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Groundwater Treatment using Steam Injection in Selected Shallow Wells within Ogbomoso South Local Government Area, Oyo State, Nigeria

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Abstract

Groundwater is a valuable resource and must be protected from any form of pollution. The pollution of groundwater by contaminants has become an increasing concern as a result of toxicity, health hazard, and industrialization. The research work focused on groundwater treatment using a steam injection method in selected shallow wells within Ogbomoso Local government area, Oyo State, Nigeria. The steam injection was incorporated as a flux source. The results of treated water were compared with World Health Organization (WHO). The physical, chemical, and biological parameters include pH, Dissolve Oxygen (DO), EC, Turbidity, Nitrate, Potassium, Iron, Zinc, Hardness, Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) were tested before and after treatment. The pH, DO, E_c, and Turbidity ranged from 7.53-7.98, 8-12 mg/L, 100-665 µS/cm, 0.014-0.106 NTU. Nitrate, Potassium, Iron, and Zinc valued varied from 0.03-2.57, 1-28.54, 1-17.06 and 0.01-0.03 mg/L, respectively. The hardness, BOD, and COD ranged 34-116 ppm, 1.5-4.5 mg/L, and 3-8.5 mg/L, respectively. The steam Injection method improves the quality of the treated groundwater sample. Steam injection method is a promising technique for groundwater remediation.

Keywords: Groundwater, Steam Injection, Pollutant, Water quality, Human Health

1 Introduction

Groundwater is the water present below the ground surface that saturates pore space in the subsurface. Groundwater may appear at the surface in the form of springs or tap by wells. Groundwater is often preferable because it tends to be less contaminated by wastes and organisms. About 40% of drinking water comes from the groundwater, almost 97% of the rural population drinks it and about 30-40% of it is useful for agricultural purposes [1]. Groundwater is generally and widely used in the national welfare of many countries for different purposes such as portable water supply for the population and livestock-breeding, industrial water supply, irrigation, biological use (mineral water), as a raw material for extracting valuable components, such as iodine and bromine (industrial water) and for central heating (thermal power water) [2].

Groundwater pollution has also been attributed to the process of industrialization and urbanization that has progressively developed over time without any regard for an environmental consequence which eventually results in the deterioration of physical, chemical, and biological properties of water [3]. Oily water results from the sea and cooling water, fuel and lube oil leaks, drainages from settling and sludge tanks, effluents from various cleaning processes, and soot from dirt particles. Oil spills include any spill of crude oil or oil distilled products (e.g gasoline, diesel, fuels, jet fuels, kerosene, Stoddard solvent, hydraulic oils, lubricating oils) that can pollute the surface of the land, air, and water environments. Exposure to toxicant pollution causes immense health impacts such as physical and mental disorders, organ dysfunction, neurological disorder, cancer, reduced life expectancy, weakening of the body's immune system, and in some cases death [4-7].

In the Ogbomoso community, studies relating to groundwater have been carried out; studies such as Investigating Pollution of Groundwater from Atenda Abattoir Wastes, Ogbomoso, Nigeria by Adegbola and Adewoye[8], Assessment of the Groundwater Quality in Ogbomoso Township of Oyo State of Nigeria by [9], and the Groundwater Potential Evaluation at Industrial Estate Ogbomoso, Southwestern Nigeria by [10]. There are also a few nitrate contaminations to mention but a few. The remediation of polluted groundwater remains a significant challenge despite over two decades of active research and development. Remediation techniques can be classified into three groups namely: biological methods e.g. bio-augmentation, bio-sparging, chemical methods e.g. chemical precipitation, carbon absorption, and physical (thermal) methods e.g. surfactant enhanced recovery, pump and treat, air sparging, dual-phase extraction, and others. Innovative technologies for subsurface remediation including in situ techniques based on heating the subsurface to enhance the recovery of organic contaminants are increasingly being evaluated for use at specific sites as the

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limitations to the conventionally-used techniques are recognized. Thermal technologies provide a means to overcome the limitation of these technologies and may, in some cases, be able to achieve clean-up rapidly. Thermally enhanced remediation technologies are promising for the removal of contaminants at heavily contaminated sites [11]. The methods include injection of hot air, hot water, or steam. Among the thermal technologies, steam injection is being investigated as a potential method for remediation of polluted groundwater.

Steam injection is a promising technology for remediating subsurface hydrocarbon contamination. Steam injection, also termed steam or thermally enhanced extraction, was initially developed by the petroleum industry for enhancing oil recovery and has more recently been adapted to remediate soil and aquifers [12]. Steam injection has been applied at some sites in the USA [13]. It has been applied in unsaturated as well as saturated zones and is generally more efficient in porous media such as sand than in low permeable soils [14]. It involves the use of high-pressure steam to recover organic contaminants by injecting the steam with increasing temperature of the sub-surface, this leads to very fast and effective remediation of the contaminated groundwater [15]. It is with this objective in mind that groundwater remediation using steam injection is being investigated as a potentially effective method for the removal of pollutants from groundwater in selected shallow wells in Ogbomoso, South-Western, Nigeria.

2. Materials and Methods

2.1 Study Area

The study was carried out in Ogbomoso which is located in the southwestern part of Nigeria (West Africa) along the guinea savannah belt of Nigeria. It is plodding into a Sudan savanna type of vegetation. The region is located in Geographical coordinates in decimal degrees (WGS84) Latitude:8.133, Longitude: 4.267 and her coordinates in degree minutes seconds are (WGS84) Latitude: 8 08' 00", Longitude: 4 16' 00'[16]. The town comprises of North and South Local Government Area. According to the 2006 census figures, she has a population of 51,249 males, 49,566 females, and a total of 100,815 people in her 18 square kilometers land area. Located in the North-Eastern part of Oyo State and is bounded in the north by Ogbomoso North LGA, in the south by Ogo-Oluwa LGA, in the east by Surulere LGA, and in the west by Orire LGA. Her headquarters is situated at Sunsun/Arowomole, Ogbomoso.

Locally, the Ogbomoso area experiences tropical rainfall which dominates most of the southwestern part of Nigeria and the area has two distinct seasons, the wet season usually between March and October, and the dry season which falls between November and February every year. The annual rainfall for the study area is 1247mm, but the amount varies from 1016 to 1524 mm and is almost entirely concentrated in the wet season. The geology of Ogbomoso comprises magmatic and granitic, calcareous, and granulitic rocks.

2.2 The Sampling

The area selected randomly across Ogbomoso town are Papa Adeyemo, Aguodo, Ayedaade, New Sawmill, Ogbegun, Sabo, and Owode. The locations of the selected shallow wells are presented in Figure 1. The well water samples collected were taken directly to the laboratory for physical and chemical analysis. Twenty liters kegs were used to collect the water samples from the well. The kegs were thoroughly washed with distilled water and labeled accordingly. At the sampling point, the containers were again rinsed with samples to be collected.

2.4 Laboratory Analysis of Samples

2.2.1 Physical tests

Physical tests carried out indicate properties detectable by the senses. The various physical tests are as follows:

1. Turbidity: This was determined in the water sample by using a Turbidity meter 10 NTU (Nephelometric Turbidity Units) with 1 - 10 NTU graduated standard was used.

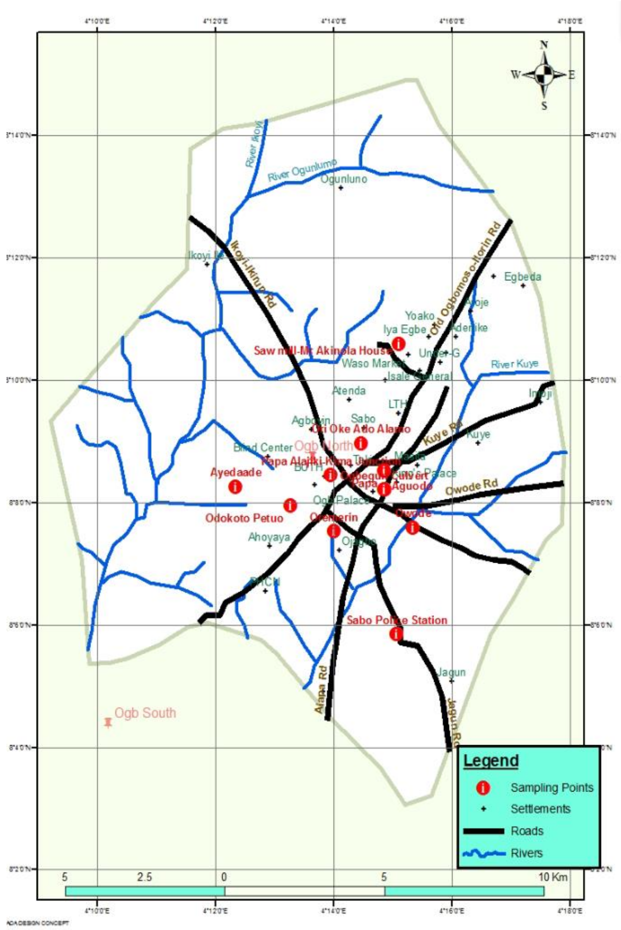

Figure 1: Map of Selected Wells in Ogbomoso

2. Total Dissolved Solids (TDS): The total dissolved solids in the water samples were determined using TDS meters and probes (Hach'sIntellica probes). Dissolved Oxygen (DO), Conductivity (E_C), Sodium, and Amonia were also measured using this probe.

3. Hardness: The apparatus used was a titer syringe plastic vessel, small transparent plastic container, and buffer solution. The cap from the small plastic syringe was removed and rinsed with the sample water. The sample was filled to the 0.5 ml mark and the cap was replaced. Five drops of hardness buffer solution were added and mixed carefully. One drop of calmagite indicator was then added. The tip of the syringe was inserted into ETDA solution and pulled out until its lower edge is on the 10 ml mark of the syringe. The EDTA titration solution is slowly added dropwise and swung to mix after each drop until the color changes. The milliliters of titration solution was read off from the syringe scale and multiplied by 300.

4. Nitrates: A 15 ml of water was prepared into two glasses each containing 5 ml of the water sample. One of the glasses was placed into left-hand opening of the checker disk. This was noted as the blank. A pocket of reagent was added to the other sample and properly mixed. The solution was marked as a

reacted sample and placed at the right-hand opening of the checker disk at a distance of about 30 to 40 cm away, and across a light source to illuminate the sample to be matched. The disk was rotated while looking at the sample through the color test window until the color is matched. The value in the test window is read as mg/l of nitrate or nitrogen ($N-NO_3$).

5. Alkalinity: Apparatus used include transparent plastic vessel, calibrated syringe, bromophenol blue indicator, and titrant solution. The cap is removed from the plastic vessel rinsed with the sample and filled with the sample to 0.5 ml mark. Drops of Bromophenol blue indicator were added and the titration syringe was filled to 10 ml with H13811.0 solution. Titration solution is added drop-wise, mixed after each drop until a color change is noted. The milliliters of titration solution used was read off from the syringe scale and multiplied by 300 to obtain mg/l (ppm).

6. Iron and Manganese: Apparatus used were color comparator cube and plastic vessels. The cap was removed from the plastic vessel and rinsed with a water sample. It was then filled to the 10 ml mark. 1 packet of the iron reagent HI 3834-0 was added. The cap was replaced and the solution mixed until solids dissolved. The cap was removed and the solution was transferred into the color comparator cube. The color that matches the solution in the cube was re- corded as mg/l (ppm) iron. Four (4) drops of Buffer Reagent were added and swirled to mix. One (1) packet of HI 38079A-0 Oxalate reagent was added and stirred for 30 seconds using a plastic spoon. This was left for about 5 minutes for the reaction to complete. One (1) drop of Calmagite indicator was added and swirled to mix. The syringe's plunger was pushed completely into the HI 380798-0 EDTA solution bottle and pulled out until the lower edge of the seal is on the 0.0 ml mark of the syringe. The milliliter of titration solution was read off from the syringe. Calculation of the mg/l (ppm) of Magnesium in the sample was as follows: ppm of mg = ml of titrant × 243.

6. Dissolved Oxygen Determination: The dissolved oxygen concentration depends on the physical, chemical, and biochemical activities in the water body, and its measurement provides a good indication of water quality. Changes in dissolved oxygen concentrations can be an early indication of changing conditions in the water body. Apparatus used includes BOD bottle of capacity 250 to 300 ml, graduated cylinder, flask, burette, pipettes. Reagents include Distilled water in a rinse bottle, alkali iodide-azide reagent, manganese sulfate ($MnSO_4.2H_2O$), and Sodium thiosulphate solution. This was done in line with American Public Health Association (APHA) and computed using equation 1.

$$DO\left(\frac{mg}{L}\right)\frac{(0.2\ X\ 1000)X\ (0.025)ml\ of\ thiosulphate}{201} \quad (1)$$

8. Biochemical Oxygen Demand Determination (BOD): This is an empirical standardized laboratory test that measures oxygen requirement for aerobic oxidation of decomposable organic matter and certain inorganic materials in water, polluted waters, and wastewater under controlled conditions of temperature and incubation period. The quantity of oxygen required for the above oxidation processes is a measure of the test using the APHA (2005) standards method as described in equation 2.

$$BOD\ O_2\left(\frac{mg}{L}\right) = \frac{(D_1 - D_2) - (B_1 - B_2)X\ F\ X\ 100}{\%\ dilution} \quad (2)$$

where D_1 is DO of the sample immediately after preparation in mg/L, D_2 is DO of the sample after 5 days incubation period in mg/L, B_1 is DO of blank (seeded dilution water) before incubation in mg/L, B_2 is DO of blank (seeded dilution water) after 5days incubation in mg/L, F is ration of seed in the diluted sample to seed in seed control (Vol. of seed in diluted sample/Vol. of seed in seed control), $B_1'$is DO of seed control before incubation in mg/L, and $B_2'$is DO of seed control after 5days incubation in mg/L.

8. Chemical Oxygen Demand Determination (COD): This is the amount of oxygen consumed by organic matter from boiling acid potassium dichromate solution. It provides a measure of the oxygen equivalent of that portion of the organic matter in a water sample that is susceptible to oxidation under the conditions of the test. Apparatus used includes Erlenmeyer flask with standard tapered glass joints, Friedrich's reflux condenser, electric hot plate, volumetric pipettes (10, 25, and 50ml capacity), burette, 50ml with 0.1ml accuracy, volumetric flasks (1000 ml capacity). Reagents used are standardized solutions of Sulphuric acid (d =1.84), Standard potassium dichromate solution, dilute standard potassium dichromate solution, standard ferrous ammonium sulfate, Silver sulfate, Reagent powder, Mercuric sulfate, Ferroin indicator solution, Sulphamic acid, Anti-bumping granules. The analysis was done in line with APHA [17] using equation 3.

$$COD\left(\frac{mg}{L}\right) = \frac{(a-b)X\ c\ X\ 8000}{v} \quad (3)$$

where a is ferrous ammonium sulfate (ml) used for blank, b is ferrous ammonium sulfate (ml) used for the sample, c is molarity (mol L^{-1}) of ferrous ammonium sulfate, and v is the volume of sample (ml).

9. Hardness Determination: Water hardness is a traditional measure of the capacity of water to precipitate soap. Apparatus includes conical flasks 100ml, burette, pipette, and spatula. Reagents and standards include buffer solution, inhibitor, Eriochrome black T indicator, sodium hydroxide (NaOH), Standard Ethylene Diamine Tetraacetic Acid (EDTA) solution, standard calcium solution. Dilute to 1000 ml to obtain 1ml = 1mg $CaCO_3$. The EDTA solution needs to be standardized against standard calcium solution such that the strength of EDTA will be 1ml = 1mg as $CaCO_3$. The procedures to be used are in line with APHA [17] and this was determined using Equation 4.

$$Total\ Hardness\ as\ CaCO_3\left(\frac{mg}{L}\right) = \frac{C\ X\ D\ X\ 1000}{mL\ sample} \quad (4)$$

where C is the volume of EDTA required by sample and D is mg $CaCO_3$ equivalent to 1mL EDTA titrant. The residue is approximately equivalent to the total content of the dissolved and suspended matter in the water sample. The term "Total Suspended Solids" (TSS) applies to the dry weight of the material that is removed from a measured volume of water sample by filtration through a standard filter.

10. Total Alkalinity Determination: The alkalinity of water is its capacity to neutralize the acid. The amount of a strong acid needed to neutralize the alkalinity is called the total alkalinity, T, and is reported in mg l^{-1} as $CaCO_3$. Apparatus used include Conical flask, 30 ml Burette, and Pipette. Reagents for the analysis are a standardized solution of de-ionized water of conductance of less than 0.2 mSm^{-1} and a pH greater than 6.0, Sodium carbonate, H_2SO_4, Phenolphthalein and Methyl orange indicator, Mixed indicator. Equation 5 is used to determine Total Alkalinity according to APHA [17].

$$T\left(\frac{mg}{L}\right) = \frac{100000\ X\ B\ X\ M}{V} \quad (5)$$

where A is the volume of standard acid solution (mL) to reach the phenolphthalein end-point of pH 8.3, B is the volume of standard acid solution (mL) to reach the end-point of methyl orange or mixed indicator, M is the concentration of acid (mol^{-1}), and V is the volume of sample (mL).

2.3 Experimental Investigation of Steam Injection Technique for Groundwater Treatment

The experimental investigation was set up. The experiment was carried out in the New Fluid Mechanics laboratory of the Mechanical Engineering Department at the Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

2.3.1 Experimental Procedure for Steam Injection Technique

Steam was generated in the steam boiler (Plate 1). The saturated steam that has been generated from the steam boiler was allowed to pass into the test chamber through the injection port by controlling the flow rate through a tap. Steam injection experiments were conducted in a three-dimensional sandbox. The sandbox has interior dimensions of 110 × 74 × 8.5 cm (Plate 2). The sandbox was packed with a layer of coarse sand to a certain level. To ensure a constant fall distance, the sand was poured through a tube. The porosity of the coarse layers was determined. The top of the sand was sealed with a thick layer of stone. This will ensure no preferential flow path developed between the sand packing and the liquid. Before each experimental run, the sandbox was equilibrated for one day before steam injection was initiated.

Plate 1: Steam Boiler

Steam was injected close to the top section of the injection at an almost constant flow rate during the experiments. The flow rate was determined using the flow meter. The sandbox was constructed of galvanized steel and a front glass panel. The glass cover allows for taking photographs, visual inspection, and access to the sand packing. The sandbox was insulated to minimize heat loss and loss of contaminants. The steam was injected into the sandbox through the injection port. The tubing from the steam boiler was electrically heated to ensure that the injection steam had a quality of approximately 100%. Steam pressure and temperature were measured just before the inlet. The sandbox was equipped with temperature sensors and pressure transducers. Effluent gas of pollutant leaves the sandbox through the extraction port and passes through a condenser. The condensed liquid was collected in a phase separator as shown in Plate 3.

As the groundwater sample is been heated up, the temperature was measured at a different time interval. In the steam injection experiment, a steam zone was created above the water table. As the contaminated area was heated, the vaporized fluid was transported to the heat front where it will condense and accumulate. The emplaced pollutant will be recovered as separate phase liquid from the top of the water table in the phase separator. When the pollutant is no longer condensed in the phase separator, the entire sand packing will be heated to steam temperature until no more pollutant will be recovered.

Plate 2: Steam Boiler, SandBox, and Condenser Set-Up

3 Results and Discussions

3.1 Results of the Laboratory Analysis on Water Samples from Selected Wells

The pH, TDS, EC, and TSS before and after treatment are presented in Table 1-4. The pH for groundwater samples from Saw-mill and Ogbegun area slightly increased between 1-4.2%. The pH for Ayedade decreased from 7.98 to 7.44. The variation may be due to Chemical composition and impurities in the groundwater samples. The pH before and after treatment are below the World Health Organization [18] benchmark of 6.5-8.

The TDS after treatment has significantly reduced by 74.3 and 63.8% for water samples in Ayeedade and Sawmill, respectively. TDS is made up of inorganic salts, as well as a small amount of organic matters. These inorganic salts present in groundwater will vapourize during steam injection (boiling). According to World Health Organization, a TDS level less than 300 mg/liter is considered excellent, between 300 and 600 mg/liter is good, 600-900 is fair, 900 - 1200 is poor and a TDS level more than 1200 mg/liter is unacceptable.

The EC after water treatment decreased from 42 to 74% for all samples considered. Electrical Conductivity (EC) measures the ionic process of a solution that enables it to transmit current. This is directly related to concentrations of ions in water. Steam injection de-ionizes water and reduces its conductivity value. The EC of the treated water is below the WHO benchmark of 1400 µS/cm.

Table 1: pH Before and After Treatment

Location	pH Before Treatment	pH after Treatment	WHO Benchmark
Sawmill	7.53	7.85	6.5-8
Ogbegun	7.50	7.60	6.5-8
Ayedaade	7.98	7.44	6.5-8

Table 2: TDS Before and After Treatment

Location	TDS Before Treatment (mg/L)	TDS after Treatment (mg/L)	WHO Benchmark (mg/L)
Sawmill	389	141	1000
Ogbegun	88	87	1000
Ayedaade	331	85	1000

Table 3: EC Before and After Treatment

Location	E_C Before Treatment (µS/cm)	E_C after Treatment (µS/cm)	WHO Benchmark (µS/cm)
Sawmill	783	282	1400
Ogbegun	175	100	1400
Ayedaade	665	171	1400

Table 4: TSS Before and After Treatment

Location	TSS Before Treatment	TSS after Treatment	WHO Benchmark
Sawmill	460	460	-
Ogbegun	320	320	-
Ayedaade	230	530	-

The TSS is the dry weight of suspended particles that are not dissolved in the water sample but can be trapped by the filter. They are suspended solid that exceed 2 microns in size below this value they are referred to as TDS. Except if contaminated by human activity, the natural filtration of groundwater through sand will be trapped particles that could have resulted in TSS. Thus, there is virtually less than 1% of TSS which was found in the Ayedaade groundwater sample. This may be due to its location and the impurities present. The sulfate content before and after treatment is presented in Table 5. The sulfate content of treated groundwater increased from 23 to 51%. This may be due to sulfate from polyatomic anions widely used in Pharmaceutical and cleaning products. It may also occur naturally from rocks. Sulfate levels above 250 mg/L may make the water taste bitter. High sulfate levels may also corrode plumbing, particularly copper piping. The major sulfates found in water are sodium, potassium, and magnesium sulfate.

Table 5: Sulphate Before and After Treatment

Location	Sulphate Before Treatment (mg/L)	Sulphate after Treatment (mg/L)	WHO Benchmark (mg/L)
Sawmill	35.65	43.87	250
Ogbegun	22.86	32.86	250
Ayedaade	39.08	59.08	250

The Phosphorus values before and after treatment are shown in Table 6. Phosphate value increased by 92% in the sample from Sawmill and decreased in Ogbegun and Ayedaade between 44-48%. Too much phosphorus can cause increased growth of algae and large aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. High levels of phosphorus can also lead to algae blooms that produce algal toxins which can be harmful to human and animal health.

The DO and Turbidity before and after treatment are presented in Tables 7 and 8. Dissolved Oxygen in the treated sample was reduced from 12-25%. This implies that dissolved oxygen was taken up by some cations and anions in water to form oxide. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress**.** The lower the concentration, the greater the stress.

Table 6: Phosphorous Before and After Treatment

Location	Phosphate Before Treatment (mg/L)	Phosphate after Treatment (mg/L)	WHO Benchmark (mg/L)
Sawmill	1.3	2.5	0.1
Ogbegun	2.1	1.1	0.1
Ayedaade	4.3	2.4	0.1

Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. A high dissolved DO level in a community water supply is good because it makes drinking water taste better. The turbidity after water treatment is reduced between 19-85% except in Ayedaade where the value remains the same. De-ionization process in steam injection generates more particles in the water column, which affects light scattering and Turbidity. Lower turbidity significantly increases the quality of groundwater water. High turbidity can significantly reduce the aesthetic quality of lakes and streams, harming recreation and tourism. It can increase the cost of water treatment for drinking and food processing. Turbidity affects the growth rate of algae (micro-aquatic plants) and other aquatic plants in streams and lakes because increased turbidity causes a decrease in the amount of light for photosynthesis.

Table 7: Dissolve Oxygen Before and After Treatment

Location	DO Before Treatment (mg/L)	DO after Treatment (mg/L)	WHO (mg/L)
Sawmill	12	9	5.0
Ogbegun	10	8	5.0
Ayedaade	13	11.5	5.0

Table 8: Turbidity Before and After Treatment

Location	Turbidity Before Treatment (NTU)	Turbidity after Treatment (NTU)	WHO (NTU)
Sawmill	0.094	0.014	5
Ogbegun	0.106	0.086	5
Ayedaade	0.093	0.093	5

The nitrate, potassium, and iron content before and after treatment are shown in Table 9 -11. Nitrate reduction in the treated water varied from 25-99%. The highest value was obtained in Ayedaade. The results show that the treatment enhanced the quality of the water more than before the water treatment. Nitrates are essential to plant nutrients, but in excess amounts, they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream.

The potassium and Iron quantity increased in the treated water from 6-90%. Potassium being the seventh most abundant element in earth crust is present in the sand used in the steam injection. This was added to the treated water and adds up to the existing value. Currently, there is no evidence that potassium levels in municipally treated drinking- water, even water treated with potassium permanganate, are likely to pose any risk for the health of consumers. It is not considered necessary to establish a health-based guideline value for potassium in drinking water. Potassium is an essential element in humans and is seldom if ever, found in drinking- water at levels that could be a concern for healthy humans. The recommended daily requirement is greater than 3000 mg. Weathering process releases iron into the water. The main naturally occurring iron minerals are magnetite, hematite, goethite, and siderite. Iron is a dietary requirement and plays an important role in natural processes.

Table 9: Nitrate Before and After Treatment

Location	Nitrate Before Treatment (mg/day)	Nitrate after Treatment (mg/day)	WHO Benchmark (mg/day)
Sawmill	1	0.85	2.6
Ogbegun	0.34	0.03	2.6
Ayedaade	2.57	0.03	2.6

Table 10: Potassium Before and After Treatment

Location	Potassium Before Treatment	Potassium after Treatment	WHO Benchmark
Sawmill	5.2	28.54	-
Ogbegun	1	16.43	-
Ayedaade	10	18.56	-

Table 11: Iron Before and After Treatment

Location	Iron Before Treatment	Iron after Treatment	WHO Benchmark
Sawmill	5.2	25.54	100
Ogbegun	1	13.53	100
Ayedaade	10	17.06	100

The Zinc before and after treatment is shown in Table 12. The value remain the same for Ogbegun and Ayedade but increased by 50%in the treated sample from Sawmill. Metals in surface runoff infiltration to groundwater aquifer and land contamination are the sources of Zinc in groundwater. The EPA has stated that drinking water should not contain more than 5 mg of zinc per liter of water (5 mg/L) because of taste. Zinc may effectively reduce inflammation, boost immune health, reduce your risk of age-related diseases, speed wound healing and improve acne symptoms.

Table 12: Zinc Before and After Treatment

Location	Zinc Before Treatment (mg/L or ppm)	Zinc after Treatment (mg/L or ppm)	WHO Benchmark (mg/L or ppm)
Sawmill	0.02	0.01	5
Ogbegun	0.03	0.03	5
Ayedaade	0.02	0.02	5

The alkalinity and hardness values before and after treatment are shown in Tables 13 and 14. The Alkalinity increased after treatment from 48-56% for samples from Sawmills and Ogbegun. Groundwater samples in Ayedaade showed a 50% decrease in Alkalinity after treatment. Alkalinity is a measure of how much acid can be added to a liquid without causing a large change in ph. Higher Alkalinity levels in surface waters after steam injection will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life. The hardness of all the water samples reduces between 12-53%. Generally, the harder the water, the lower the toxicity of other metals to aquatic life. In hard water, some of the metal ions form insoluble precipitates and drop out of the solution, and are not available to be taken in by the organism. Large amounts of hardness are undesirable mostly for economic or aesthetic reasons.

Table 13: Alkalinity Values Before and after Treatment

Location	Alkalinity Before Treatment	Alkalinity after Treatment	WHO Benchmark (mg/l)
Sawmill	58	184	200
Ogbegun	30	84	200
Ayedaade	164	82	200

Table 14: Hardness Values Before and after Treatment

Location	Hardness Before Treatment (ppm)	Hardness after Treatment (ppm)	WHO Benchmark (ppm)
Sawmill	116	54	300
Ogbegun	56	34	100
Ayedaade	116	102	100

The Phosphate, BOD and COD variations before and after treatment are presented in Table 15-17. Phosphate increased in all the samples between 29-50%. Phosphates are chemical components that contains phosphorus. While phosphate is essential for plant and animal life, too much of it can cause a form of water pollution known as eutrophication. Biological Oxygen Demand (BOD) reduced by 24% after treatment for Sawmill groundwater sample. The BOD values for Ogbegun and Ayedade remain the same. BOD directly affects the amount of Dissolved Oxygen (DO) in rivers and streams. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die.

Table 15: Phosphate Before and after Treatment

Location	Phosphate Before Treatment mg/L	Phosphate after Treatment mg/L	WHO Benchmark
Sawmill	0.7	0.9	-
Ogbegun	0	0.45	-
Ayedaade	0.6	0.9	-

Table 16: BOD Before and after Treatment

Location	BOD Before Treatment	BOD after Treatment	WHO Benchmark (mg of oxygen per liter)
Sawmill	4.5	3.4	40
Ogbegun	1.5	1.5	40
Ayedaade	2.6	2.6	40

Table 17: COD Before and after Treatment

Location	COD Before Treatment	COD after Treatment	WHO Benchmark (mg/L)
Sawmill	8.5	2.8	120
Ogbegun	3.2	3.0	120
Ayedaade	6.0	3.0	120

The COD value was reduced for all groundwater samples between 6-67%. Higher COD levels connote a greater amount of oxidizable organic material in the sample, which will reduce Dissolved Oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher aquatic life forms.

4 Conclusions

In this research work, the experimental investigation of water purification using steam injection was carried out. The experiment compares the results before water treatment to after water treatment. It shows that there were many improvements to the water samples after the water treatment. The pH, Phosphate, Alkalinity, Zinc, Iron, Potassium, and Sulphate increased in the treated groundwater samples after steam injection. Similarly, COD, BOD, DO, Hardness, Nitrate, Turbidity, Phosphorous, EC, and TDS decreased in the treated samples. This implies that the steam injection technique improves the quality of treated groundwater samples.

Recommendation from the Study

Steam injection technique can be used to improve the physical component of the water samples and a few chemical characteristics.

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Ethical issue

Authors are aware of and comply with, best practices in publication ethics specifically about authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that no conflict of interest would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses, and manuscript writing.

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