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A kinetics study of the treatment of groundwater using commercial activated carbon

[1]Onwuzuruike, Cynthia., [2]Egharevba, Felix., [3]Okojie, Victor., [4]Akpoveta, Vincent., [5]Jatto, Osazuwa., [6]Idagan, Meg. and [7]Obielumani, Joy.

[1,2,3,5,6,7]Department of Chemistry, Ambrose Alli University, Ekpoma, Edo State. Nigeria.
[4]Department of Chemical Sciences, Ondo State University of Science and Technology, Okitipupa, p.m.b 001, Ondo State, Nigeria

Email: akpovin2@gmail.com

ABSTRACT

The kinetics of groundwater purification obtained from Irrua, Esan Central LGA, Edo State, Nigeria is examined by running the sample at different flow rates through a sediment filter with a commercial granular activated carbon (GAC) adsorbent/filter encapsulated in a cartridge at room temperature. The physicochemical parameters of untreated and treated water samples were determined following standard methods for water and wastewater analysis. Their kinetics were examined using the Lagergren Pseudo First Order as well as Pseudo Second Order models respectively, and their volumetric flow rates rationalized with water quality parameters (DO, COD and BOD). BOD_5 results shows that its treatments adequately fits the Pseudo Second Order model with correlation coefficient of 0.967 as against the Pseudo First Order model with a correlation coefficient of 0.578, while treatment of COD fits the Pseudo First Order model having obtain a correlation coefficient of 0.989 as against 0.928 for Pseudo Second Order model. As flow rate decreases, COD and BOD_5 decreases, while DO increases as a result of adsorption. The optimum flow rate determined for groundwater is $111cm^3$/min which is in consonance with the contaminant load of the groundwater.

Keywords: kinetics, flow rate, granulated activated carbon, sediment filter, groundwater, treatment.

1.0 INTRODUCTION

The importance of water to the existence of living organisms is increasingly been threatened by growing human population, as the demand for more water of high quality for domestic purposes and economic activities increases (UNEPGEMS, 2000). Between 1.2 to 2.4 billion persons are denied access to portable and safe water, as such suffers from lack of safe water supply and secured sanitation respectively (Galadima et. al. 2011). In many developing countries, Nigeria in particular, more than half of the population is affected. Fresh groundwater represents the main source of safe water for household, agricultural and even industrial applications. Water of good quality finds importance in drinking, cooking, recreation, farming and fishing activities bringing about its inevitability in society evolution and civilization (Orubu, 2006 and Aboyeji, 2013).

Water pollution results from the introduction of unwanted materials into water bodies with potentials to threaten human and other natural systems. Various treatment methods available for removal of these materials includes, adsorption, ion exchange, reverse osmosis, chemical oxidation, precipitation, distillation, gas-stripping, solvent extraction, complexation and bio-remediation. Of the treatment techniques available, adsorption has shown to be an effective and efficient method for separating hazardous contaminants from water body (Mukherjee *et* *al.*, 2006). Adsorption involves the accumulation of substances on the surface of a solid or liquid. The surface area of the adsorbent plays an important role in adsorption. The larger the surface area, the greater the extent of adsorption. Activated carbon has been extensively used as adsorbents, catalysts and catalyst supports in a variety of industrial and environmental applications. Surface characteristics tend to largely control and determine adsorption capability and catalytic activity (Boppart *et al.*, 1996; Bansal *et al.*, 1998). The increasing use of activated carbon by individual home owners is due to the environmental friendly nature of activated carbon. It can easily be disposed of without causing serious environmental problems. Carbonaceous adsorbent material is readily available, nontoxic or hazardous and renewable because of the ease of recovering the substances absorbed through other means of separation (Kamrin *et al.*, 1990). However, the activated carbon materials are interesting adsorbents, because of their high capability of adsorbing various organic and inorganic compounds. Commercial activated carbons obtained from agro materials like coconut shell, wood or coal are usually manufactured to produce precise and desirable surface properties (Hamadi *et al.*, 2004). Particles of the activated carbon has a porous structure which consists of a network of interconnected macropores, mesopores, and micropores that provide a good capacity for the adsorption of adsorbate molecules due to its high surface area (Derylo *et al*., 2010).

A tripartite consideration of flow rate of water sample, adsorption capacity of carbon/ polypropylene filter and quality parameters (DO, COD, BOD_5) would elicit more pragmatic and assured approach to water quality management and processing. This research is therefore aimed at studying the effectiveness and efficacy of utilizing commercial granular activated carbon cartridge installed with sediment filter for the treatment of groundwater, as well as establishing appropriate kinetics models from a rationalization of optimum volumetric flow rate with water quality parameters.

2. MATERIALS AND METHODS:

2.1 Sampling Technique and Study Area

Groundwater sample was obtained using the grab sampling technique from boreholes in Irrua, Esan Central LGA, Edo State, Nigeria. Geographically, Edo State lies between longitude 5 degrees East and 6.45 degrees East, and latitudes 6.1 degrees North and 7.30 degrees north.

Figure 1: Map of sampling area- Irrua

2.2 Materials

The pre-filtration cartridge (PFC) also known as sediment filter purchased commercially has a length of 50 cm with a core size (inner diameter) of 2.5 cm, an outer diameter of 6.3 cm and a micron rating of 0.5 microns norminal. The granular activated carbon filter cartridge (GAC) has a length of 50 cm, an inner diameter of 2.8 cm, a core size of 2.75 cm and a micron rating of 5 micron norminal. The housing case for the GAC filter cartridge and sediment cartridge has length of 50.8 cm.

2.3 Experimental

The improvised treatment facility (comprising PFC and GAC) were connected in series using PVC pipes to a 30-liter plastic bucket with a cover which was taken as the storage chamber for the raw water sample before treatment took place. The connection was done in such a way that the case that housed the sediment filter was closest to the water storage chamber followed by the GAC filter cartridge. The treatment facility was mounted on the wall with the aid of mounting bracket screws. The groundwater sample was passed through the treatment chamber and the following parameters: COD, BOD_5, DO, pH, EC, Turbidity, TSS, TDS, Cl, P, Ca, Mg, Fe, Pb, THC were determined by standard methods of water and wastewater analysis (Ademoroti, 1996). The flow rate was controlled and measured mechanically by how much water was discharged per minute.

2.4 Theory

Various kinetics theories and equations have been proposed for adsorption amongst which are the Lagergren Pseudo-first order, Pseudo-second order kinetics and Freundlich adsoption isotherm (Vafajoo *et al*, 2014). They were selected to test their applicability in the present research.

According to Lagergren First order kinetics,

$$\ln (q_e - q_t) = \ln q_e - k_1 t \quad \ldots (1)$$

In which, the q_e (mg/g) is the amount of adsorbed COD or BOD_5 at equilibrium, q_t (mg/g i.e mg of solute per g of adsorbent) the amount of adsorbed COD or BOD_5 at time t and k_1 the adsorption rate constant (min^{-1}). On the other hand, the Pseudo-second order equation provides that:

$$t/q_t = (k_2 q_e^2)^{-1} + t/q_e \quad \ldots (2)$$

In which, k_2 (g/mg.min) is the pseudo-second order adsorption rate constant while the q_e (mg/g) the amount of adsorbed COD at equilibrium. In the Freundlich adsorption isotherm

$$\frac{x}{m} = KCe^{1/n} \quad \ldots (3)$$

$\frac{x}{m}$, the mass of the solute adsorbed per mass of adsorbent, Ce- concentration of the solution at equilibrum.

2.5 Relationship Between Adsorption capacity with Lagergren Equation and Flow Rate

From the foregoing, a tripartite consideration was made for adsorption capacity, Lagergren Pseudo First Order and Pseudo Second Order equations in relation with flow rate. The linearized form of Freundlich equation at equilibrium is

Adsorption capacity, $\ln \frac{x}{m} = \ln K + \frac{1}{n} \ln Ce \quad \ldots (i)$

Lagergran first order, $\frac{dqt}{dt} = K_p(q_e - q_t)$

i.e., $\ln (q_e - q_t) = \ln q_e - q_t \quad \ldots (ii)$ q_e = COD or BOD at equilibrium (untreated water) q_t = COD or BOD at time, t (after treatment)

Comparing (i) and (ii)

$$\ln K + \frac{1}{n} \ln Ce = \ln q_e - q_t$$

∴ $\ln\frac{x}{m} = \ln(q_e - q_t)$…………….(iii)

$\frac{dv}{dt} \alpha \frac{x}{m}$;

∴ $\frac{dV}{dt} = K''\frac{x}{m}$ where K″ is composed of proportionality with adsorption capacity at equilibrium from a consideration of Poiseulle's and Freundlich equations.

However, flow rate can be put into functional $\frac{dv}{dt}$

Freundlich and flow constants. Therefore, flow rate is functionally proportional to adsorption capacity at equilibrium.

From Poiseulle's equation $\frac{dv}{dt}$ = K′ΔP……………………………(iv) and

Freundlich $\frac{x}{m}$ = KCe$^{1/n}$ or KP$^{1/n}$ as the case may be…………………………………(v)

Cross comparing equation (iv) and (v)

$\frac{dv}{dt}$ = KP$^{1/n}$ ……………………………………………… … …….(vi) and $\frac{x}{m}$ = K′ΔP…………………………………………… ……………(vii)

Given that KP$^{1/n}$ is essentially of the form K′ΔP (viii)

$\ln(q_e - q_t) = \frac{1}{K''}\frac{dV}{dt}$ …………………………….(ix)

Finally, from equation (iii)

$\frac{dV}{dt} = K''\ln(q_e - q_t)$……………………….

3.0 RESULTS AND DISCUSSION

In Table 1-2 are shown the results of the physicochemical analysis of untreated and treated sample of groundwater at room temperature.

Table 1. The physicochemical data of untreated and treated groundwater from Irrua Edo state, Nigeria using sediment filter cartridge and GAC filter cartridge of (0.5 and 5 microns) respectively.

S/NO	*Parameters*	*Units*	*Values for untreated groundwater*	*Values for treated groundwater after 5minutes*	*WHO Standard for drinking water*	*FME Standard for drinking water*	*NIS for drinking water*
1	pH		6.00 ± 0.14	6.80 ± 0.11	6.50 – 8.50	6.50 – 8.50	6.50-8.50
2	Electrical Conductivity	µS/cm	185.80 ±0.60	116.90 ± 1.29	250.00	NA	1000.00
3	Total Suspended Solid(TSS)	mg/L	1.10 ±0.07	BDL	NA	> 1000	NA
4	Total Dissolved Solid(TDS)	mg/L	91.50± 1.49	58.50 ± 1.24	NA	500.00	500.00
5	Turbidity	NTU	BDL	BDL	5.00	1.00	5.00
6	COD	mg/L	56.50 ± 1.05	3.10 ± 0.10	NA	NA	NA
7	BOD_5	mg/L	3.90 ± 0.49	0.50 ± 0.07	NA	0 at 2025^{o}C	NA
8	DO	mg/L	5.60 ± 0.88	6.40 ± 0.23	NA	7.50	NA
9	Chloride	mg/L	27.60 ± 0.12	27.10 ± 1.00	250.00	250.00	250.00
10	Phosphorus	mg/L	0.15 ± 0.01	0.09 ± 0.00	NA	>5.00	NA
11	Lead	mg/L	BDL	BDL	0.01	0.05	0.01
12	Calcium	mg/L	4.53 ± 0.01	4.50 ± 0.03	NA	NA	NA
13	Magnesium	mg/L	2.24 ± 0.04	2.24 ± 0.01	NA	NA	0.20
14	Iron	mg/L	0.18 ± 0.02	0.13 ± 0.00	0.30	1.00	0.30
15	THC	mg/L	2.50 ± 0.01	BDL	0.10	NA	NA

KEY

BDL: Below Detectable Limit, NA: Not Available

FME: Federal Ministry of Environment

NIS: Nigerian Industrial Standard

THC: Total Hydrocarbon

Table 2. Result of the treatment of ground water using sediment filter 0.5 microns only for some parameters.

S/NO	*Parameters*	*Units*	*Untreated Ground Water*	*Treated Ground water*
1	pH		6.0 ± 0.14	6.3±0.25
2	TSS	mg/L	1.1 ± 0.07	BDL
3	TDS	mg/L	91.5 ± 1.49	65.0±0.43
4	TS	mg/L	92.6 ± 0.00	65.0±0.00
5	BOD_5	mg/L	3.9 ± 0.49	3.5 ± 0.12

6	COD	mg/L	56.5 ± 1.05	50.2±1.23
7	DO	mg/L	5.6 ± 0.88	5.9 ± 0.39

TS: Total solids

Tables 3 to 7 show the results of the kinetics plots of Pseudo first or second orders as the studies of the treatment of groundwater using case may be of the Lagergren model for the the Lagergren Pseudo first and second order treatments using COD and BOD_5 only.
equations. Figures 2 to 5 presents kinetics

Table 3. Data on the treatment of groundwater using sediment filter cartridge (0.5 microns) and GAC filter cartridge (5 microns) at different times.

Parameters	Unit	Untreated groundwater	Pretreatment	Successive treatment time using GAC						
				0.2	5	10	15	20	25	30
DO	mg/L	5.60± 0.88	5.90± 0.25	0.55	0.88	0.43	0.35	0.16	0.45	0.67
BOD_5	mg/L	3.90± 0.49	3.50± 0.53	1.20± 0.51	0.50± 0.07	0.47± 0.12	0.42± 0.09	0.38± 0.25	0.33± 0.08	0.29± 0.05
COD	mg/L	56.5 0± 1.05	50.20± 1.50	3.60± 1.15	3.10± 0.1	2.80± 1.07	2.20± 0.05	1.80± 0.87	1.50± 0.58	1.20± 0.75
Volume	cm^3	-	1000	1000	950	890	820	750	695	608
Flow rate	cm^3/min	-	0.00	5,000 min	190 min	89 min	54.66 min	37.50 min	27.80 min	20.26 min
				6.20±	6.40±	6.70±	7.00±	7.30±	7.60±	8.00±

Table 4. Data of kinetic study for the treatment of ground water using COD for a Pseudo First Order Lagergren equation.

	0.2 min	5 min	10 min	15 min	20 min	25 min	30 min	Time
3.9684		3.9778	3.9834	3.9942	4.0018	4.0073	4.0127	$\ln(q_e - q_t)$
$\ln q_e$	4.0342	4.0342	4.0342	4.0342	4.0342	4.0342	4.0342	

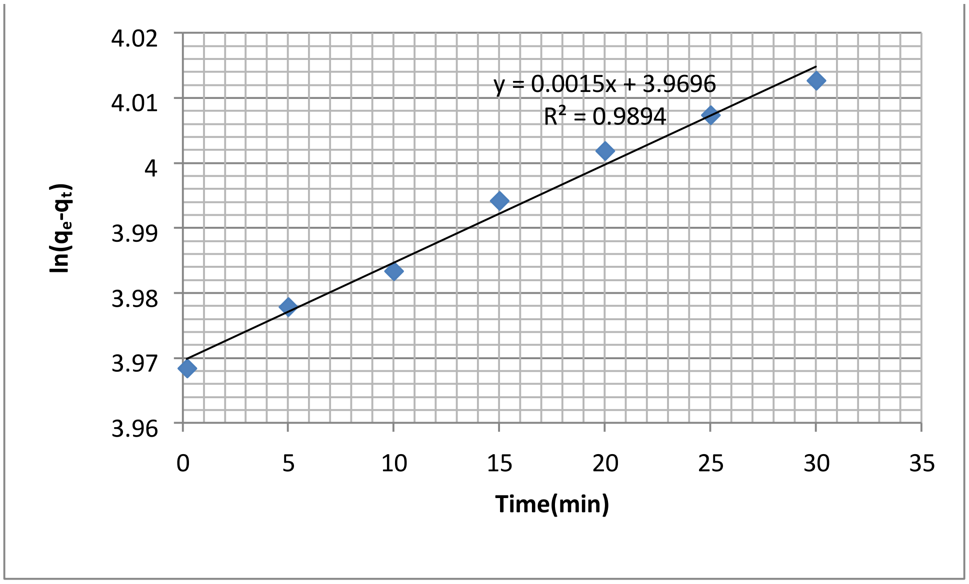

Figure 2. A graph of ln (q_e – q_t) against time t for COD of groundwater (First order)

Table 5. Data of kinetic study for the treatment of groundwater using COD for a Pseudo Second Order Lagergren equation.

Time	0.2 min	5 min	10 min	15 min	20 min	25 min	30 min
t/q_t	0.0555	1.6129	3.5714	6.8181	11.1111	16.666	25

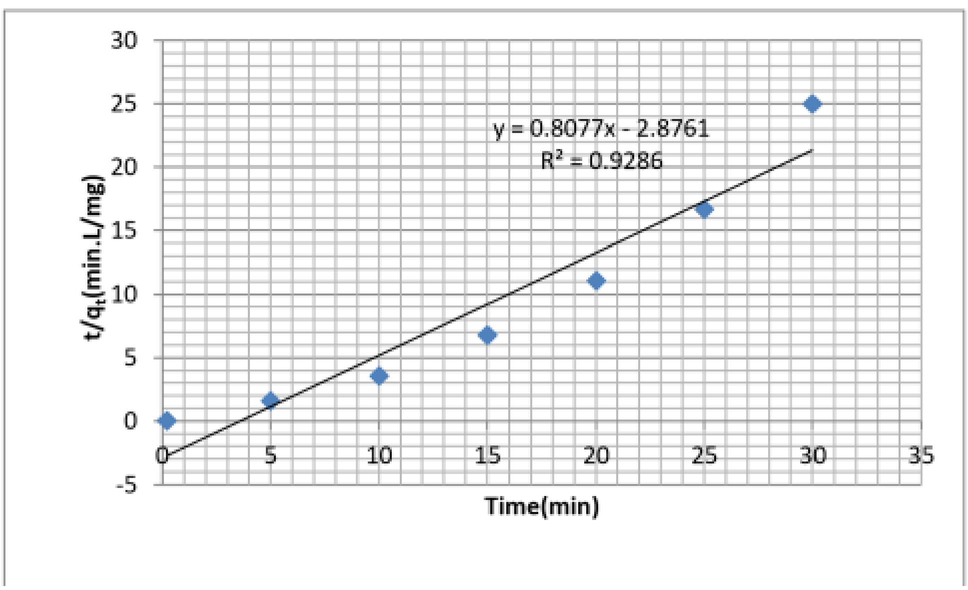

Figure 3. A graph of t/q_t against Time for COD of ground water (Lagergren pseudo-second order)

Table 6. Data of kinetic study for the treatment of groundwater using BOD_5 for a Pseudo First Order Lagergren equation.

Time 0.2 min 5 min 10 min 15 min 20 min 25 min 30 min $\ln(q_e - q_t)$ 0.9932							
$\ln q_e$	1.3609	1.3609 1.2237	1.3609 1.2305	1.3609 1.2470	1.3609 1.2584	1.3609 1.2705	1.3609 1.2837

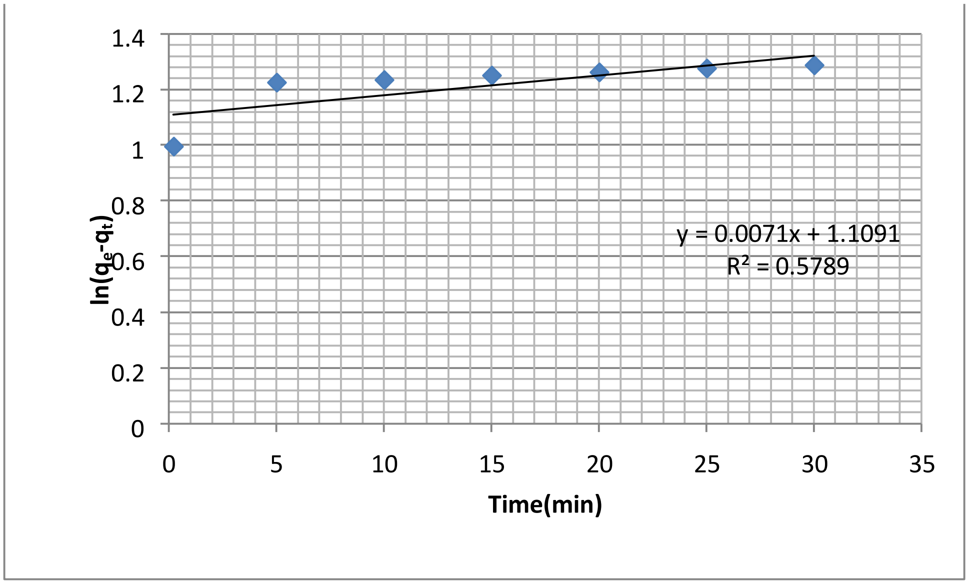

Figure 4. A graph of $\ln(q_e - q_t)$ against time for BOD_5 of ground water (Lagergren pseudofirst order).

Table 7. Data of kinetic study for the treatment of ground water using BOD_5 for a Pseudo Second Order Lagergren equation.

Time	0.2 min	5 min	10 min	15 min	20 min	25 min	30 min
t/q_t	0.1666	10	21.76	35.71	52.63	75.75	103.4

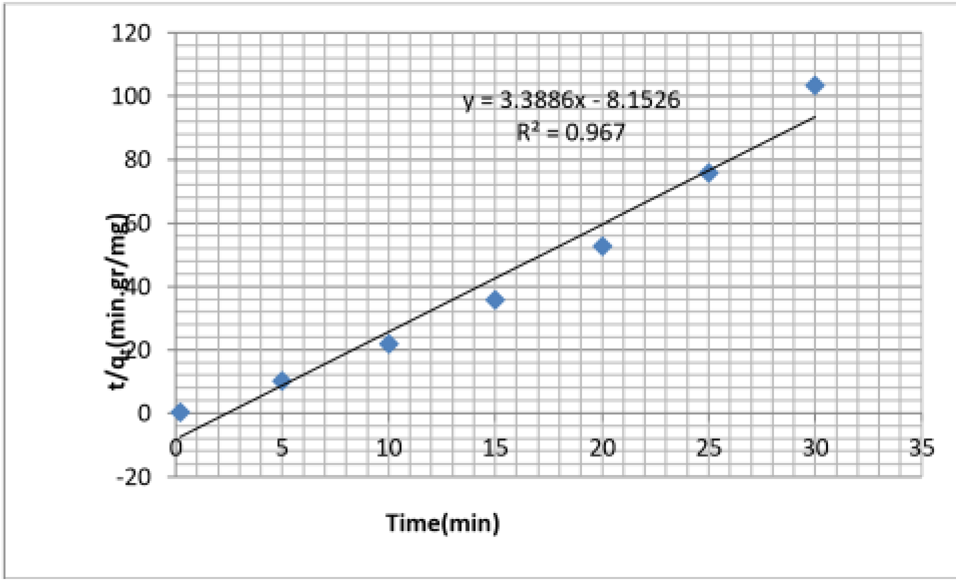

Figure 5. A graph of t/q_t against time for BOD_5 of groundwater (**Lagergren pseudosecond order**).

In Table 8 is shown the variation of flow rate with water quality parameters COD, BOD_5 and DO, while Figure 6 report the plots of DO, COD and BOD_5 values with respect to flow rate. It can be seen that the quality parameter assumed an optimum value at a certain flow rate.

Table 8. Variation of COD, BOD_5 and DO with flow rate for groundwater

Flow rate (cm^3/min)	*COD (mg/L)*	*BOD_5 (mg/L)*	*DO (mg/L)*
5000	3.60 ± 1.15	1.20 ± 0.51	6.20 ±0.55
190	3.10 ± 0.1	0.50±0.07	6.40 ±0.88
89	2.80 ± 1.07	0.47 ± 0.12	6.70 ±0.43
54.66	2.20 ± 0.05	0.42 ± 0.09	7.00 ±0.35
37.5	1.80 ± 0.87	0.38 ± 0.25	7.30 ±0.16
27.8	1.50 ± 0.58	0.33 ± 0.08	7.60 ±0.45
20.26	1.20 ± 0.75	0.29 ± 0.05	8.00 ±0.67

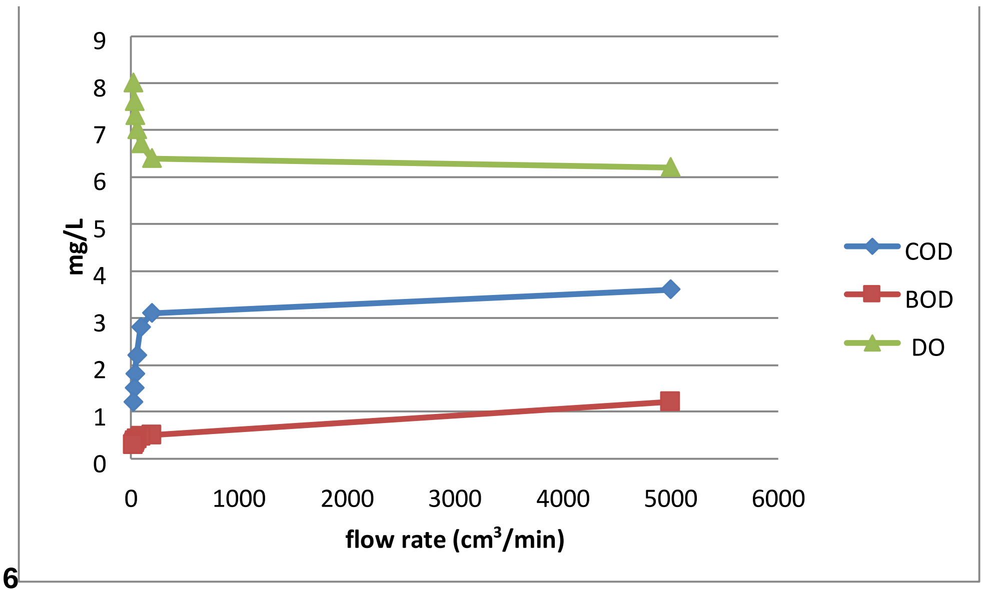

Figure 6. Plots of COD, BOD_5, and DO against flow rate for groundwater

Table 9. Pseudo first and second order rate constants with their correlation coefficients for the treatment of ground water and optimum flow rate obtained from the plot of COD, BOD_5 and DO.

Quality parameter	*Pseudo First Order k_1 (min^{-1})*	*R^2*	*Pseudo Second Order k_2 (L/mg.min)*	*R^2*
COD	$1x10^{-3}$	0.989	0.807	0.928
BOD_5	$7x10^{-3}$	0.578	3.388	0.967

OPTIMUM FLOW RATE

111 cm^3/min

The results of the physicochemical analysis of untreated and treated groundwater as well as pretreated water using 0.5 microns nominal sediment filter are presented in Tables 1 and 2 respectively. The pH of the sample before treatment is found to be 6.00, but increases after treatment using GAC filter and sediment filter to 6.80. The appreciation in pH will be due to the reduction in some acidic components of the raw water sample. This is at variance with the findings of Suneetha et. al., (2014), where decreased pH values were reported in groundwater from India treated with activated carbon. This observed decrease in acidity however fell within the WHOs maximum allowable limit (UNEPGEMS, 2000). The electrical conductivity data for the groundwater before and after treatment were found to be 185.8 µS/cm and 116.9 µS/cm respectively as seen in Table 1. The data shows a decrease in electrical conductivity of the water sample which could be as a result of adsorption of organic matters and minerals by the sediment filter and granular activated carbon filter cartridge. This agrees with the findings of Suneetha et. al., (2014), where decreased EC values were reported in groundwater from India treated with activated carbon. The electrical conductivity data obtained is however below the WHO drinking water standard (UNEPGEMS, 2000).

The total suspended solids (TSS) and total dissolved solid (TDS) of ground water were found as 1.1 mg/L and 91.5 mg/L respectively before treatment, with an after treatment reduction of TDS value to 58.50 mg/L and TSS value below detection limit as evident in Table 1. The report of Suneetha et. al., (2014) supports this result. These values however fell within permissible standards for drinking water. Turbidity values before and after treatments were not detected, indicating insignificant turbidity levels. The values for chloride and phosphorus were 27.60 mg/L and 0.15 mg/L respectively for untreated ground water sample, while values of 27.10 mg/L and 0.09 mg/L were respectively found for the treated groundwater sample. This is similar to the report of Suneetha et. al., (2014), where such reduction on treatment was observed. It is observed that the values for chloride and phosphorus were below recommended standards.

Calcium and magnesium values were found as 4.53 mg/L and 2.24 mg/L respectively before treatment, but found to be 4.50 mg/L and 2.24 mg/L respectively after treatment as seen in Table 1. Calcium and magnesium are the main culprit for water hardness. The magnesium content of both treated and untreated groundwater is quite high when compared to recommended permissible limits (UNEPGEMS, 2000). Similar observation was made by Kamrin *et al* (1990) in home water treatment using activated carbon. In their observation, fluorides, chlorides, nitrates, hardness (calcium and magnesium) were not removed by activated carbon to any significant degree but by reverse osmosis. Iron values before and after treatment were found to be 0.18 mg/L and 0.13 mg/L respectively. The value of Iron after treatment is below the value recommended by regulatory bodies (UNEPGEMS, 2000). Lead is seen to be below detectable limit, while total hydrocarbon (THC) has a value of 2.50 mg/L; however THC was not detected after treatment which is indicative of the effectiveness of the treatment. The values obtained for dissolved oxygen (DO) before and after a 5 minutes treatment time were found to be 5.6 mg/L and 6.4 mg/L respectively as seen in Table 1, indicating an enhancement in DO. The increase in DO after treatment disagrees with the findings of Suneetha et. al., (2014), where a decrease was reported on treating India groundwater with activated carbon.

In Table 2 are shown some physicochemical parameters considered for the pretreatment (sediment) filter. In most urban and municipal treatment facilities, the sediment filter is mounted to remove suspended solids and reduce contaminant load on GAC. The extent to which the sediment filter was effective is shown.

Dissolved oxygen value increases steadily as treatment time varies, from 5.6 mg/L in the untreated ground water to 8 mg/L after 30minutes as seen in Table 3. It is seen from the result, that there is significant reduction in contaminants level bringing about an increase in dissolved oxygen content. Whereas the value of BOD_5 decreased from 3.9 mg/L to 3.5 mg/L after pretreatment using sediment filter, and further reduced significantly to 0.29 mg/L after 30 minutes of treatment using GAC filter jointly installed with sediment filter. The value obtained for COD in the untreated water is found to be 56.5mg/L, but decreased to 50.2 mg/L after treatment with sediment filter as seen in Table 2. Successive treatments at timely intervals using GAC filter jointly installed with sediment filter gave COD value of 1.2 mg/L after 30 minutes of treatment as seen in Table 3. A steady decrease in COD is observed as time of treatment increases.

The results of the treatment of groundwater was subjected to kinetics studies using Lagergren Pseudo-first and Pseudo-second order kinetics models, and the variation of water quality parameters with the flow rate of water discharged through the improvised treatment facility observed; as presented in Tables 4 to 8. The integrated form of the Lagergren Pseudo-first order equation [$\ln (q_e q_t) = \ln q_e - k_1 t$] provides that a plot of $\ln (q_e q_t)$ against time (t) should apparently give a linear relationship with a slope of k_1 corresponding to the Pseudo-first order adsorption rate constant and an intercept of $\ln q_e$. On the other hand, the linear form of the Lagergren Pseudo-second order equation [$t/q_t = (k_2 q_e^2)^{-1} + t/q_e$] requires that a plot of t/q_t against time should give a linearized relationship with a slope (k_2) of $1/q_e$ corresponding to the Pseudo-second order adsorption rate constant and an intercept of $\frac{1}{k_2 q_e^2}$.

The correlation coefficients R^2 obtained from the corresponding plots as seen in Figures 2 to 5 were applied to determine the appropriate kinetics models that suited the experimental data. The Pseudo-first order plot for COD gave values of K_1 (Pseudo-first order adsorption rate constant) and correlation coefficient R^2 as 0.001 min^{-1} and 0.989 respectively; while for BOD_5, K_1 and R^2 were 0.007 min^{-1} and 0.578 respectively, as obtained from Figures 2, 4 and tabulated in Table 9. The Pseudo-second order plot for COD gave an adsorption rate constant K_2 of 0.807 L/mg.min and a correlation coefficient R^2 of 0.928, while a pseudo-second order adsorption rate constant K_2 and correlation coefficient R^2 of 3.388 L/mg.min and 0.967 were respectively obtained for BOD_5 as seen in Figures 3, 5 and tabulated in Table 9. The optimum flow rate is deduced to be 111 cm^3/min from Figure 6. The treatment for COD in groundwater best fits a Lagergren Pseudo-first order rate model since a better correlation coefficient of 0.989 was obtained from a Pseudo-first order plot as against 0.928 for Pseudo-second order plot. Similar result was reported by Vafajoo *et al.,* (2015) in an investigation of a petrochemical wastewater treatment utilizing granular activated carbon. In that report, the most desirable kinetics equation was Pseudo-firstorder resulting in more than 90% correlation coefficient of COD linear plot (Vafajoo *et al.,* 2015).

However, the R^2 value obtained from the Pseudo-second order plot clearly indicates that the BOD_5 treatment followed a Lagergren Pseudo- second order kinetics model. This finding is in agreement with Ho and McKay (1998), where the rate limiting of the treatment may be more of chemisorptions than physical adsorption between the adsorbent and the adsorbate. It thus shows from this result that the concentrations of the adsorbates (COD and BOD_5) were quite negligible when compared to the adsorbent. A Pseudo-first order kinetics model for COD treatment via adsorption shows that the COD adsorption rate had a partial first order with the concentration of the adsorbent in excess such that its adsorbent concentration is inconsequential to the overall kinetics rate process, thereby culminating in an overall Pseudo-first order kinetics. On the other hand, a partial second order with respect to BOD_5 adsorption could be correctly justified for the BOD_5 treatment, since its treatment follows a Lagergren Pseudo- second order kinetics model; with the adsorbent of no kinetics consequence since it is in excess when compared to BOD_5 concentration.

The effectiveness and efficacy of utilizing commercial granular activated carbon cartridge installed with sediment filter for the treatment of groundwater as well as the identification of its appropriate kinetics mechanism has been exposed from the findings of this study and hence cannot be overemphasized.

4.0CONCLUSION AND RECOMMENDATION

This study reveals latent facts about the usefulness and effectiveness of commercial granular activated carbon cartridge installed with sediment filter for the removal of contaminants from groundwater. The kinetics investigation was based on the presumption of the Lagergren adsorption model since it has been previously found suitable for most adsorption studies. The kinetics study of the treatment shows that BOD_5 treatment follows the Lagergren Pseudo-second order kinetics while that of COD follows the Lagergren Pseudo-first order kinetics model. This model best described the treatment when compared to the Freundlich isotherm.

It is observed from the findings of this study that the treatment of water using commercial granular activated carbon cartridge installed with sediment filter becomes more effective as the time of treatment increases.

A critical consideration of the water quality parameters analyzed suggests that commercial granular activated carbon cartridge installed with sediment filter provides a more promising facility and reliable technique for the treatment of groundwater for drinking and domestic purposes.

The established optimum flow rate that guaranteed optimum quality parameters suggests that such optimization studies must be conducted to determine the optimum flow rate to be employed for the treatment of water before embarking on large scale in-line treatment.

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