surface waters, pollutes the atmosphere, and degrades soil health. Not all of the fertilizer that is applied are taken up by the crops, and the remainder accumulates in the soil or is lost as runoff. Nitrate fertilizers are much more likely to be lost to the soil profile through runoff because of its high solubility and like charges between the molecule and negatively charged clay particles [**6**]. Arsenic and fluoride have been recognized by the World Health Organization (WHO) as the most serious inorganic contaminants in drinking-water on a worldwide basis. The metalloid arsenic can occur naturally in groundwater, as seen most frequently in Asia, including in China, India and Bangladesh [**7**].Volatile organic compounds (VOCs) are a dangerous contaminant of groundwater. They are generally introduced to the environment through careless industrial practices. Primary VOC pollutants found in groundwater include aromatic hydrocarbons such as BTEX compounds (benzene, toluene, ethyl benzene and xylenes), and chlorinated solvents including tetrachloroethylene (PCE), trichloroethylene (TCE), and vinyl chloride (VC). BTEX are important components of gasoline. PCE and TCE are industrial solvents historically used in dry cleaning processes and as a metal degreaser, respectively [**8**].

Water pollution due to increased agricultural industrial and domestic has become a serious concern worldwide. Various toxic pollutants have been detected in drinking water sources at alarming levels. Anionic pollutants, one of the important classes of aquatic pollutants, need special attention for their removal from water as usually there will be no organoleptic changes in water when anions are present even at low concentrations, thereby increasing the health risks. Ion exchange (IE) technology has been proven as one of the best technologies for water and wastewater treatment. In this review, a compilation of various IE materials reported in the vast literature, used for the removal of various anions (nitrate, fluoride, per chlorate, arsenate, chromate, phosphate, etc.) from water. Ion exchange is an exchange of ions between two electrolytes or between an electrolyte solution and a complex [**9**]. Adsorption of a substance involves its accumulation at the interface between two phases, such as a liquid and a solid or a gas and a solid. The molecule that accumulates, or adsorbs, at the interface is called an adsorbates, and the solid on which adsorption occurs is the adsorbent. Adsorbents of interest in water treatment include activated carbon, ion exchange resins, adsorbent resins; metal oxides, hydroxides, and carbonates, activated alumina, clays, and other solids that are suspended in or in contact with water. Adsorption plays an important role in the improvement of water quality [**10**]. Activated carbon and certain resins will adsorb organic compounds in an aqueous phase, such as groundwater, or in a vapor phase, such as air. Stripping of groundwater that contains VOCs produces vapor-phase organic compounds [**11**]. Adsorption of organic compounds attract concentrations from natural waters is an important problem in water purification. Essentially all synthetic organic chemicals that must be removed in water treatment by adsorption must compete with natural or background organic matter for adsorption sites. The heterogeneous mixture of compounds in natural waters adsorbs on activated carbon and reduces the number of sites available for the trace compounds, either by direct competition for adsorption sites or by pore blockage [**12**]. Coagulation and flocculation treatment is a method to aggregate fine particles and colloids dispersed stably in water and to make their large flocs which are easily separated from water through settling, floating processes and so on. Ferric salts and aluminum salts are usually used as coagulants. High molecular weight synthetic polymers are used as flocculants. Coagulants neutralize the surface electrical charges of particles and break their stable dispersion in water. Flocculants combine with neutralized particles and form large flocs [**13**].

2. STATEMENT OF THE RESEARCH PROBLEM

The main water characteristics include natural and chemical can determine the type of water by observation and water analysis of the water resource in order to determine its suitability Water sources are subject to changes in their properties and validity when they contain levels of salts or other pollutants to the extent that the rates accepted and authorized by the World Health Authority are met. There has been much talk recently about the viability of drinking water in Khartoum state. This prompted the researcher to discuss this problem to find out the properties of drinking water in Khartoum state. Using PHREEQC modeling software to reduce the salt content in groundwater by saturation index (S1).Samples of groundwater will be treated by ion-exchange column and activated carbon adsorption column.

3. OBJECTIVES

3.1 General Objectives:

The goal of the study is to assess and treat groundwater to reduce the contaminants and associated chemicals of health risks to an acceptable safe level.

3.2 Specific Objectives:

The major impurities of groundwater are classed in two main groups the first dissolved and the second suspended solids and gaseous. To undertake and operate the design and laboratory experiments as follows:

1. Design of a processing unit and operate an ion-exchange column for water treatment using Zeolites as packed bed.
2. Design of a processing unit and operate adsorption column for water treatment using activated carbon as packed bed.

3. Laboratory measurements for treated water which include such as chemical parameters out let of ion-exchange and adsorption columns{ PH, Mg^{2+}, Ca^{2+}, K^{+}, (NO^{3-}) , (NO^{2-}) , Fe^{3+}, F^{-}, (NH_3) , (SO_4^{2}) , (HCO^{3-}) , (CL^{-}), TDS, EC, Oder and Color}.
4. To analyze sample for taste and odors by designed apparatus (subjective).
5. Compare the results with standard values recommended by World Health Organization (WHO) and Sudanese Standard (SSMO) for Drinking water.
6. Using PHREEQC modeling software version 3 to detect variation of salt content in groundwater by saturation index (S_1).
7. IBM SPSS Statistics program version 20 for groundwater will be used for correlations.

4. MATERIAL AND METHOD

Khartoum State is one of the eighteen states of Sudan. Although it is the smallest state by area (22,142 km^2), however it is the most populous (5,274,321 in 2008 census). It contains the country's largest city by population, Omdurman, and the city of Khartoum, which is the capital of the state as well as the national capital of Sudan. The capital city contains offices of the state, governmental and non-governmental organizations education, cultural institutions, and the main airport. The city is located in the heart of Sudan at the confluence of the White Nile and the Blue Nile, where the two rivers unite to form the River Nile.

The confluence of the two rivers creates a unique effect. As they join, each river retains its own color: the White Nile with its bright whiteness and the Blue Nile with its alluvial brown color. These colors are more visible in the flood season. The state of Khartoum is divided into seven localities (KHARTOUM, BAHRI, OMDURMAN , JABALAWLIYA , SHARQ AL-NlL, UM-BADA and, KARARI) .The state lies between longitudes 31.5 to 34 °E and latitudes 15 to 16 °N. It is surrounded by River Nile State in the north-east, in the north-west by the Northern State, in the east and southeast by the states of Kassala, Gedaref , Gezira, and in the west by North Kordofan Fig.**1**.

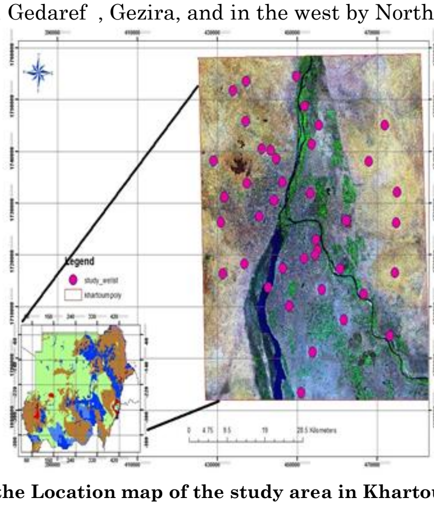

Fig.1. the Location map of the study area in Khartoum state

4.1 Sample collection

Samples were collected from 39 Borehole in February 2019 from the seven Localities (Khartoum, Omdurman, Khartoum Bahri, Jabalawlya, Sharq Al Neel, Ombada and Karary). Samples were collected in pre-cleaned plastic polyethylene bottles for treatment by activated carbon and adsorption ion-exchange column. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the groundwater to be taken for treatment. Each of the groundwater samples was analyzed for *17* parameters, including Bicarbonate, Sulfate, Calcium, Magnesium, Sodium, pH, Total Dissolved Solids (TDS), Nitrate, Ammonia, Fluoride, Iron, Nitrite, Potassium, Chlorine, Odor, Color and Electrical Conductivity (EC). Sampling locations are shown in Fig .**1**

4.2 Sample Size of Boreholes

To calculate sample size of target group from the total number of boreholes in Khartoum state shown in Table .1 the researcher used the Yamane formula (1973) to identify appropriate total boreholes in each locality. This formula is reliable to 95% and less than 5% deviation factor.

$$n = \frac{N}{1+N(e)2}$$

Where:-

e = Deviation sampling =0.05

N=Total of boreholes.

n = size of sampling

$\frac{1042}{1+1042(0.05)2} = 289$

Therefore, the sampling size is 289 samples

The samples size according to number of boreholes in each locality and determine the final sample size for each borehole:-

1. Locality of Khartoum $\frac{99}{1042} * (289) =$ 27

Final samples size: - $\frac{27}{289}*(39) = 3.6 \approx$ 4

2. Locality of JabalAwliya $\frac{168}{1042} * (289) =$ 47

Final samples size $\frac{47}{289}*(39) = 6.3 \approx$ 6

3- Locality of Sharq an-Nīl $\frac{300}{1042} * (289) =$ 83

Final samples size: - $\frac{83}{289}*(39) = 11.2 \approx$ 11

4. Locality of Bahri $\frac{77}{1042} * (289) =$ 21

Final samples size: - $\frac{21}{289}*(39) = 2.8 \approx$ 3

5. Locality of Omdurman $\frac{85}{1042} * (289) =$ 24

Final samples size: - $\frac{24}{289}*(39) = 3.2 \approx$ 3

6. Locality of Ombadda $\frac{112}{1042} * (289) =$ 31

Final samples size $\frac{31}{289}*(39) = 4.1 \approx$ 4

7. Locality of Karary $\frac{201}{1042} * (289) =$ 56

Final samples size: - $\frac{56}{289}*(39) = 7.5 \approx$ 8

Table .1. Sampling locations of the boreholes from Khartoum State

NO	Locations	Number of boreholes	Samples size	Final samples size
1	Khartoum	99	27	4
2	Jabal Awliya	168	47	6
3	Sharqan-Nīl	300	83	11
4	Bahri	77	21	3
5	Omdurman	85	24	3
6	Ombadda	112	31	4
7	Karari	201	56	8
Total		1042	289	39

4.3 Sampling Techniques

Samples of groundwater analyzed for treatment by Design ion-exchange column and one activated carbon column and done according to the following:

1. Designed, constructed and operated ion-exchange columns for water treatment using Zeolites.
2. Designed construct and operate adsorption column for water treatment using activated carbon as packed bed.
3. To analyze the Chemical parameters of ground water at out let of ion-exchange.{ PH, $Mg^{2+,}$ Ca^{2+} ,K^+, Na^+, (NO^{3-}) , (NO^{2-}) , Fe^{3+} ,F^- , NH_3 , (SO_4^{2-}), (HCO^{3-}), cl^-, TDS, EC } shown that Figure (3-2).
4. To analyze the Chemical parameters of ground water at out let of activated carbon adsorption column {Color and odors} shown that Fig. 2.

4.4 Modeling software Techniques

The study aims to use modeling PHREEQC to detect variation of salt content in groundwater after and before treatment. Use the PHREEQC version 3 at 25 C^0 and pressure 1atm using Thermodynamics data to determine the saturation index (S_1) of different minerals in various solutions. Positive S_1 indicates super saturation or precipitation of secondary minerals and negative S_1 indicates the under saturation or dissolution of minerals. An S_1 of ±0.5 indicates equilibrium conditions to classify the samples boreholes and calculation for a groundwater sample are useful in predicting the presence of reactive minerals in the groundwater system and estimating mineral reactivity.

4.5 Saturation index

The saturation index (S_1) is a widely used indicator in hydro geochemical study. It describes the saturation status of minerals in the groundwater. When S_1=0, the minerals in the aqueous solution are in equilibrium status, when S_1<0, the minerals in the aqueous solution have not reached saturation, and bear on a dissolution trend, when S_1>0, a supersaturated status of minerals in the aqueous solution is indicated and mineral deposition will occur. The determination of the PHREEQC index is a tool towards this effect. The objective of this study determined to reduce the PHREEQC saturation index of groundwater and associated chemicals of health risks to an acceptable safe level in Khartoum State. PHREEQC Index concept has been adopted for this effect with design of ion-exchange column and adsorption column for groundwater water treatment.

4.6 Utilized statistical software

Correlation Index was applied to the results in order to determine the relations between the investigated parameters by using the SPSS statistical package program (version 20).Factor Analysis (FA) was applied to the results in order to determine effective factors on groundwater of Khartoum State according to correlated variables.

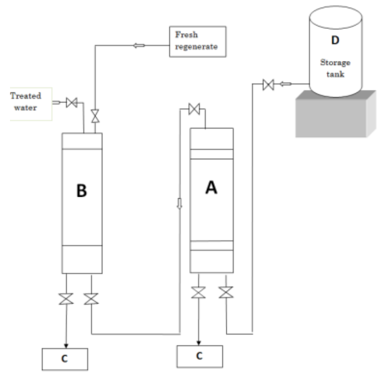

Fig .2. Water treatment unit (figure plotted scale)

Keys:
A: adsorption column
B: ion-exchange column
D: Storage tank (Feed vessel)
C: Flushed water

4.7 Flow rate in the design model

Water Quantity tank = area tank volume *water height (D)

Q= (A*h) = 0.785*(12)2 *30 =3391cm^3

$$\text{flowrate} = \frac{\text{tank Volume}}{\text{T(retention time)}} = \frac{3391}{40} = 85\text{cm}^3/\text{min}$$

At this average flow rate of 85cm^3/min the obtained average efficiency was as follows:-

For NH_3 = 93.2%
Fluoride = 78%
Fe = 87%
Na = 70%
NO_3 = 93%
NO_2 = 67%
SO_4. = 76%
TDS = 69%
Color =45.9%

Comment:-

Form the above results of the model NH_3 has the highest efficiency of 93.2% where for color the efficiency is the lowest 45.9%.

5. RESULTS AND DISCUSSION

5.1 Result of Hydrogen Ion Concentration (pH)

pH is an indicator of acidity or alkalinity of a solution. Usually has no direct impact on consumers, but it is one of the most important operational water quality parameters

(SSMO, 2016). The analyzed samples of pH in all locations before and after treatment are normal limit according to Sudanese Standards and Metrology Organization SSMO. The average of pH variations by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is 12.6%, 8.2%, 11.19%, 11.36%, 8.4%, 12.9% and 8.5% respectively.

5.2 Result of Magnesium ion (Mg^{+2})

The analyzed samples of Magnesium in all locations before and after treatment are normal limit according to Sudanese Standards and Metrology Organization SSMO. The average of magnesium reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is ***62***%, 55%, 56%, 72%, 56%, 58% and ***43***% respectively.

5.3 Result of Ammonia (NH_3)

The analyzed samples of ammonia in locations before the treatment where it was found that seven boreholes unconformity to Sudanese Standards and Metrology Organization SSMO Includes one borehole in locality of Khartoum (EL SHAGARA) and Includes six boreholes in locality of JabalAwliya and after treatment is normal limit values compared with SSMO permissible limits. The average of ammonia reduction by treatment in localities of Khartoum, Bahri , Omdurman, JabalAwliya, Sharqan-Nīl, Ombadda and Karari is 86% ,97% ,95% , 100%,92% , 88% and 94% respectively.

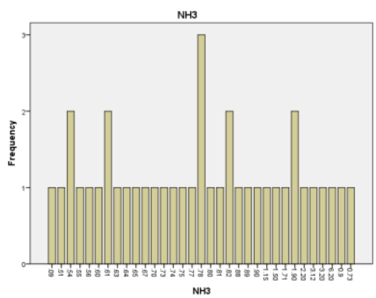

Fig.3. The Bar Chart of NH_3

5.4 Result of Calcium ion (Ca^{+2})

The analyzed samples of Calcium in all locations before and after treatment are normal limit according to the Sudanese Standards and Metrology Organization. The average of calcium (Ca) reduction by treatment in localities of Khartoum, Bahri, Omdurman, JabalAwliya, Sharqan-Nīl, Ombadda and Karari is ***60***%, 66%, 32%, 64%, 61%, 64% and ***55***% respectively.

5.5 Result of Sulfate ion (SO_4^{2-})

The analyzed samples of Sulfate in locations before the treatment Where it was found that there are three boreholes unconformity to Sudanese Standards and Metrology Organization SSMO Includes two of boreholes in localities of Khartoum {GEBRA NO NO (15), EL GEREIF MARBA (5)} and one of boreholes in localities of Bahri (UM ALGURA).After treatment is normal limit values compared with SSMO permissible limits. The average of sulfate reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is ***81***%, 87%, 64%, 65%, 74%, 70% an ***82*** % respectively.

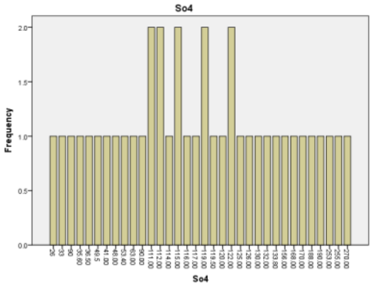

Fig.4. The Bar Chart of SO_4

5.6 Result of Nitrite ion (NO^{2-})

The analyzed samples of Nitrite in locations before the treatment where it was found that the Thirteen boreholes unconformity to Sudanese Standards and Metrology Organization SSMO Includes one boreholes of Khartoum {GEREIFWEST (ALESLAHEYA)}, Includes one boreholes of localities of Bahri { NEPTA}, Includes two borehole in localities of Omdurman { HJILIJA and AL-EGELAB} , Includes tow boreholes in localities of Jabal Awliya{ ARAK THALEH, AL-SALMA (NEMARY)},Includes three borehole in localities of Sharqan-Nīl{ UMDUM, AL-TEREASSAB and AL-FADENIA} , Includes one borehole of Ombadda { AWLAD ELSOBAB },and Includes four borehole in localities of Karari { AL-HARISAB, ALTHOWERA(1), ALFATH NO (2) and AL-NOFOLAB }.After treatment is normal limit values compared with SSMO permissible limits. The average of Nitrite reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is 89%, 83%, 97%, 90%, 94%, 99% and 97% respectively.

5.7 Result of Nitrate ion (NO^{3-})

The analyzed samples of Nitrate in locations before the treatment where it was found that the three boreholes unconformity to Sudanese Standards and Metrology Organization SSMO Includes two boreholes of Khartoum {ELSHAGARA ,EL GEREIFWEST (ALESLAHEYA)} and Includes one of borehole in localities of Jabal Awliya { ARAK THALEH }.).After treatment is normal limit values compared with SSMO permissible limits. The average of Nitrate reduction by treatment in localities of Khartoum, Bahri, Omdurman, JabalAwliya, Sharqan-Nīl, Ombadda and Karari is 73%, 80%, 17%, 75%, 58%, 59% and 71% respectively.

5.8 Result of Sodium ion (Na^+)

The analyzed samples of Sodium in locations before the treatment where it was found that the three boreholes unconformity to Sudanese Standards and Metrology Organization SSMO Includes two boreholes of Khartoum{EL SHAGARA, GEBRA NO (15)} and Includes one of borehole in localities of Sharqan-Nīl {ALTAWEETAT}.After treatment is normal limit values compared with SSMO permissible limits. The average of Sodium reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is 54%, 82%, 86%, 60%,61%, 75% and 74 % respectively.

5.9 Result of Potassium ion (K^+)

The analyzed sample of Potassium in all locations before and after treatment no Standards limit according to the Sudanese Standards and Metrology Organization SSMO and WHO. The average of potassium reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is34%,91%,93%,78% 71%,75% and 83% respectively.

5.10 Result of ferric ion (Fe^{+3})

The analyzed sample of iron in locations before the treatment where it was found that the twenty one boreholes unconformity Sudanese .Standards and Metrology Organization SSMO .Includes two boreholes of Khartoum{GEBRA NO (15), ELGEREIFWEST (ALESLAHEYA)}, Includes one borehole in localities of Bahri {UM ALGURA}, Includes three of boreholes in localities of Omdurman{ AL-ASKAN(ALSAFWA City No7), HJILIJA and AL-EGELAB}, Includes six of boreholes in localities of Sharqan-Nīl{UMDUM, AL-TEREASSAB, AL-HADIBAB,AL TAWEETAT, HAY-ALHOODA and EL HAG YOSEF ALWEHDA NO (1)}, Includes three of boreholes in localities of Ombadda and Includes six of boreholes in localities of Karari. After treatment is normal limit values compared with SSMO permissible limits. The average of iron reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is 100%, 65%, 85%, 77%, 92%, 90% and 96% respectively.

5.11 Result of Fluorite ion (F^-)

The analyzed sample of Fluorite in locations before the treatment where it was found that the twenty five boreholes unconformity Sudanese Standards and Metrology Organization SSMO Includes one borehole of Khartoum {EL GEREIF MARBA(5)}, Includes one borehole of Bahri {CAFOURI (ALNOUR MOSQUE)} , Includes one borehole of Omdurman{ HJILIJA }, Includes four borehole of Jabal Awliya{AL-KHALAKLA KUBA NO(4) and AL-SALMA (NEMARY)}, Includes nine borehole of Sharqan-Nīl{UMDUM, AL-RAHAMA, AL-TEREASSAB, AL-HADIBAB, AL-TAWEETAT, HAY-ALHOODA, ALBAN HILAT KOKO(2), EL HAG YOSEF ALWEHDA NO (1) and EL HAG YOSEF ALTAKAMOL(3)}, Includes four borehole of Ombadda {HLHASANAB,UM-BADA ALAMIRA NO (***45***), AWLAD ELSOBAB and UM-BADA AL-HAARA(***8***)} and five borehole of Karari {AL-HADANANO(6) ALSHAHYNAB SOUTH, ALTHOWERA NO (1), ELSARHA and ALFATH NO (2)}.After treatment is normal limit values compared with SSMO permissible limits. The average of fluorite reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is 77***%*** , 72%, 65%, 70%, 89%, 92% and 79% respectively.

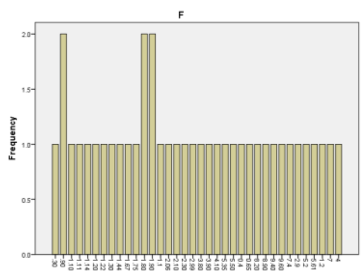

Fig.5. The Bar Chart of F

5.12 Result of Color

The analyzed sample of Color in locations before the treatment where it was found that the twelve boreholes unconformity Sudanese Standards and Metrology Organization SSMO Includes one borehole of Khartoum { GEBRA NO(15)} Includes, one borehole of Bahri{ UM ALGURA }, Includes one borehole of Omdurman{AL-ASKAN(ALSAFWA City No 7)}, Includes one borehole of Jabal Awliya{ AL-SALMA (AL BAHERA) }and Includes eight borehole of Sharqan-Nīl{ UMDUM , AL-RAHAMA , AL-HADIBAB , AL-SAREEA, HAY-ALHOODA, ALBAN HILAT KOKO NO (2) EL HAG YOSEF ALWEHDA NO (1) and EL HAG YOSEF ALTAKAMOL NO (3)}. After treatment is normal limit values compared with SSMO permissible limits. The average of Color reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl , Ombadda and Karari is 38%, 12%, 31%, 32%,87%,100% and 19% respectively.

5.13 Result of Chloride ion (cl$^-$)

The analyzed sample of Chloride in all locations before and after treatment is normal limit according to the Sudanese Standards and Metrology Organization SSMO. The average of chlorine reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is 20%, 45%, 50%, 39%, 39%, 26% and 40% respectively.

5.14 Result of Total Dissolved Solids TDS

The analyzed sample of Total Dissolved Solids in location before the treatment where it was found that eighteen boreholes unconformity Sudanese Standards and Metrology Organization SSMO Includes four boreholes of Khartoum{ELSHAGARA, GEBRA NO(15), EL GEREIF WEST (ALESLAHEYA and EL GEREIF MARBA NO (5)}, Includes one borehole of Bahri {NEPTA}, Includes two borehole of Omdurman {HJILIJ and AL-EGELAB}, Includes four boreholes of Jabal Awliya {UM-RABAH (AL-SALMANIYA), ARAKTHALEH, ZOHAL and SALMA (NEMARY)}, Includes five boreholes of Sharqan-Nīl {AL-RAHAMA, AL-TEREASSAB, AL-TAWEETAT, HAY-ALHOODA and EL HAG YOSEF ALTAKAMOL NO (3) },Includes one borehole of Ombadda { UM-BADA AL-HAAR NO*(8)* },Includes one borehole of Karari{ AL-HADANA NO(6)} After treatment is normal limit values compared with SSMO permissible limits. The average TDS reduction by treatment in localities of Khartoum, Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari is 73%,70%,76%,66%,72% and,59% respectively.

5.15 Result of Odor

The analyzed sample of Odor in locations before the treatment where it was found that nineteen boreholes unconformity Sudanese Standards and Metrology SSMO Includes two boreholes of Khartoum {GEBRA NO (15) and EL GEREIF MARBA(5)}, Includes two borehole of Bahri{ NEPTA and UM ALGURA }, Includes six boreholes of JabalAwliya{ AL-KHALAKLA KUBA NO(4),UM-RABAH (AL-SALMANIYA), AL-SALMA (AL BAHERA*)*,ARAK THALEH, ZOHAL and SALMA (NEMARY)}, Includes five boreholes of Sharqan-Nīl { UMDUM , HAY-ALHOODA , ALBAN HILAT KOKO NO (2) , EL HAG YOSEF ALWEHDA NO (1) and EL HAG YOSEF ALTAKAMOL NO (3)}, Includes two of boreholes in localities of Ombadda (HLHASANAB and AWLAD ELSOBAB) and Includes two boreholes in localities Karari {ELSARHA and AL-NOFOLAB}.After treatment is normal limit values compared with SSMO permissible limits. The average Odor reduction by treatment in localities of Khartoum, Bahri, Omdurman, JabalAwliya, Sharqan-Nīl, Ombadda and Karari.

5.16 The average of Sodium adsorption ratio (SAR)

Sodium adsorption ratio is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. The formula for calculating the sodium adsorption ratio (SAR) after treatment if irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilth. This will also lead to a decrease in infiltration and permeability of the soil to water, leading to problems with crop production. Sandy soils will have less problems, but fine-textured soils will have severe problems if SAR is greater than 9. When SAR is less than 3, there will not be a problem.

5.17 Result the Modeling Software

The results of the PHREEQC simulation model of groundwater samples showed that they are under saturation and that there are spatial differences in the main cations {Na^+ , K^+ , Ca^{2+} and Mg^{2+} } and anions {(SO_4^{2-}) ,F^- ,(NO^{3-}) ,(NO^{2-}) and CL^-} and variations in TDS. The results of the average reduction to modeling the content of salt before and after treatment in locality of Khartoum, Bahri, Omdurman, JabalAwliya, Sharqan-Nīl, Ombadda and Karari locality were 28%,15%,14%,21%,24%,10%and12% Respectively.

***5.18* Result of SPSS by Correlation Index**

The relations among the investigated physical and chemical water quality parameters in groundwater of boreholes in Khartoum state were determined by using all the data n = 15 for all parameters and all the detected relations are given in Table. 2. The statistical analysis of data of groundwater samples from the seven localities areas in Khartoum state. The analyzed groundwater quality of the sampled boreholes are characterized by positives correlation coefficients between HCO^{3-} with Na+ (r= 0.862), Na^+ with K^+ (r = 0.503) and between Na with TDS (r = 0.565).

Table 2. Descriptive Statistics

Items	Mean	Std. Deviation	N
PH	7.3303	.34173	39
NH3	2.4110	5.73099	39
Mg	21.1039	9.38524	39
Ca	62.0554	22.50100	39
So4	114.7385	63.13065	39
NO2	2.9185	5.23750	39
NO3	17.6646	12.85114	39
Na	98.2692	95.64415	39
K	21.3590	17.92974	39
Fe	3.0815	8.85736	39
F	6.2469	7.83538	39
Odor	.0000	.00000	39
Color	9.2897	11.54430	39
cl	51.2926	39.00670	39
TDS	918.8133	531.46138	39
EC	1313.9031	759.98977	39

*6.*CONCLUSION AND RECOMMENDATION

6.1 Conclusion:

It was concluded that adsorption columns and ion exchange were very effective in reducing the content of salts in the groundwater. The obtained results from analysis program where saturation index (S_I) Modeling using PHREEQC enabled prediction of the saturation state of minerals and indicated the dissolution and precipitation reactions occurring in the groundwater.

The results of the average reduction modeling of the content of salt by locality before and after treatment of Khartoum , Bahri, Omdurman, Jabal Awliya, Sharqan-Nīl, Ombadda and Karari were 28%,15%,14%,21%,24%,10% and 12% Respectively. This was due to the treatment process designed through the treatment equipment.

The groundwater samples that were treated by adsorption columns and ion exchange taken from 39 wells scattered from Khartoum State showed considerable decrease among the examined samples mainly, with respect to their {(NO3-), (NO2-), Fe, F-, (NH3), (SO42-), TDS, Color and Odor}.The results indicated that most of the samples before treatment were not suitable for drinking according to SSMO standards. Which mostly fell above the maximum permissible levels, it was found after treatment that most of the analyzed samples were chemically fit for the human consumption (according to the permissible limits of the WHO or SSMO).

The statistical analysis of data of groundwater samples from the seven localities in Khartoum state, showed considerable values of correlation coefficients, and their significance levels will help in selecting the proper treatments to minimize the contaminations of groundwater of Khartoum state. There is an increasing awareness among the people to maintain the groundwater at their highest quality and purity levels and the present study may prove to be useful in achieving the same. The result of this research shows that the integration of the multivariate statistical techniques helps to delineate the groundwater chemical variations and to find the major controls on the groundwater quality.

6.1 Recommendation:

Based on the results and conclusions obtained from this study, the following recommendations are drawn:-

A comprehensive study of the boreholes located south of Khartoum state must be conducted, as these boreholes contain a high percentage of ammonia above the allowable limit of the recommended by the SSMO, where it is noticed with at take samples From field work in the locality of Khartoum and JabalAwliya, that there are boreholes that have been closed by Khartoum State water corporation. After its establishment one year ago.

There must be sufficient information on the groundwater wells, whether government or private centralized management.

The asbestos must be replaced and iron pipes used in the distribution system with plastic pipes. To avoid nitrate contamination of groundwater one must focus on the major sources of human-caused nitrogen (fertilizer and manure) and the agricultural practices that can minimize the losses of nitrogen from these sources.

Legislative acts and regulations for well drilling and proper disposal of effluents must be Introduced and applied.

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