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Treatment of Underground Water in Industrially Polluted Communities in Ogoni Land

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Abstract

This research work evaluates the possible contaminants in underground polluted water in Ogoni land especially in Gokana, Eleme, Khana and Tai Local Government Area of Rivers State. Two sites were used in each of the Local Government Areas making a total of eight (8) locations where the evaluations of these contaminants were done. These areas are highly characterized with petroleum activities and as such are termed polluted thus causing the underground water to be highly contaminated. The raw water collected from the locations were analysed to determine the physicochemical properties. About twenty-one (21) pollutants were found to be present in the sites. The contaminants concentrations were recorded and compared to standards set by the World Health Organization (WHO) and United Nations Environment Programme (UNEP). Adsorbents made from plantain peels and rice husk were used to determine the adsorptions effect. It was noticed from the results that turbidity, TSS, Nitrates, Ammonia, Dissolved Oxygen and sodium were the only pollutants that were effectively absorbed from the contaminated underground water. Also, in terms of performances of adsorbents, rice husk adsorbent had a better efficiency as it adsorbed more of the pollutants than plantain peels adsorbents. Finally, when the results were compared to the standards set by the WHO/ UNEP, only turbidity, TDS, conductivity, colour, taste, pH, Cl^-, total hardness SO_4^{2-}, NO_3^-, THB, and sodium were below the limits set by WHO and UNEP while the other parameters were above the limits and thus remediation is needed to curb the effect of those parameters. The results of the experiments were agreement with the aim and objectives of this research.

Keywords :

Pollutants, Dissolved oxygen, PH, WHO, TSS,TDS, Total Hardness

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1. INTRODUCTION

The WHO *Guidelines for Drinking-water Quality* (WHO, 2004; WHO, 2006) cover both microbial and chemical contaminants of drinking-water and describe in detail the scientific approaches used in deriving guideline values for those contaminants. They thus provide sound guidance for ensuring an appropriate level of safety and acceptability of drinking-water for the development of national standards, while taking into consideration the specific problems and cultural, social, economic and environmental conditions of a particular country. The criteria for including specific chemicals in the WHO *Guidelines for Drinking-water Quality* (WHO, 2004; WHO, 2006) are any of the following: there is credible evidence of occurrence of the chemical in drinking-water, combined with evidence of actual or potential toxicity the chemical is of significant international concern the chemical is being considered for inclusion, or is included, in the WHO Pesticide Evaluation Scheme (WHOPES) programme (approval programme for direct application of pesticides to drinking-water for control of insect vectors of disease).Applying these criteria, the guidelines list nearly 200 chemicals for which guideline values have been set or considered (WHO, 2004; WHO, 2006). This number may change over time. It is important to note that the lists of chemicals for which WHO guideline values have been set do not imply that all those chemicals will always be present, nor do they imply that specific chemicals for which no guideline values currently exist will not be present in a water supply. However, it is not necessary for national or local authorities to develop risk management strategies for each and every chemical for which guideline values have been set, rather to identify and select those chemicals that may be of greatest priority for risk management

purposes in the particular setting. Groundwater is abstracted from many different types of aquifers, some of which may be highly susceptible to pollution as a consequence of human activity. The vulnerability of groundwater sources is important when assessing the risks to groundwater posed by various activities. Some aquifers are protected by one or more layers of impermeable material, such as clay, that lie above the saturated zone and that will prevent or retard the transport of chemicals from their sources to the saturated zone. Also, aquifers at certain depths may be protected from chemicals (even from some naturally occurring chemicals) that may be present at other depths in the geological profile. Fluoride, arsenic and (to a lesser extent) selenium are naturally occurring chemicals that have been responsible for severe health effects due to exposure through drinking-water in many countries (Barnes, 2011; Bewas, 1998). Their distribution in groundwater is widespread and their possible presence in surface water should not be ruled out, because groundwater discharge is frequently a major contributor to surface water bodies (BGS, 2001).

Nitrate may be naturally occurring, although its presence in drinking-water is more often associated with contamination by excessive use of fertilizers (both inorganic and organic), in combination with inappropriate farming practices and/or sewage. This chemical occurs widely throughout the world in both groundwater and surface water, and presents a particular problem in shallow wells (Casey *et al*, 2013; Bhutiani *et al*, 2016). Nitrate is a major problem for bottle-fed infants, in whom the risk of ethaemoglobinaemia ("blue-baby syndrome"), increases as the concentration of nitrate rises above 50 mg/L. The risk is increased by the presence of nitrite, which is a much more potent methaemoglobinaemic agent than nitrate, and by the presence of microbial contamination, which can lead to gastric infections in infants. Significant concentrations of iron and manganese occur throughout the world in groundwater. They can cause severe discolouration of water, which may lead to consumers turning to other, microbial unsafe sources of drinking-water. Iron and manganese also frequently cause operational problems (Chorus & Bartram, 2000; Cherry, 2003; Chen *et al,* 2016). The presence of lead in drinking-water can cause severe health effects and is primarily a consequence of the use of lead plumbing and lead-containing metal fittings in buildings. Although lead may be present in source waters, this is unusual except in some mining areas. Generally, lead is not a high priority for routine monitoring programs because of the variability from building to building, but possible risks posed by lead in drinking-water should be assessed in localities where lead has been extensively used in plumbing materials, particularly if the water supplied is corrosive or is likely to dissolve lead. If lead concentrations significantly exceed guideline values, it may be appropriate to apply mitigating measures, such as corrosion control or replacement of pipes and plumbing materials. Indicator parameters are measurements that give information about the chemical condition of groundwater or a surface water body.

These parameters are easily measured in the field and are valuable in guiding further investigations. For example, pH is an important indicator of the ability of water to dissolve minerals from rocks and soil; dissolved oxygen concentration indicates whether the water is aerobic or anaerobic; and redox potential can indicate whether or not the water is reducing in nature. The results of measurements of such parameters can indicate the potential presence of hydrogen sulfide or dissolved iron and manganese. An example of a very simple test would be to shake a water sample in a bottle to aerate it – if the water becomes brown; this would indicate the presence of dissolved iron or manganese in water that was anaerobic (Deshmukh & Asher, 2016; Chilton, 2005; Chapelle, 2014).

Geological or mineralogical information suggests that potentially hazardous chemicals may be present in elevated concentrations in the rocks, soils or groundwater within the catchment area (Biglari *et al*, 2016).Ground or surface water used for water supplies has or is suspected of having a pH of less than 4.5 (IAEA, 2008). High concentrations (blooms) of cyanobacteria (blue-green algae), such as *Microcystis* sp. and *Anabaena* sp. occur in slow-moving or still surface waters with a moderate to high concentration of nutrients, particularly phosphorus. Blooms can occur in both deep and shallow waters, but are more usual in relatively still periods with a moderate to high light intensity. It is difficult to predict whether a bloom will produce toxins, but experience in a number of countries has shown that more than 50% of blooms will generally produce toxins at some stage (Chorus and Bartran, 2000).

Chemical fertilizers are used in most parts of the world, although less so in developing countries because of the high cost. The nitrogen content in chemical fertilizers is known, and application rates can be determined accurately. These may vary depending on the cropping system used. Nutrients are more immediately available for plant uptake in chemical fertilizers than in manure; however, they may be more easily leached into groundwater if used in excess. Slow-release fertilizers reduce this loss (Pickens *et al*, 2008). Factors such as soil type, climate, and depth of the water table and the use of irrigation determine the rate and extent of nitrate transport into groundwater and surface water (Sumner & McLaughlin, 2006). Feedlots are sited close to existing water supply wells and rivers used for water supply (these pose a greater threat than facilities located at a distance from water supplies). Feedlots are located next to sinkholes, abandoned mine shafts, abandoned wells or other features that allow drainage direct access to the water table (WRI, 1987). Wastewater and water used for washing livestock stalls is allowed to percolate into the ground locally or through soak ways, or to contaminate surface water through runoff. Wastewater from feedlots is collected for treatment in unlined or poorly managed treatment ponds, which can leach into the ground or overflow. Wastewater from treatment ponds is applied to fields in excessive amounts, contributing to nitrate leaching (Weil *et al,* 1990). Stormwater/urban runoff is discharged to ground close to a well-used for potable water supply. Stormwater is discharged: to surface water close to a potable water supply point into sinkholes or other features typical of limestone that link to groundwater used for drinking-water to a soakwell or infiltration basin where the water table is close to the surface. The pH of the storm-water is less than 4.5 (Golke *et al,* 2015)). Groundwater is used for water supply in an urban area where chlorinated solvents are, or have been, stored, used or disposed of (Pionke *et al*, 1990).

Nara *et al*, (2013) worked on Ground water Risk Assessment Model (GRAM) for well field protection assessment model on ground water was developed on 30 potable water supply system under protecting drinking water quality across South Australia. The model was based on multi-barrier approach using likelihood of release, contaminant pathway and consequence equation. The vulnerability and well integrity of groundwater has been in corporate to the route component of the model. Protected water reserves and heavily stocked grazing lands were the materials for such model. The results from the model indicated that is systems were low risk, 4 for medium and 11 systems as high risk. This risk was due to poor well construction as bacteria and caliform are sign of such.

Ujile, (2013) researched on evaluating groundwater contamination process and developing framework for qualitative management in parts of Nigeria. High Fe from Itakpe Fe ore deposits migration into the groundwater, salt water intrusion enhanced by high level industrialization due to dredging works, crude oil exploration and exploitation, complex foundation works for the construction of surface facilities and crude oil spillages all occurs in the region of Niger Delta and Nigeria as a whole were the possible groundwater contaminations happened in the region,. Poor and improper waste management system has also affected and increase groundwater problems in Africa.

Remediation's processes and best management practices were adopted and suggested in this work for the retardation of the rate of contamination of groundwater when connected, will cause the water to be drinkable and reliable quality retained for usage.

Table 2.1: Hydraulic Parameters in Rivers State and Bayelsa

S/N	**Location**	**Aquifer**	**Depth(m)**	**Transitivity (T) m^2/s**	**Storativity(s)**	**Specific Capacity M^3/hrm**
1	Bori	1	33	0.0105	31200	19.01

2	Yenagoa	1	40	0.0858	35300	55.2
3	Isiokpo	1	38	0.021	–	–
4	Choba	1	40	0.0106	–	–
5	Omoku	1	34	0.0112	–	–
6	Nembe	2	195	0.0382	10700	75.1
7	pH, Moslow Rd	2	165	0.051	–	130.1
8	pH, Elelenwo	2	151	0.0879	–	128.1
9	Eleme	4	302	0.113	27500	139.7
10	Akpajo	4	300	0.0718	–	120.00
11	Onne	5	300	0.0414	–	130.1

Source: United Nations, 2010

Table 2.2: Groundwater Contamination Level in some Niger Delta

Parameters	**WHO's Standard**	**Contaminate Range**	**No of borchole Contaminated**	**% Contamination**
Iron (mg/l)	0.3	05-10	47	42.34
Chloride (mg/l)	250	260-810	9	8
Salinity (mg/l)	250	260-2500	25	10
Hardness (mg/l)	3.6	7-488	85	77
pH	6.5-8.5	3.8-6.3	60	54

Source: Ujile, 2003.

Aliewe and Al-Khatib (2004) worked on Hazard and risk assessment on the groundwater. Groundwater pollution dangers and assessing of it was considered in this research paper. Higher level and total faecal coliforms were indicated from the hydrology studies and microbial analysis. Possible research methods were listed here for quick resolution by the government to tracked the menace.

Salman *et al*, (2019) carried out evaluation of human risks of surface water and groundwater contamination with Cd and Pb. Groundwater heavily contained Cd and Pb is termed unhealthy because is called polluted water since these heavy metals cause risk to human health. Atomic Absorption spectrometry was used to determine the concentrations level of Cd and Pb in the groundwater and compared with WHO standards. The result indicates that the groundwater was contaminated.

Uduakkobong and Augustine, (2020) stated that phosphates in waste water are removed using chemical is expensive. Hence the absorption of phosphates iron was considered. The kinetics isotherms, and thermodynamics of absorption were carried out to get mechanism of absorption. The results indicate that absorption capacities increased with an increase in contact time, absorbent dosage, and initial phosphate concentration. The result also indicates that the absorption was governed by several mechanism dominating diff stages of absorption pseudo-second order kinetic and Lagmuir Isotherm adequately described the absorption of phosphates onto brick with maximum absorption capacity of 5.35mg/g. thermodynamically, the absorption process was exothermic and proceeded spontaneously, indicating that waste brick can be used as alternative for the effective removal of phosphates from wastewater.

Anthony and Harrison (2002) researched on groundwater contaminant and source. Since of the pollutants commonly present in groundwater were discussed. These were checked with water quality parameters such as pH, oxygen dissolved, and conductivity comparable with the WHO’s standard. A case study was sited from California groundwater as proven by California groundwater management, groundwater Resources Association of California.

IAEA, (2011) reports on remediation of contaminated groundwater was studied, since groundwater was understood from this report as an integral part of hydrologic cycle of polluted surface water. General approach to management and selection criteria for remedial action of ground water pollution was followed phased approached was recommended because of most cost effective and environmentally sound disposition of a contaminated site. This consist of

Assessment of existing information and data; initial planning and decision making for action consideration; selection of site characterization / monitoring requirements, assessment of remediation technologies for appropriate applications and selection of remediation strategy to be employed. Logical approach was also recommended where complied, reviewed and analyzed existing data and information; identified the contamination and its sourced; described the hydrological system, developed useful model and identified the potential affected population and their points of contact with the contaminated groundwater were conceptual to remediation of pollutants from groundwater. Modeling application to remediation analysis and design were based on before, during and after remedial action to ascertain optimal operational parameters and also to predict long term impacts due to residual contamination. The remediation models were solved either analytically or numerically for results and analysis.

United Nations, 2010 recommended and published parameters present in the Rivers and Bayelsa States towns near groundwater and their level of contaminations in-terms of depth, transmissivity storage and specific capacity as shown in table 2.1.

Ujile, (2013) worked on groundwater contamination and sources and came out with table 2.2. below for the range of contamination and Boreholes numbers affected by and the percentage of contaminants in the Niger Delta specifically in pollutants parameters such as iron, Cl^-, salinity, hardness and pH.

Chilton, (2016) worked on groundwater quality assessment of various groundwater sources and pollutants involvement that makes groundwater unhealthy for domestic usage as compared by World Health Organization standards. Possible sources and concentrations of Natural groundwater components are shown in table 2.4 below:

Table 2.3: Sources and Concentration of Natural Groundwater Contaminants

Component	Natural Sources	Concentration in Natural Water
Dissolved Solved	Mineral constituents dissolved in water	Usually < 5,000mg/l, but some brines contain as much as 300,000mg/l
NO_3^-	Atmosphere, legumes, plants animal excrement	Usually < 10mg/l

Na	Feldspars (albite), clay minerals, evaporites such as halite, NaCl, industrial wastes.	Generally < 200mg/l, about 10,000mg/l in sea water, 25,000mg/l in brines.
K	Feldspars (orthoclase microcline), feldspathoids, some micas, clay mineral	Usually <10mg/l, upto 100mg/l in hot springs and 25,000mg/l in brines.
Ca, Mg	Amphiboles, feldspars, gypsum, pyroxenes, dolomite, aragonite, calcite, day minerals	Usually < 100mg/l for Ca; < 50mg/l for mg. brines many contains upto 75,000mg/l for Ca and 57,000mg/l for Mg.
HCO_3; CO_3^{2-}	Limestone, dolomite	Usually < 10mg/l and < 500mg/l for Co_3^{2-} and HCO_3 respectively exceed 50mg/l and 1000mg/l in water highly charged with sodium.
Cl^-, SO_4^{2-}	Sedimentary rock; a little from igneous rock for Cl^- and oxidation of sulphide ores, gypsum, anhydrite	<10mg/l and <300mg/l for resp. Cl^- and SO_4^{2-}. Exceeds 1000mg/l and 200,000mg/l influence by acid mine drainage in some brines. Cl^{-1} approx. 19300mg/l in sea water and upto 200,000mg/l in brines too.
SiO_2	Feldspars, ferromagnesian and clay minerals, Amorphous silica, Chert and Opal	1 – 30 mg/l and 100mg/l for high concentrations many reach 4000mg/l in brines.
F^-	Amphiboles (hornblende) apatite, fluorite, mica	< 10mg/l, but upto 1,600mg/l in brines.
Fe	Igneous Rocks: amphiboles, ferromagnesian micas, FeS, FeS_2 and magnetite, Fe_3O_4 and stones, Sulphides or Fe clay minerals	<0.5mg/l in fully aerated H_2O, groundwater with pH<8 can contain 10mg/l; in frequently 50mg/l many be present.
Mn	Arises from soils and sediments. Metamorphic and sedimentary rocks and mica biotic and amphibole hornblende minerals contain large quantities of Mn	<0.2mg/l; groundwater contains > 10mg/l

Source: Bouwer, (2007)

WHO, (2006) worked on protecting groundwater for health by managing the quality of drinking water sources scientific background, understanding the drinking water catchment, situation analysis, approaches to drinking water source and protection management and pollution source management were investigated.

Groundwater pollutants are the released of chemical or/pollutants into the ground which migrate through the forces of science and engineering. Such pollutants are Arsenic and Flouride pathogenic substances, Nitrates, organic compounds (such as VOCs), metals such as Pb, Mn, Cu, Fe, Cd, Cr etc., pharmaceuticals, sewage and sewage sludge, fertilizers and pesticides, commercial and industrial leaks, hydraulic fracturing, landfill leaks, interactions with surface water, groundwater quality monitoring, Land zoning for groundwater are the possible contaminant of groundwater (WHO, 2006; Ross,, 2010; Banks and Battigelli, 2002).

Sudarshan, (2019) worked on groundwater pollution and Vulnerability Assessment. Containments of groundwater such as heavy metals and leaching potential of various organic and inorganic from poorly manage residual waste products (biosolids, landfills, latrines and septic tanks) were investigated. Pollution problems on groundwater were evaluated.

2.2 Groundwater Contamination

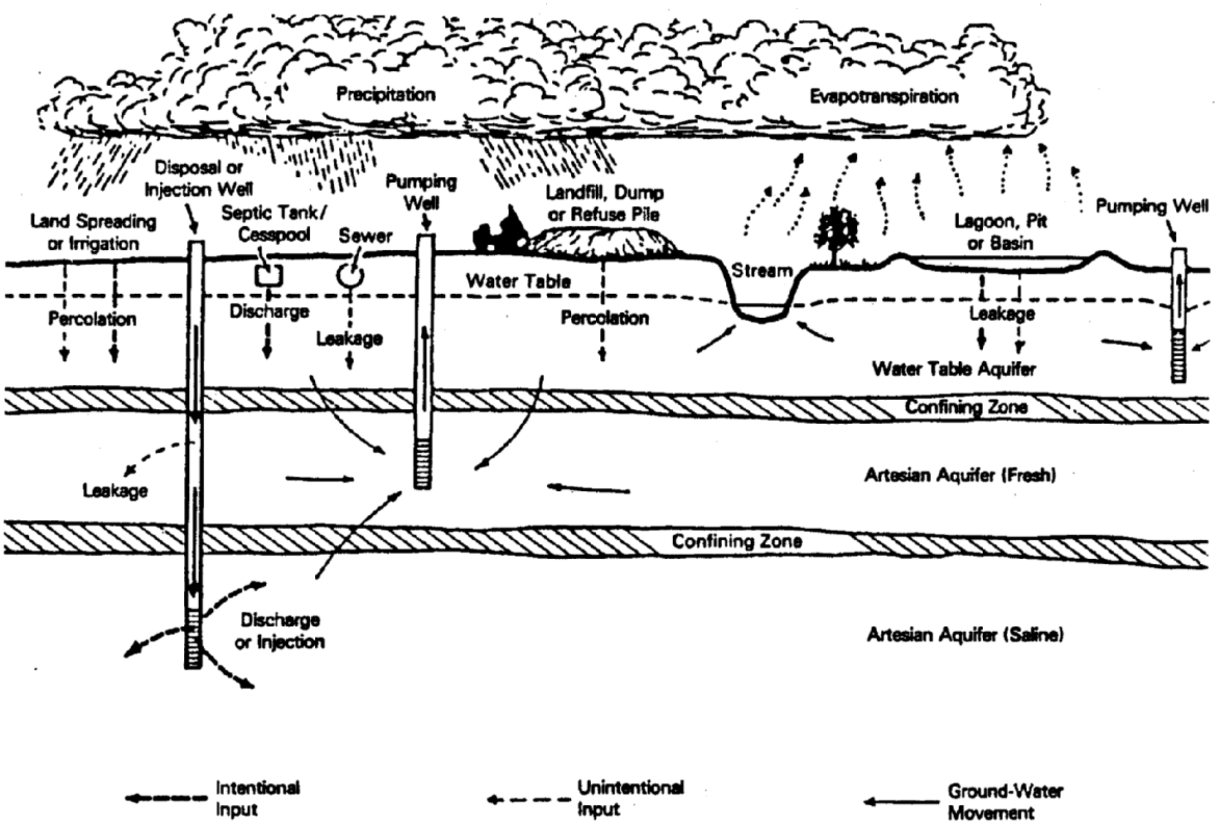


Figure 2.1: Sources of groundwater contamination (Geraphty and Miller, 2015)

The groundwater iron distribution map of part of the region is shown in Figure 2.1. The figure shows that Yenagoa has very high iron concentration of 1 to 8 mg/l. The River Niger deposits all loadings from the upper Niger at the Deltaic zones. It divides at some 130 km south of the apex into the Rivers Nun and Forcados. Yenagoa is located east of the confluence of River Nun and Ekole River. Niger Delta Environmental Survey Report NDES 2001 asserted that the River Niger carries iron loadings from the deposits of Itakpe Iron Ore and perhaps through the processes of dispersion, advection, inter aquifer exchange move the pollutants to the groundwater aquifer. This can be corroborated from the analysis carried out on 112 borehole water samples in the region. The result shows that 42.34% of the 112 samples are polluted with Iron loadings and other parameters considered are shown in Table 2.2 (Ujile, 2003). The investigation shows that towns and villages along the River Niger and its tributaries have iron loadings between 1.5mg/l to 10mg/l. For example, Yenegoa 4.5mg/l; Amarata, 3.0mg/l; Peremabiri 4.5mg/l; Toru Ndoro 4.5mg/l; Torufani 3.5mg/l; Umuoji and Idama 10mg/l; Harry's Town 8.0mg/l other communities could be obtained from the Iron distribution contour map in Figure 2.1. The main body of groundwater in major parts of the Niger Delta is contained in very thick and extensive sand and gravel aquifers of the Benin formation. The available borehole data shows three main aquiferous zones (Geake *et al*, 2015). These are upper, middle and lower aquifer systems. Within the mangrove swamps salinity level of waters is high.

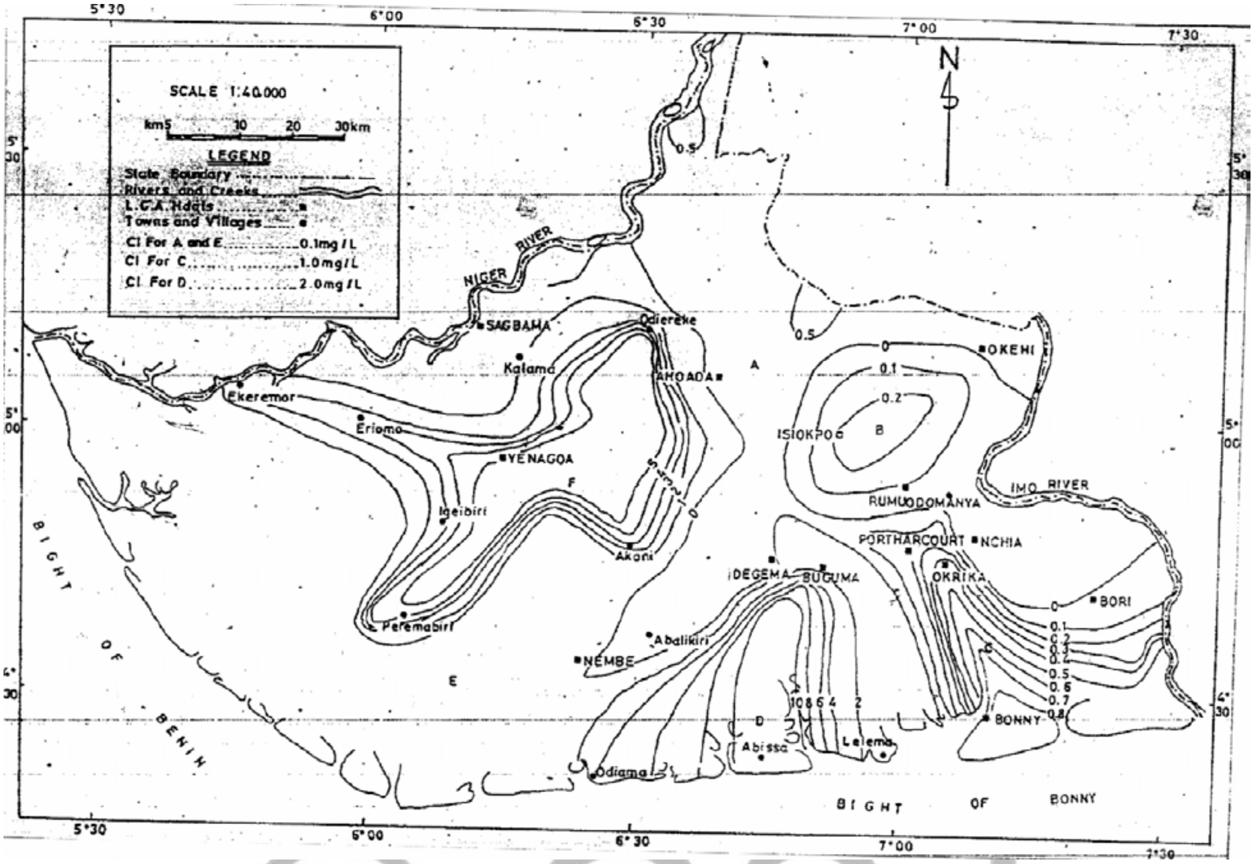


Figure 2.2: Groundwater Iron distribution map of Rivers/Bayelsa States, Nigeria (Ujile, 2007)

It was reported that, since these areas are not protected from the dynamic zones of the deltaic front, it is possible for saline water to flow inland creating a transition zone between fresh and saline waters. Fresh water extraction from swamps requires borehole to be drilled to depth beyond 220m. Within the sandbars and beaches of the coastal areas, boreholes have to go deeper to reach fresh water. The groundwater classification based on geo-electric sounding of some cities has identified three broad types, namely: potable water, ferrous water and groundwater contaminated with saline intrusions NDES 2001 Report.

Statement of Problem

The migration of pollutants from air, land sewage/refuge through run-off, surface water to underground water causes the water unsafe and polluted, unfit for domestic usage and drinking. This is due to the presents of heavy metals, (such as Fe, Cu, Cd, etc), NO_3^{-1},SO_4^{-2}, dissolves gases, petroleum hydrocarbon, TSS, TDS, Turbidity and pH (very low and high concentrations) whose values are above the world Health Organization and United Nations limits and standard, thus the need to evaluate and treat by removing or absorbing some or all the possible contaminants in the underground water (especially under the area study i.e. selected areas on the four different local governments areas of Ogoni land) with locally sourced absorbents

Aim of the Study

The research work is aimed at the evaluation and treatment of underground water in parts of Ogoni land: A case study of four most industrially polluted and less industrially polluted communities in the land.

Objectives of the Study

In other for this research work to achieve its aim, the procedures are systematically followed to:

i) Examine the sources of contaminants in the underground water by analyzing and characterizing the raw samples collected in these areas.

ii) Determine the physico-chemical properties/ parameters of the underground water in parts of Ogoni land.

iii) Prepare locally absorbents from plantain peels and Rice Husk for the treatment of the underground water in parts of Ogoni land.

iv) Carryout laboratory analysis for proper identified cationic concentrations values of pollutants thereby absorbing of these pollutants from the underground water using locally prepared absorbents from the plantain peels and rice husk.

v) Treat and evaluate the underground water by recording the concentrations of the contaminants left after each treatment after proper characterization of the treated samples.

vi) Compare the data generated (i.e. results obtained from (v) above) with the World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) standard.

vii) Analyze and generate results from the laboratory experiment and discussed properly.

Justification of the Study

Groundwater contamination possesses great danger to the health of humans and environment due to the industrialization and petroleum activities happening in the environment. Possible study the pollutants present in the underground water and know how to reduce the concentration level to barest minimum, below the standards set by world Health organizations and United Nations will help us to keep the ground water safe for drinking and domestic usage.

Scope of the Study

The research work focuses on the examination of contaminations caused by heavy metals, petroleum products and others in the underground water. The evaluation of the possible pollutants in the underground water through sampling and laboratory analysis will be carried out. The preparation of locally sourced absorbents from plantain peels and rice husk for the treatment of the unground water in Ogoni land, carried out specifically in four most industrially and four less industrially polluted communities in the land. The comparison of the concentration of pollutants present in the underground water with the standards set by WHO, FEPA and United Nations.

2. Materials

The materials used are:

Plantain peels and Rice Husk are the locally sourced materials used as adsorbents, while other materials and apparatus used during the preparation and the main adsorption experiment include graduated beaker, sieve, funnels, distilled water, test tubes, desiccators, weighing balance, bucket, crusher, filter papers, conical flasks (reactor), spatula, oven, measuring cylinder, crucibles, thermometer, pH meter, stop watch, Atomic Absorption spectrophotometer (AAS), Hose capillary tubes and calculator. Also, the following reagents were used: NaOH, H_2S0_4 and HNO_3.

3. Methods:

3.2.1 Experimental Procedures

The experimental procedures carried out in this study are stated according to the sequence of events.

3.2.1.1 Sample Collection

Underground water used for the experiment was collected from hand dug well very close to crude oil polluted sites in these Communities in Ogoniland of Rivers State. The Communities are some of the major oil producing Communities in Nigeria, which have been faced with many water challenging issues due to oil spill. The plantain peels and Rice Husk were obtained from oil mill Market in Obio/Akpo Local Government Area of Rivers State.

3.2.1.2 Preparation of Samples

The collected water, plantain peels and rice husk were transported to the laboratory and then, subjected to analysis.

3.2.1.3 Preparation of Plantain Peels and Rice Husk Particles

The raw plantain peels and rice husk were first prepared according to the method described by Sharma (2016). They were first sun-dried for 2 days and further dried in oven at controlled temperature of 70-100°C for 4 hours to expel all moisture content. After drying, they were washed with tap water and then with distilled water to remove dirt or unwanted particles, and then further dried in preparation for crushing. After crushing to fine powdered particles, they were sieved through 0.18mm mesh to obtain a uniform particle size. The grinded particles of the plantain peels and rice husk were soaked in 0.1 N NaOH for 9 hours and washed again with distilled water to remove lignin and then dried. The particles were further washed with distilled water soaked this time around, into 0.1 N H_2S0_4 for another 9 hours to remove traces of alkalinity, and then washed thoroughly with distilled water. After washing, they were again sun-dried and stored in desiccator in preparation for the adsorption experiment.

3.2.1.4 Physicochemical Analysis of Samples

The investigation of contaminants underground in the eight (8) sites of Ogoni land was the main target of this research work. Raw samples (contaminated underground water) were collected in eight (8) sites, four local government areas of Ogoni land ie Mr. Mon Ledibari's compound, Bodo city (G_1) and Tomorrow leaders' foundation, Yeghe town (G_2) all in Gokana Local Government Area; Mr. Stephen Osaro's compound, Ogale town (E_1) and central mosque, trailer park (E_2) in Elemen Local Government Area; community central borehole, Kpea town (K_1) and Mr. Emmanuel Neebani's compound, Lorre town (K_2) in Khana Local Government Area; and Tai council secretariat (T_1) and Mr. Mbadee's compound, Nornwa town (T_2), and sent to laboratory for physico-chemical analysis for the 8 (eight) sites were revealed and displayed in Appendix II.

The procedures to determine the parameters through characterization of the underground water are stated below.

i. Odour Test

The sense organ of smell was put into usage to detect whether the samples were odorous. The perception of the sense organ of smell was used to detect odour, from one of the characteristic of water, it is odourless; so if the nitrate detect odour, then the water is unfit for domestic usage.

ii. Colour Test

The eye as an organ was used to detect colour present in the samples. From normal understanding, water supposed to be colourless, hence the eye was used to detect this physical property of the contaminated underground water

iii. Taste Test

Taste-buds of tongue were used to determine the taste of the underground water. Most of the time, polluted water has taste.

3.2.1.5 Collection of Water Samples for Physiochemical Analysis

Water samples for physicochemical parameters were collected from eight sites in the four local government areas of Ogoni land. Collection of water samples for heavy metals analysis was collected using glass bottle container rapped with foil paper. For Dissolved Oxygen (DO), Water sample were collected using well labeled DO bottle for easy identification, etc.

1. Temperature

The temperature of each sampling stations was determined in-situ as follow: The temperature of the water was measured with mercury- in glass thermometer and recorded accurately. The Graduated thermometer was read from $0^{0}C$ - $100^{0}C$. The edges of the glass thermometer were held constantly inside the water until a paper reading was taken.

2. Turbidity and Electrical Conductivity

Horiba water checker model 10 was used for this analysis. About 200ml of water sample were put into a container and the instrument was inserted. The mode was used to select the parameter (turbidity) required and the value was read off from the screen of the instrument and recorded.

3.2.1.6 Measurement of Chemical Parameters

1. pH (Hydrogen Ion Concentration) ASTM

The sample was measured using pH meter (pH meter, jenway model No.2010).A little quantity of sample was put in a container or beaker and shaken thoroughly. The pH electrode was immersed in a sample and the result was read off from the meter and recorded. Before the pH measurement, a buffer solution was used to standardize the pH meter

2. Dissolved Oxygen (DO) ASTM D888A

The samples were fixed by adding a divalent manganese solution and a strong alkaline precipitant of manganese hydroxide and prevent biological activities. The samples were acidified and were titrated with a standard sodium thiosulphate using starch as the indicator. And the results were expressed in mg/1 of dissolved oxygen.

3. Chloride (Cl^-)

Chloride ion in the water sample was determined using silver nitrate ($AgNO_3$) titration method. 100ml of water sample was transferred into a 250ml Erlenmeyer flask, 0.5ml of $K_2C_rO_4$ was also added as an indicator which gave the solution a yellowish color. A standard $AgNO_3$ solution was added dropwise from a 25ml burette until a brick red color developed throughout the sample, marking the end of the titration.

Calculation Chlorine ion concentration in the original sample in mg/1 was calculated as follows:
Chloride (mg/1) = (v_1-v_2) x 0.988 x 1000/Volume of sample used (3.1)

Where v_1 = $AgNO_3$ that will be used in titration

v_2= volume of $AgNO_3$ that was used for titration of blank.

N/B: All physicochemical were determined using methods adopted from ASTM (1986).

4. Nitrate (NO_3)

2ml of H_2SO_4 and 0.2ml of brine was added to 2ml of the water sample. This was transferred into a boiling water bath of about 98C and covered for about 25mins. It was then removed and allowed to cool and transferred into the instrument (spectronic 21) for its absorbance reading at 410nm. Calculation: Nitrate concentration in the sample was calculated using the formula:

Nitrate (mg/1) = (Abs. value-blank value) x factor (3.2)

5. Ammonia (NH_3)

Ammonia-nitrogen levels in water were determined by standard method. 0.2ml phenol solution was added to 5ml of the water sample and then 0.2ml sodium nitroprocide and mixed thoroughly by shaking. 0.5ml of an oxidizing reagent was added and allowed to stand before measuring at 630nm with the spectrophotometer. The concentration of ammonia was calculated using this formula:

Ammonia (mg/1) = (Abs. value-blank value) x factor. (3.3)

6. Sulphate (SO_4)

Sulphate level was measured using the gravimetric method and also by standard test method. 20ml of the sample was measured into a 50ml Erlenmeyer flask and 1ml conditioning reagent added into it. $BaCl_2$ crystals was then be added and resulting solution was become turbid. This was then measured in the instrument at 420nm, and the sulphate concentration was calculated using the formula:

Sulphate (mg/1) = (Abs. value-blank value) x factor. (3.4)

7. Total Dissolved Solid (TDS)

The TDS of the water sample was determined using conductivity bridge, lovibond NS meter type cm-21. The electrode of the meter was standardized by dipping it into distilled water. The electrode was then immersed into the water sample. After the meter was stabilized the result was read off and recorded

3.2.1.7 Analysis of Heavy Metal (ASTM)

Analysis of metals was carried out using atomic absorption spectrophotometer. Sample preparation was by acid digestion followed by filtration through a 0.45 micro membrane filter. Ten aliquots of the filtrates were used to analyze for Iron (Fe) ASTM D1068. The minimum detectible unit is 0.001mg. The AAS was used to determine the physicochemical properties of the underground water sample, particles of plantain peels and rice husk. The analysis was performed to know the heavy metals present in the underground water and also the other ions. Although, many heavy metals were determined by but sodium ion was only investigated for the adsorption process as it was the only metal that can be adsorbed using the adsorbents.

3.2.1.7.1 Preparation of Heavy Metal Concentration

The desired initial concentration of sodium ions was obtained by weighing a known weight of it. For this purpose, 2g, 5g,10g, 15g and 20g each of the metal ion was weighed and diluted in measured volume of the contaminated solution to obtain the concentrations of 10mg/I, 20mg/l, 30mg/I, 40mg/l and 50mg/I.

4 RESULTS AND DISCUSSION

The adsorption of contaminants from the different water samples were considered using plantain peels and rice husk as adsorbents as shown below.

4.1 Experimental Results

Table 4.1: Effect of Plantain Peels Adsorbent on Turbidity in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	4.53	4.97	4.53	4.97	4.97	4.97	4.53	2.66
1	3.17	2.02	1.92	3.09	3.62	1.9	3.5	1.9
2	3	1.56	1.82	2.86	3.12	0.82	3.1	1.41
3	2.89	1.04	1.01	2.41	2.96	0.66	2.5	1
4	2.62	0.82	0.62	2.08	2.63	0.51	2.11	0.88
5	2.02	0.23	0.11	1.83	2.22	0.23	1.87	0.11

Table 4.1 shows the effect of plantain peels adsorbent in treatment of the water in terms of turbidity. The turbidity which is a measure of the clarity of water can be easily affected by the amount of contaminants. From the table it can be seen that as time is increasing for each sample so is turbidity decreasing.

Table 4.2: Effect of plantain peels adsorbent on TSS in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	4.5	6.34	4.5	6.34	6.34	6.34	4.5	4.6
1	3.23	3.22	3.53	3.93	3.7	3.26	3.1	2.92
2	3.01	2.89	3.11	2.15	2.56	2.17	2.82	2.01
3	2.92	2.01	2.91	1.81	1.55	1.18	2.11	1.92
4	2.16	1.73	2	1	0.58	0.95	1.79	1.01
5	1.35	1.05	1.53	0.82	0.12	0.15	1.32	0.33

Table 4.2 measures the adsorption of TSS in eight polluted sites of the four local Government areas in Ogoni land using plantain adsorbent. It is also observed that as time is increasing TSS is decreasing in all the eight sites.

Table 4.3: Effect of Plantain Peels Adsorbent on Nitrates in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	2.92	2.23	2.2	2.88	2.84	2.06	2.85	2.86
1	1.9	1.92	1.68	1.7	1.49	1.91	1.4	1.87
2	0.8	1.03	1.01	0.5	0.55	0.88	0.71	0.68
3	0.66	0.86	0.95	0.3	0.4	0.55	0.51	0.49
4	0.23	0.65	0.8	0.2	0.25	0.33	0.41	0.2
5	0.14	0.45	0.58	0.1	0.05	0.11	0.31	0.13

Table 4.3 depicts the adsorption of nitrates using plantain peels adsorbent in four different local Government areas in Ogoni land. From the table it is observed that as the time in hours is increasing the amount of Nitrate is decreasing because more nitrate is adsorbed as time is increasing.

Table 4.4: Effect of Plantain Peels Adsorbent on Ammonia in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	1.62	1.617	1.632	1.615	1.607	1.621	1.611	1.613
1	0.66	0.65	0.66	0.68	0.63	0.66	0.65	0.67
2	0.532	0.511	0.6	0.59	0.58	0.6	0.62	0.58
3	0.51	0.48	0.55	0.54	0.55	0.58	0.6	0.48
4	0.435	0.411	0.42	0.45	0.48	0.54	0.59	0.45
5	0.399	0.321	0.311	0.35	0.4	0.49	0.55	0.33

3.

Table 4.4 shows the absorption of ammonia using plantain adsorbent in eight (sites) collected from four Local Government Area in Ogoni land. From the table it can be seen that as time in hours is increasing the amount of ammonia is decreasing.

Table 4.5: Effect of Plantain Peels Adsorbent on Dissolved Oxygen in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	8.5	8.21	8.5	8.21	8.21	8.21	8.5	8
1	4.78	5.83	5.37	5.71	5.5	5.26	5.3	5.36
2	4.1	4.8	5	5.2	5	5	5	5.01
3	3.1	4	4.8	4.8	4.5	4.8	4.81	4.85
4	2.1	3.8	4.2	4.2	4	4.13	4.12	4.35

5	1.1	3	3.8	3.8	3.8	3.68	3.92	4

Table 4.5 shows the absorption of dissolved oxygen using plantain adsorbent in eight (sites) collected from four Local Government Area in Ogoni land. From the table as time in hours is increasing the amount of dissolved oxygen is decreasing.

Table 4.6: Effect of Plantain Peels Adsorbent on Sodium in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	1.55	1.4	1.8	0.94	1.23	2.58	2.16	1.81
1	0.98	0.74	0.95	0.85	0.98	0.74	0.99	0.701
2	0.72	0.54	0.8	0.6	0.9	0.61	0.9	0.51
3	0.52	0.48	0.67	0.53	0.78	0.51	0.7	0.32
4	0.4	0.41	0.58	0.41	0.7	0.38	0.42	0.21
5	0.32	0.391	0.41	0.31	0.62	0.14	0.21	0.11

Table 4.6 shows the adsorption of sodium using plantain adsorbent in eight (sites) collected from four Local Government Area in Ogoni land. From the table it can be seen that as time in hours is increasing the amount of sodium is decreasing.

Table 4.7: Effect of Rice Husk Adsorbent on Turbidity in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	4.53	4.97	4.53	4.97	4.97	4.97	4.53	2.66
1	2.55	1.88	1.5	2.81	3.08	3.01	2.4	1.68
2	2	1.34	1	2.05	2.76	2.45	2	1.21
3	1.83	0.99	0.82	1.82	2.34	2.11	1.5	0.85
4	1.13	0.66	0.31	1.64	2	1.84	1	0.45
5	0.97	0.11	0.05	1.05	1.56	1.65	0.55	0.23

5.

Table 4.7 shows the effect of Rice Husk adsorbent in treatment of the water in terms of turbidity which is a measure of the clarity of water. It can also be observed that as the time in hours is increasing so is the turbidity decreasing.

Table 4.8: Effect of Rice Husk Adsorbent on TSS in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	4.5	6.34	4.5	6.34	6.34	6.34	4.5	4.6
1	2.81	2.8	3.17	3.08	3.4	2.5	2.6	2.8
2	2.23	2.13	3	2	2.5	2	1.89	1.92
3	1.63	1.96	2.81	1.45	1.4	1	1	1.83
4	1.11	1.05	1.9	0.85	0.4	0.8	0.92	0.98
5	0.57	0.82	1.15	0.5	0.1	0.1	0.35	0.25

Table 4.8 measures the adsorption of TSS the eight polluted sites of the four local government areas of the Ogoni land using rice husk adsorbent. It is also observed that as time is increasing TSS is decreasing in all the eight sites.

Table 4.9: Effect of Rice Husk Adsorbent on Nitrate in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	2.92	2.23	2.2	2.88	2.84	2.06	2.85	2.86
1	1.93	1.95	1.76	1.73	1.66	1.95	1.56	1.89
2	1.23	1.3	1.11	1.13	1	1.3	1	1.05
3	0.9	1	0.95	0.87	0.91	1	0.83	0.88
4	0.85	0.88	0.81	0.78	0.81	0.85	0.78	0.77
5	0.71	0.71	0.68	0.69	0.72	0.78	0.67	0.6

Table 4.9 depicts the adsorption of nitrates using rice husk adsorbent in four different areas in Ogoni land. From the table it is observed that as the time in hours is increasing the amount of Nitrate is decreasing because more nitrate is adsorbed as time is increasing.

Table 4.10: Effect of Rice Husk Adsorbent on Ammonia in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	1.62	1.617	1.632	1.615	1.607	1.621	1.611	1.613
1	0.68	0.68	0.69	0.68	0.65	0.69	0.67	0.68
2	0.6	0.6	0.61	0.62	0.53	0.59	0.6	0.53
3	0.5	0.5	0.52	0.55	0.48	0.48	0.51	0.48
4	0.4	0.42	0.45	0.48	0.38	0.39	0.43	0.38
5	0.3	0.33	0.38	0.35	0.27	0.29	0.3	0.26

Table 4.10 shows the absorption of ammonia using Rice Husk adsorbent in eight (sites) collected from four Local Government Area in Ogoni land. From the table it can be seen that as time in hours is increasing the amount of ammonia is decreasing.

Table 4.11: Effect of Rice Husk Adsorbent on Dissolved Oxygen in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	8.5	8.21	8.5	8.21	8.21	8.21	8.5	8
1	4.5	5.2	5.18	5.4	4.84	4.92	4.88	5.1
2	4	4.8	4.71	5.01	4	4.11	4.01	4.5
3	3.5	4	3.9	4.36	3.56	3.89	3.68	3.89
4	3	3.12	3	3.82	2.93	3	3.11	3.03
5	2.61	2.81	2.56	2.96	2	2.45	2.78	2.83

Table 4.11 shows the absorption of dissolved oxygen using plantain adsorbent in eight (sites) collected from four Local Government Area in Ogoni land. From the table it can be seen that as time in hours is increasing the amount of dissolved oxygen is decreasing.

Table 4.12: Effect of Rice Husk Adsorbent on Sodium in four different LGAs in Ogoni Land

Time	G1	G2	E1	E2	K1	K2	TI	T2
0	1.55	1.4	1.8	0.94	1.23	2.58	2.16	1.81
1	0.7	0.55	0.8	0.6	0.94	0.95	0.87	0.42
2	0.6	0.42	0.65	0.5	0.9	0.8	0.8	0.38
3	0.5	0.3	0.42	0.42	0.83	0.72	0.71	0.3
4	0.3	0.28	0.3	0.32	0.6	0.6	0.61	0.21
5	0.28	0.12	0.28	0.12	0.51	0.52	0.51	0.15

Table 4.12 shows the adsorption of sodium using rice husk adsorbent in eight (sites) collected from four Local Government Area in Ogoni land. From the table it can be seen that as time in hours is increasing the amount of sodium is decreasing.

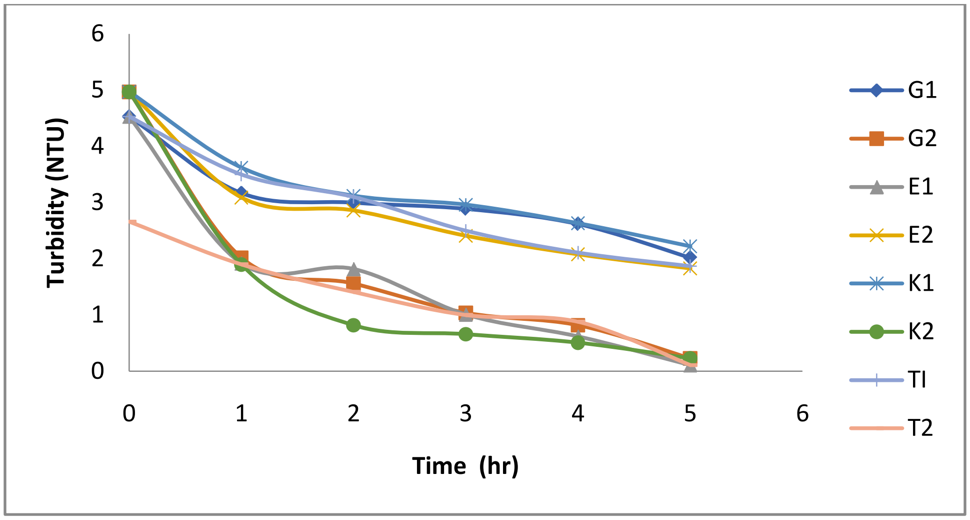


Figure 4.1: Variation of Turbidity with Time in eight Sites(four different LGAs) using Plantain Peel Adsorbent

Figure 4.1 demonstrate the relationship between turbidity and time variation using plantain peel adsorbent. Norwa town in Tai Local Government (T_2) had the least turbidity concentration in all the areas sampled, while the other areas had high concentration of turbidity.

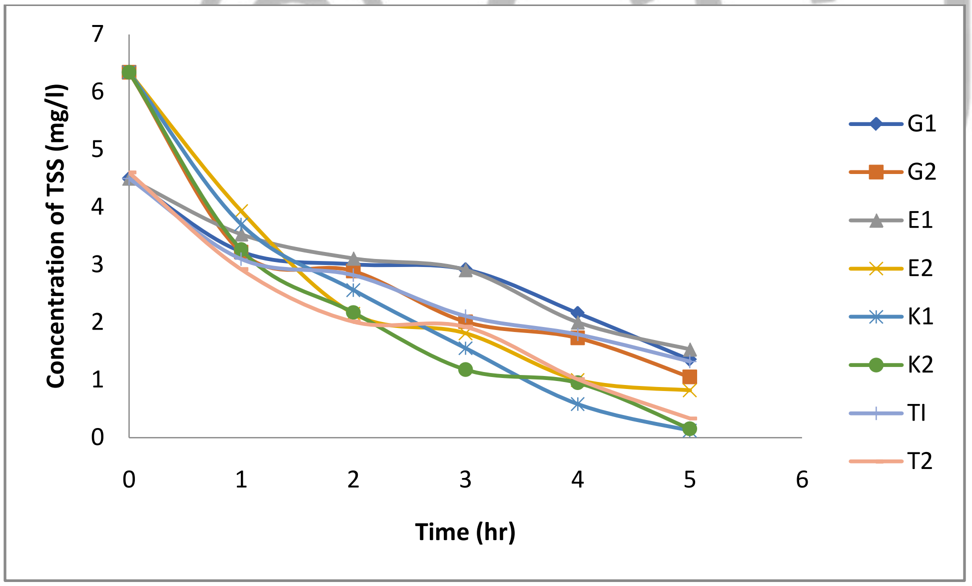


Figure 4.2: Variation of TSS with Time in eight Sites(four different LGAs) using Plantain Peel Adsorbent

Figure 4.2 depicts the relationship between the variation of TSS with time using plantain peel adsorbent. It is also observed that all the samples taken from eight sites have high concentration of TSS, hence the need to remedy the situation through locally formulated adsorbent at a cheaper rate for the adsorption process has to be considered in these areas.

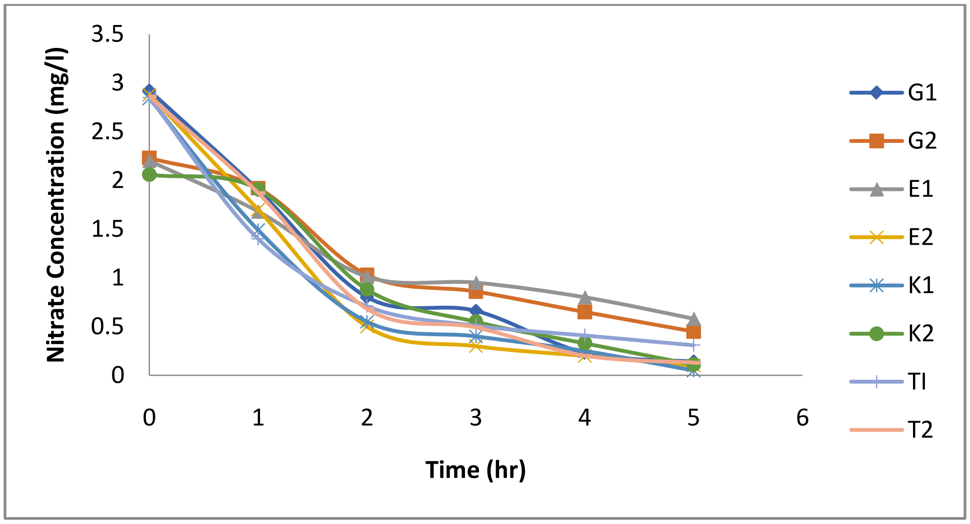


Figure 4.3: Variation of Nitrate Concentration with Time in eight Sites(four different LGAs) using Plantain Peel Adsorbent

Figure 4.3 shows the variation of nitrate concentration with time using plantain peel adsorbent in the adsorption of nitrates in eight (8) stations of the four Local Government areas of Ogoni land. Nitrates present in the polluted stations (sites) were low in concentration and the adsorption ability of the nitrates using plantain adsorbent in dependent on time.

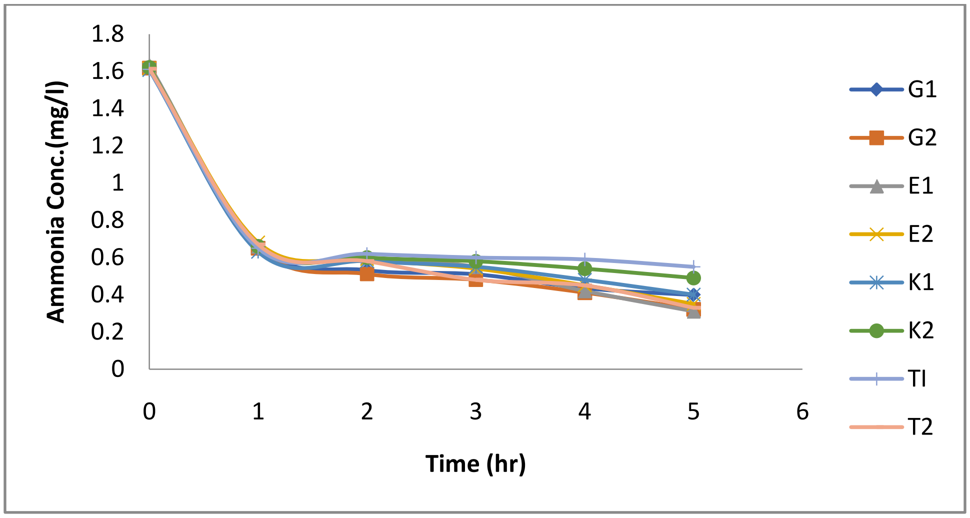


Figure 4.4: Variation of Ammonia Concentration with Time in eight Sites(four different LGAs) using Plantain Peel Adsorbent

Figure 4.4 depicts the profile plot how ammonia concentration is changing with time using plantain peel adsorbent in the absorption of ammonia. It is clearly seen that from figure 4.4 the concentration of ammonia is decreasing with time because more ammonia is been absorbed. The concentration of ammonia present in the eight locations of the four Local Government Areas of Ogoni are considered low when compared to WHO standard.

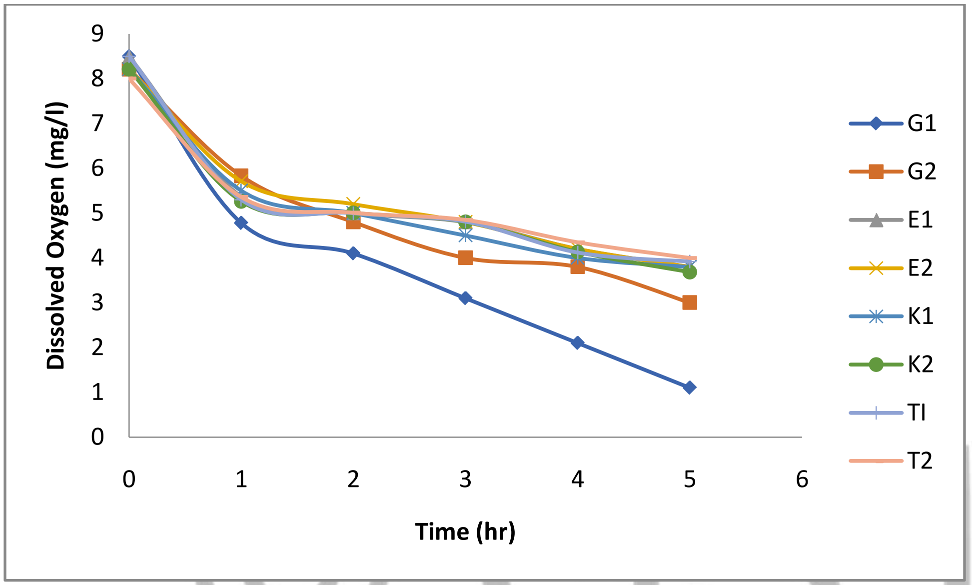


Figure 4.5: Variation of Dissolved Oxygen Concentration with Time in eight Sites(four different LGAs) using Plantain Peel Adsorbent

Figure 4.5 demonstrates how the concentration of dissolved oxygen is changing with time using plantain peel adsorbent on the absorption of dissolved oxygen on the eight contaminated sites. Though the concentration of dissolved oxygen was relatively high in these areas, the adsorbent was found to be effective because the amount of dissolved oxygen it was high.

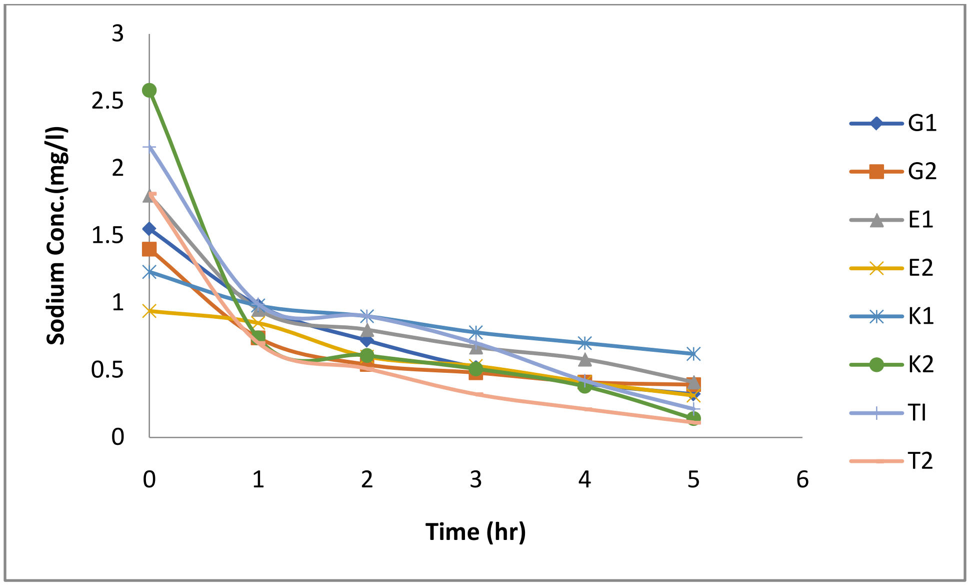


Figure 4.6: Variation of Sodium Concentration with Time in eight Sites(four different LGAs) using Plantain Peel Adsorbent

Figure 4.6 shows the variation of sodium concentration with time using plantain peel adsorbent on the adsorption of sodium ion. The concentration of Na in the areas sampled was low compared to the standard set. The exponential decrease of the amount of sodium in the sampled areas shows the effectiveness of the adsorbent as reliable and better for the adsorption of Na.

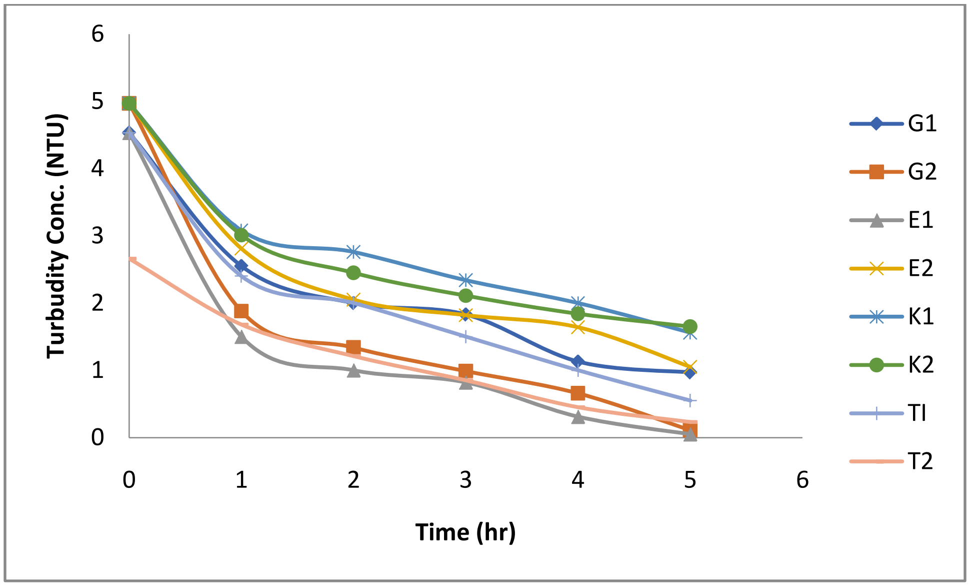


Figure 4.7: Variation of Turbidity Concentration with Time in eight Sites(four different LGAs) using Rice Husk Adsorbent

Figure 4.7 demonstrate how turbidity is changing with time using rice husk adsorbent. Norwa town in Tai Local Government (T_2) had the least turbidity concentration in the areas sampled. The other areas had high concentration of turbidity, though the adsorbent was still found to be efficient.

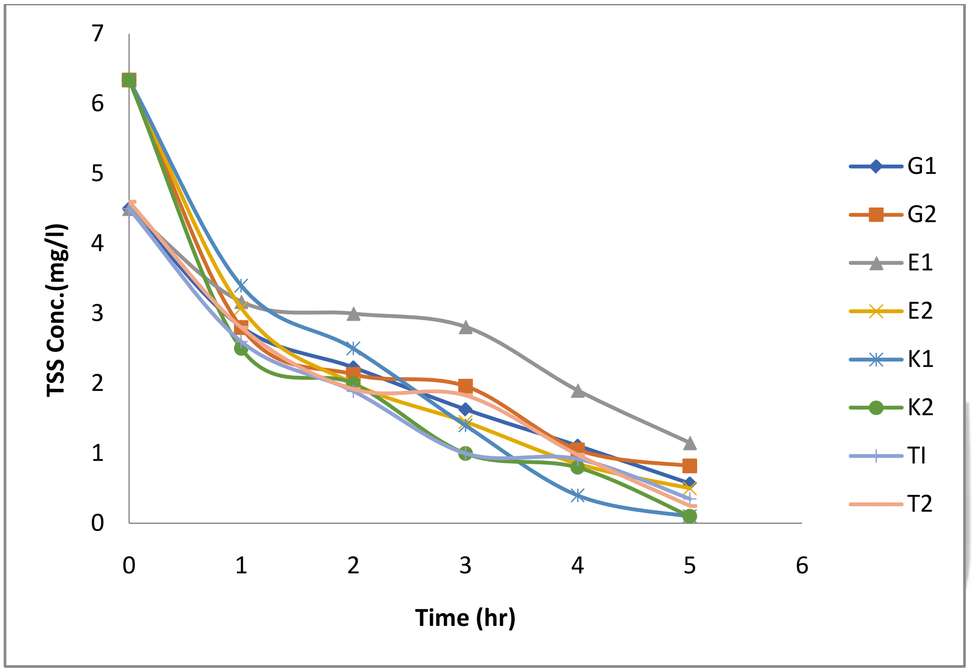


Figure 4.8: Variation of TSS Concentration with Time in eight Sites(four different LGAs) using Rice Husk Adsorbent

Figure 4.8 depicts the relationship between the variation of TSS concentration with time using rice husk adsorbent. The samples analyzed had high concentration of TSS, hence the need to remedy the situation through locally formulated adsorbent at a cheaper rate for the adsorption process is to be considered in these areas.

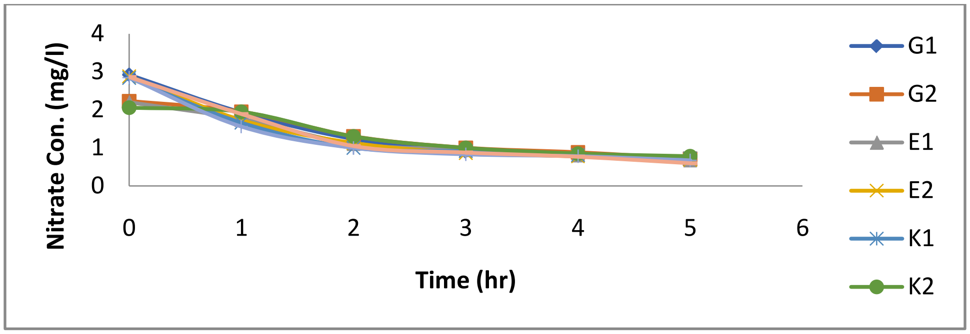


Figure 4.9: Effects of Rice Husk Adsorbent on Adsorption of Nitrates on different Stations (different LGAs)

Figure 4.9 shows the variation of plantain adsorbent in the adsorption of nitrates in the eight (8) stations of the four Local Government areas of Ogoni land with time. Nitrates present in the polluted stations (sites) were low in concentration and the adsorption ability of the nitrates using rice husk adsorbent is dependent on time of adsorption.

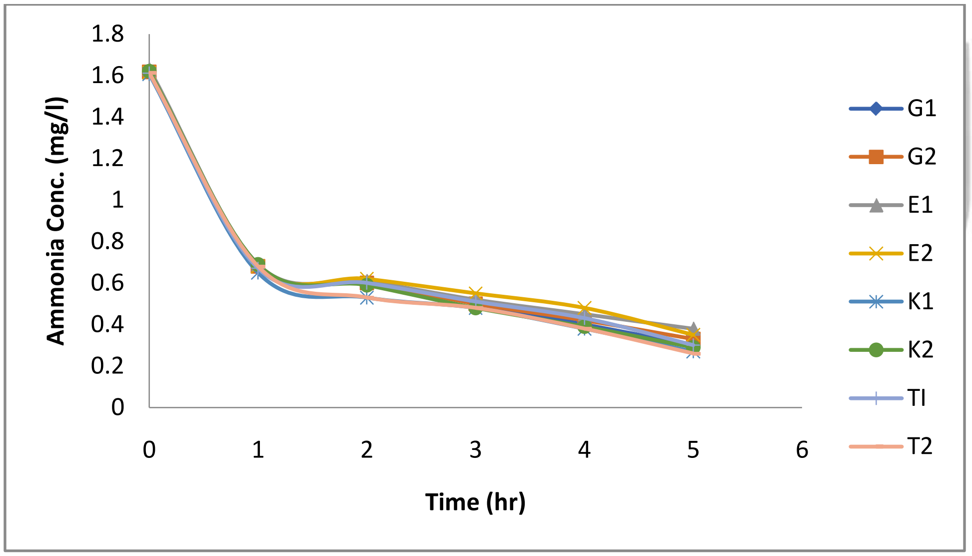


Figure 4.10: Effects of Rice Husk Adsorbent on Absorption of Ammonia on different Stations (different LGAs)

Figure 4.10 depicts the effect of rice husk absorbent in the absorption of ammonia and time of absorption. The concentration of ammonia decreases with time indicating that absorption of (NH_3) has taken place. The amount of ammonia present in the eight locations of the four Local Government Areas of Ogoni land were found to be low.

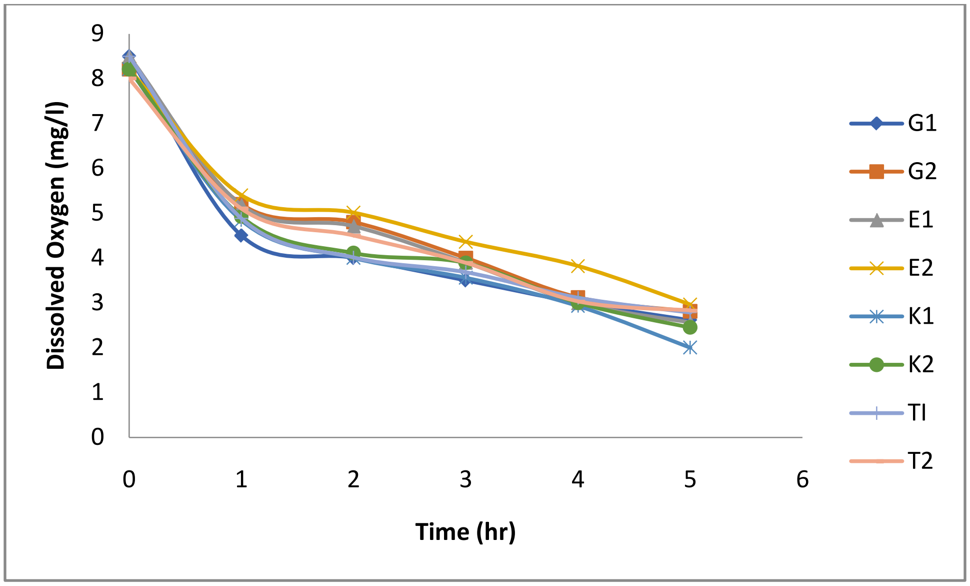
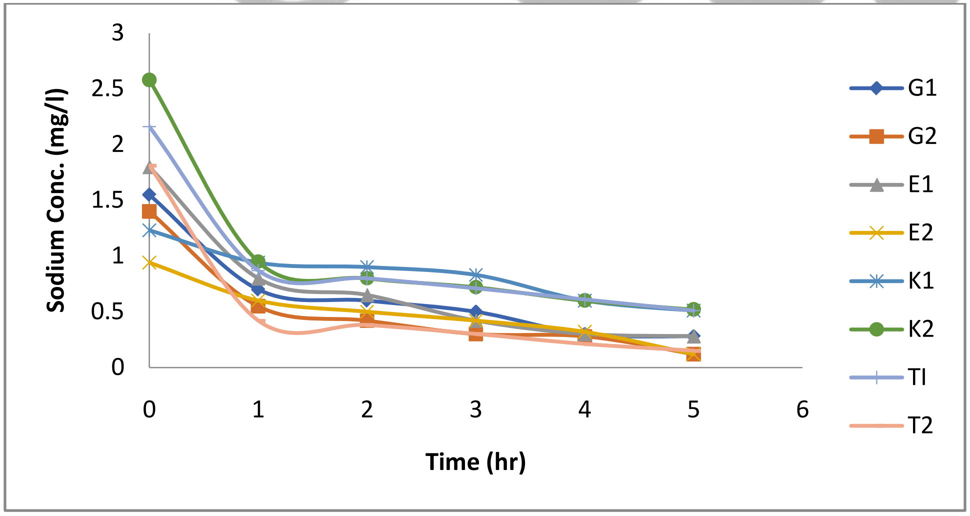


Figure 4.11: Effects of Rice Husk Adsorbent on Absorption of Dissolved Oxygen on different Stations (different LGAs)

Figure 4.11 demonstrates the effects of rice husk adsorbent in the absorption of dissolved oxygen in the contaminated areas of Ogoni land with time of absorption. Though the concentration of DO was relatively high in these areas the adsorbent was found to be effective.



14. **Figure 4.12: Effects of Rice Husk Adsorbent on Absorption of Sodium on different Stations (different LGAs)**

Figure 4.12 shows the variation of rice husk adsorbent on the adsorption of sodium ion with time. The concentration of Na in the areas sampled was low compared to the standard set. The exponential decrease of the amount of sodium in the sampled areas shows that the adsorbent is reliable and better for the absorption of Na.

Other contaminants analyzed in the eight (8) areas of the four different Local Government Areas of Ogoni land were TDS, conductivity, pH, Cl^- total hardness, sulphates, Fe and temperature. These pollutants have not been absorbed with either plantain or rice husks absorbents. This indicates that there are no effects of absorbents on the absorption of he listed pollutants analyzed in the areas

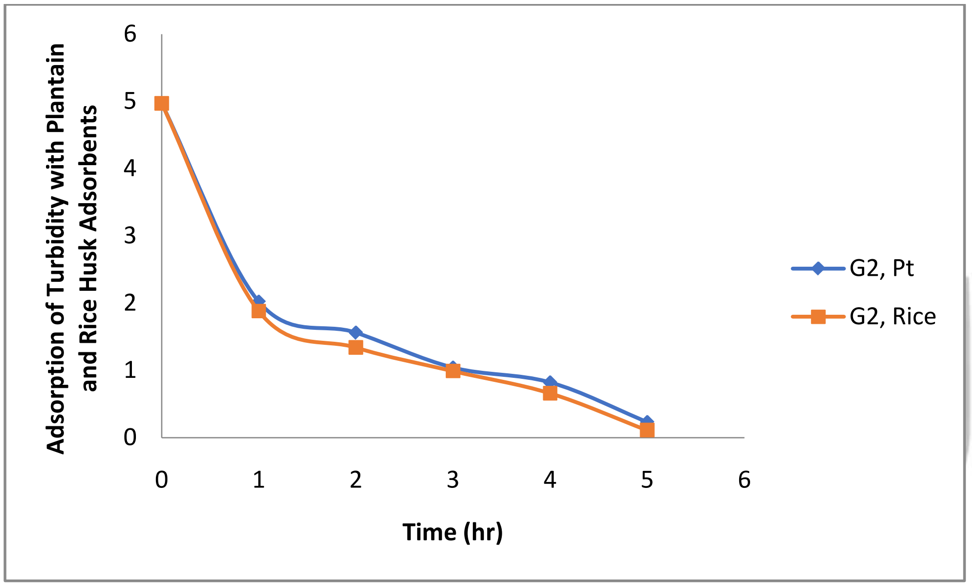


Figure 4.13: Effect of Adsorbents on the Absorption of Turbidity in Gokana LGA using Plantain Peel and Rice Husk

Figure 4.13 depicts the effects of absorbents on the absorption of turbidity in contaminated areas of Gokana Local Government Area. The performances of the absorbents i.e. plantain and rice husk absorbents on the absorption of turbidity in Yeghe-town especially in the Tomorrow's Leaders foundation compound where the sample was taken and analyzed is shown in figure 4.13. Rice husk adsorbent in more efficient and performed better than plantain adsorbent.

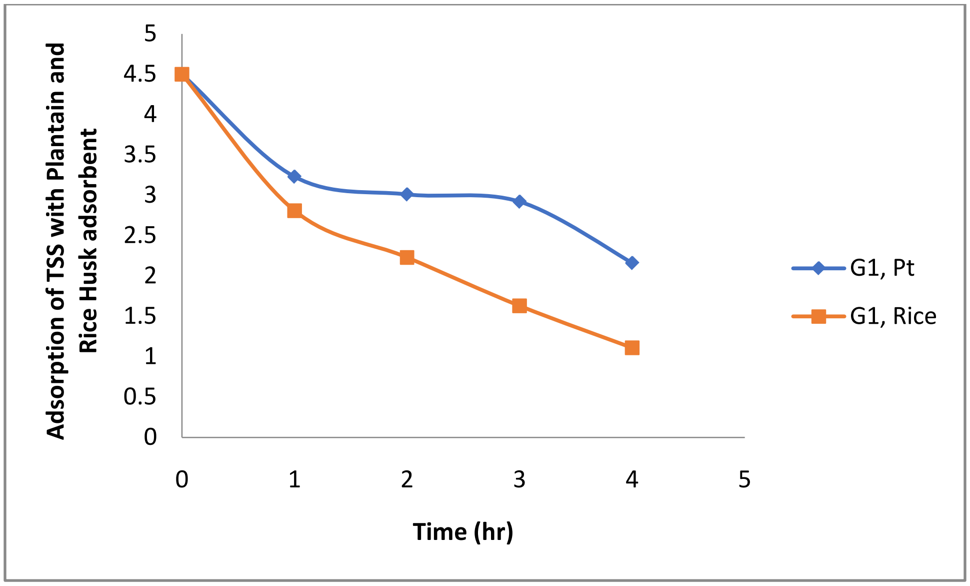


Figure 4.14: Effect of Adsorbents on the Adsorption of Total Soluble Solute (TSS) in Bodo City Area of Gokana LGA using Plantain Peel and Rice Husk adsorbent

Figure 4.14 demonstrate the performance evaluation of two different adsorbents on the adsorption of TSS samples taken from location of Mr. Ledibabari’s compound, Bodo City of Gokana Local Government Area. As shown, rice husk adsorbent performed better than plantain adsorbent because the amount of TSS adsorbed is more with rice husk than plantain adsorbent.

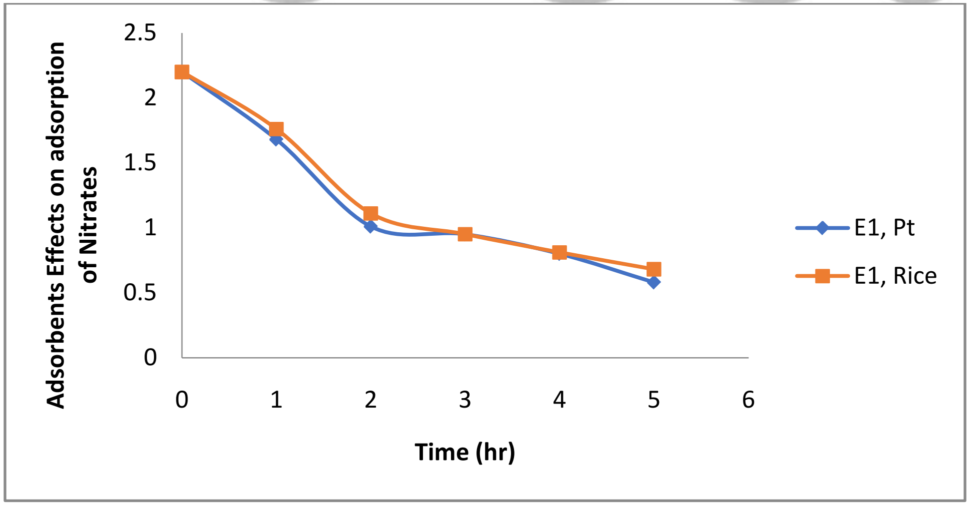


Figure 4.15: Effect of Adsorbents on the Adsorption of Nitrates in Ogale Area of Eleme LGA Using Plantain Peel and Rice Husk

From Figure 4.15, the performance evaluation of the adsorbents on the adsorption of nitrates taken from Mr. Stephen Osaro’s compound, Ogale town, Eleme Local Government Area showed that there was a drastic reduction in the amount of nitrates in the contaminated areas where the sample was collected and analyzed. As shown in figure 4.15, plantain adsorbent performed better than rice husk adsorbent.

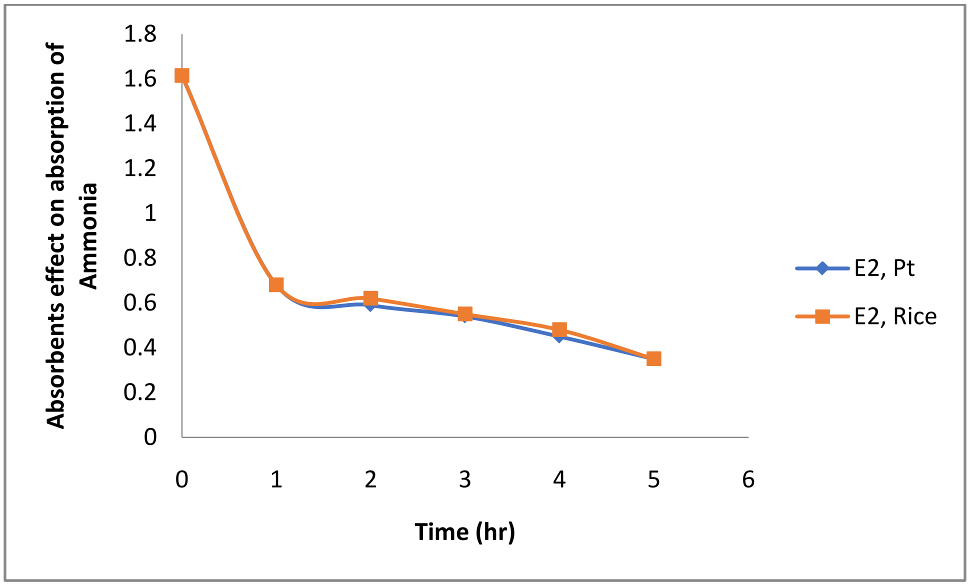


Figure 4.16: Effect of Adsorbents on the Absorption of ammonia in Trailer Park, Eleme LGA Using Plantain Peel and Rice Husk

Figure 4.16 indicates the effects of adsorbents on the absorption of ammonia, No difference was observed between the absorption effects of both adsorbents, This means that both adsorbents were found to be highly efficient.

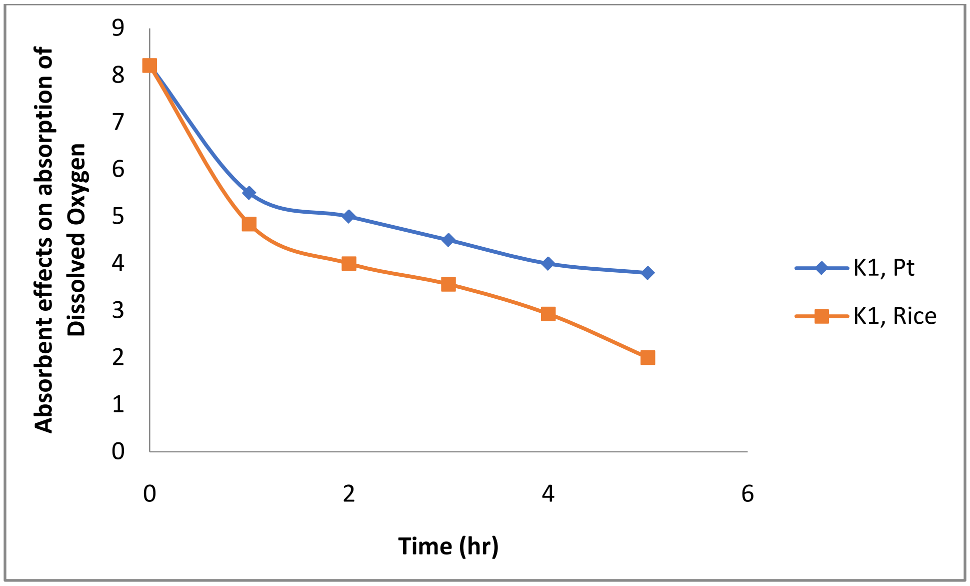


Figure 4.17: Effect of Adsorbents on the Absorption of Dissolved Oxygen in Kpea Town Area of Khana LGA Using Plantain Peel and Rice Husk

The effect of absorption of dissolved oxygen in community central bore hole, Kpea town, Khana Local Government Area of Ogoni land contaminated area with time is shown in Figure 4.17. the variation of the of the DO with time using plantain peel and rice husk adsorbents and the result indicated that rice husk adsorbent is a better adsorbent than plantain peels due to its effectiveness, though both adsorbents are good for absorption of DO, but the rice husk is better. As time increases the amount of DO present in the contaminated area reduces exponentially for both absorbents.

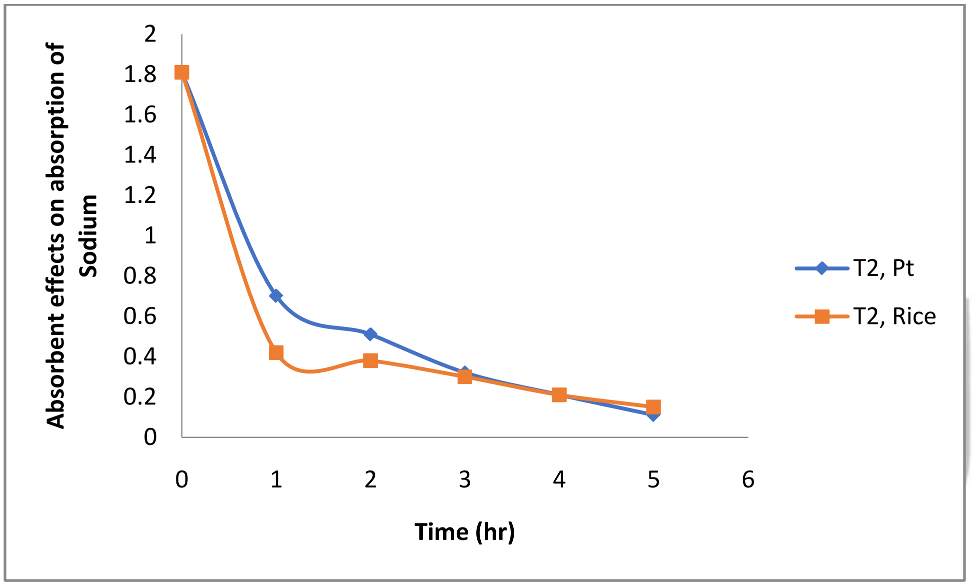


Figure 4.18: Effect of Adsorbents on the Absorption of Sodium in Norwa Town of Tai LGA

The performance evaluation of the different adsorbents on the adsorption of sodium ion in contaminated soil of Mr. Mbadee's compound Norwa town, Tai Local Government Area of Ogoni land was measured with time as shown in Figure 4.18. High amount of Na was adsorbed for both adsorbents as time increases, though rice husk performed better than plantain peels adsorbent. As time increases the amount of Na reduces exponentially.

4.1.1 Results Interpretation

Each four local government areas (Gokana, Eleme, Khana and Tai) used eight sites for sample collections : for Gokana, we have Mr. Ledibabari's compound Bodo City (G_1) and Tomorrow leader's foundation, Yeghe town (G_2); for Eleme, we have Mr. Stephen Osaro's compound, Ogale (E_1) and central mosque, trailer park (E_2); for Khana, we have community central borehole, Kpea town (K_1) and Mr. Emmanuel Neebani's compound, Lorre town (K_2); and for Tai, we have Tai secretariat (T_1) and Mr. Mbadee's compound, Norwa town (T_2).

Twenty-one (21) parameters were analyzed as a result of physio-chemical tests conducted on the eight sampling areas. These are states as thus: turbidity, TSS, TDS, Taste, conductivity, colour, pH, Cl^-, total hardness, SO_4^-, NO_3^- NH3, odour, temperature, Na, dissolved oxygen, E-coli, T-coli, THB, and Iron (Fe) out of these parameters; the one that were below the WHO/ united nation limits and are acceptable, thus making the underground water not to be polluted with these parameters are: Turbidity, TDS, conductivity, colour, taste, pH, Cl^-, total hardness, SO_4^-, NO_3^- THB, types of the coli, and Na. while the rest of the parameter after analyzed gave concentration above the WHO/united nation standard limits. Hence causes the underground waters of the 8 locations sampled polluted with these contaminants. The and contaminants are: TSS, Fe, NH_3, DO, temperature. These parameters are present in large amount compared to the standard set by WHO/United nations.

Plantain peels and rice husk activated carbon (after carbonization of the materials) gave absorbents which were used for the absorption of the pollutants. The results from the analysis indicated that only turbidity, TSS, nitrates, ammonia, DO and sodium were effectively and efficiently absorbed the parameters, the remaining parameters cannot be absorbed by these absorbents. So the initial analysis and the final ones were same throughout, no changes of concentrations whereas, for the former parameters (turbidity, TSS, SO_4^-, NO_3^-, DO and Na) changes their respective initial amount to very small amounts left after the must have been treated with both adsorbents. The effectiveness and performance evaluation of the absorbents were compared and rice husk adsorbent was majority the better one than the plantain peels adsorbent.

4.2 Adsorption of Metal ion (Na ion) and Composition Analysis of the Underground Water in the Locations

The kinetics models and isotherm adsorption models results are presented and discussed in Tables 4.13 and 4.14 and also Figures 4.19 to 4.33.

4.2.1 Effect on Na Metal Adsorption by the Adsorbent

The effects of initial Na metal concentration in solution, adsorbent dosage and contact time on the removal of in the polluted water by plantain peels and rice husk particles have been studied.

4.2.1.1 Effect of Initial Concentration on Adsorption Capacity of Adsorbents

Effect of initial concentration of Na metal on the adsorption capacity of adsorbents particles was carried out to determine the adsorption capacity of the particles in taking up Na ions in aqueous solution. The initial concentration of the investigated metal ions was varied from 10mg/l to 50mg/I at 10mg/I interval using 2mg dose of adsorbent in 100ml of the solution, The adsorbents particles at different times were left in the solution until equilibrium was established. The analysis of metal ions removed by the particles of adsorbents at equilibrium is shown in Figures 4.19, 4.20

Table 4.13: Parameters for various Kinetic Models: Initial Conc.=20mg/l; pH=6.7; Adsorbent dose = 5g and time = 1hr.

Kinetic Model	Parameter	Plantain Peels	Rice Husk
Pseudo-1st Order	$k_1(hr^{-1})$	0.1117	0.1217
	$q_e(mg/g)$	4.852	4.431
	R^2	0.816	0.898
Pseudo-2nd Order	$k_2\left(\frac{g}{mg}.hr^{-1}\right)$	0.0058	0.00164
	$q_e(mg/g)$	119	115
	R^2	0.952	0.963
Elovich Kinetics	b (g/mg)	0.0416	0.407
	$\varphi\left(\frac{mg}{g}.hr^{-1}\right)$	50.161	50.779

	R^2	0.98	0.985
Intra-Particle Diff.	$k_d\left(\frac{mg}{g}.hr^{-1}\right)$	31.577	32.186
	R^2	0.989	0.993

Table 4.13: Adsorption Isotherm Parameters for the Adsorption of Na ion onto Adsorbents Particles

Adsorption Isotherm Model	Parameter	Plantain Peels	Rice Husk
Langmuir	$q_m(mg/g)$	22.22	0.0832
	$k_L(l/g)$	5.845	25
	R^2	0.816	0.898
	R_L	0.0077	0.0018
Freundlich	N	2.1	0.61
	k_f	27.65	23.956
	N	2.1	0.61
	R^2	0.675	0.919
Tempkin	B(J/mol)	-20.989	-65.73
.	$A_T(l/mg)$	0.346	0.759
	R^2	0.979	0.979
Dubinin-Radushkevich	$\varepsilon(kJ/mol)$	2.8	3.1
	$\beta(mol^2/kJ^2)$	6.28E-7	5.22E-7
	R^2	0.979	0.978

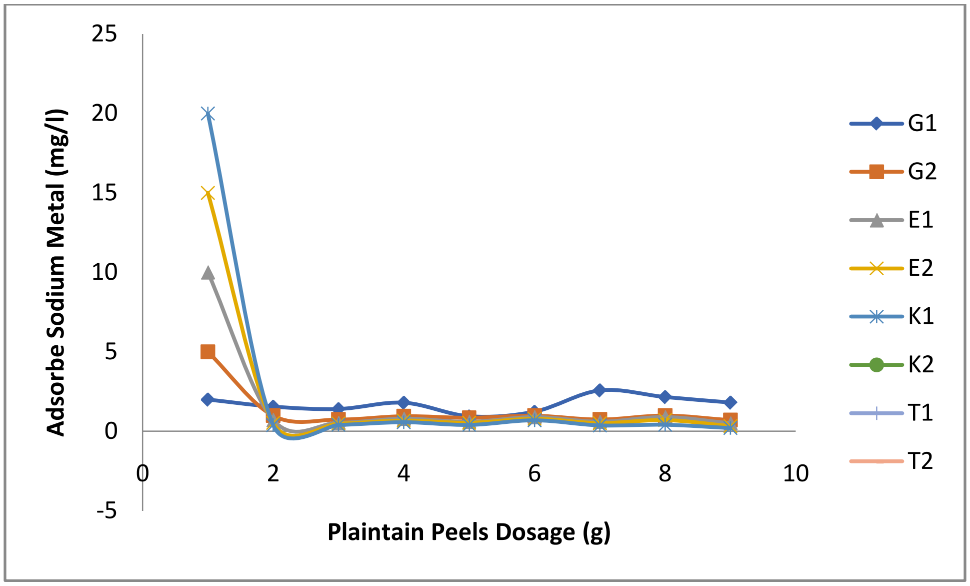


Figure 4.19: Effect of Plantain Peels Adsorbent Mass on Na Removal

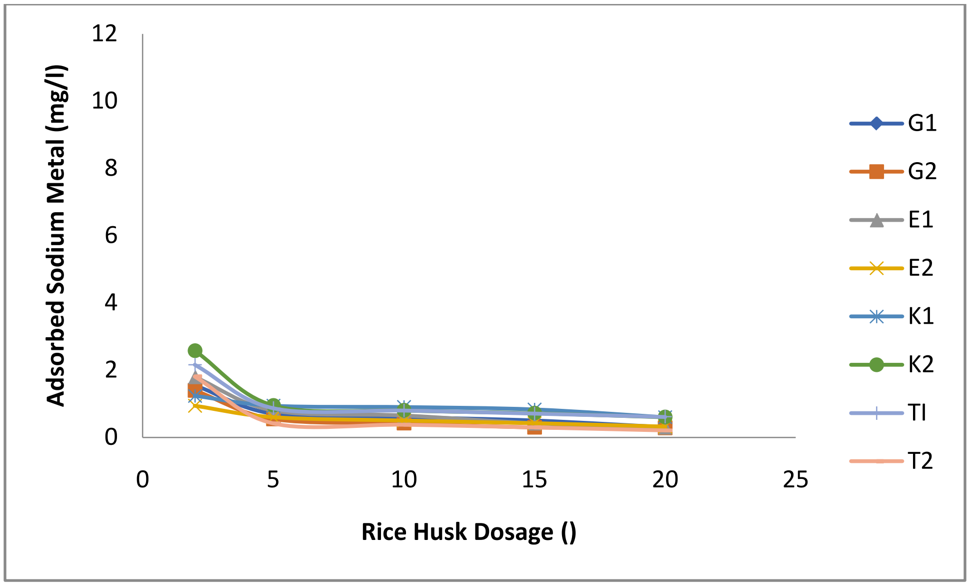


Figure 4.20: Effect of Rice Husk Adsorbent Mass on Na Removal

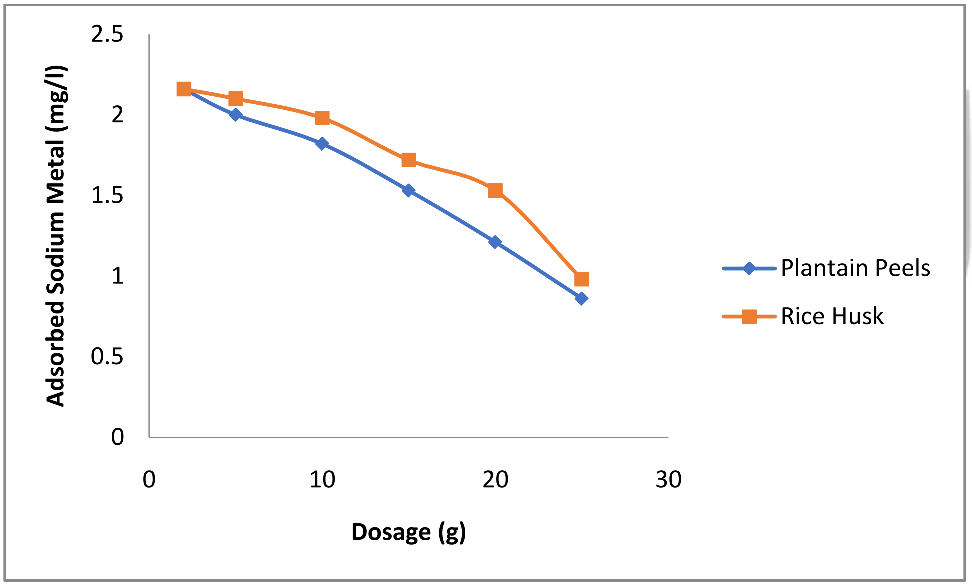


Figure 4.21: Effect of Adsorbents Mass on Na Removal

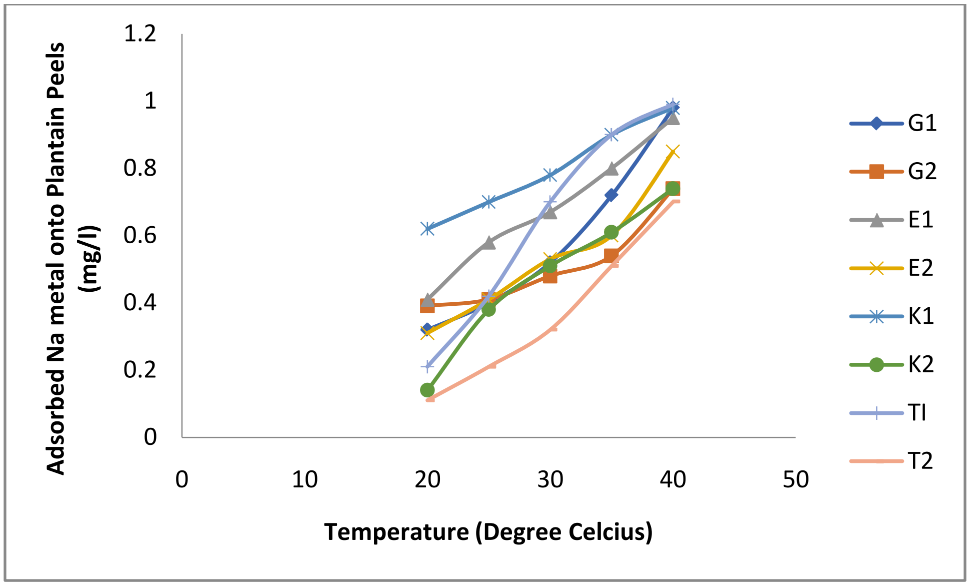


Figure 4.22: Effect of Temperature on Na Adsorption onto Plantain Peels Particles on the eight sites

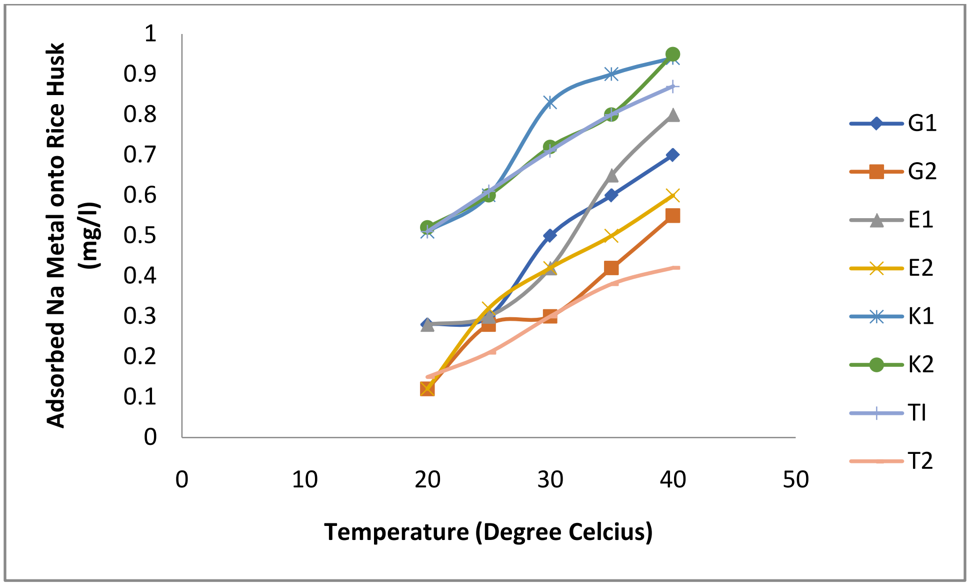


Figure 4.23: Effect of Temperature on Na Adsorption onto Rice Husk Particles on the eight sites

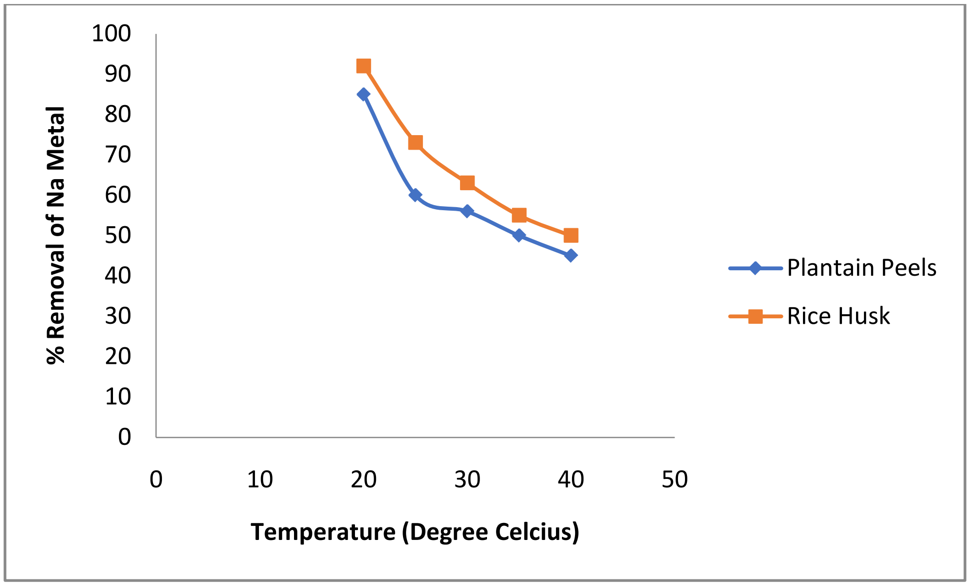


Figure 4.24: Effect of Temperature on Na Adsorption onto Adsorbents Particles on the eight sites

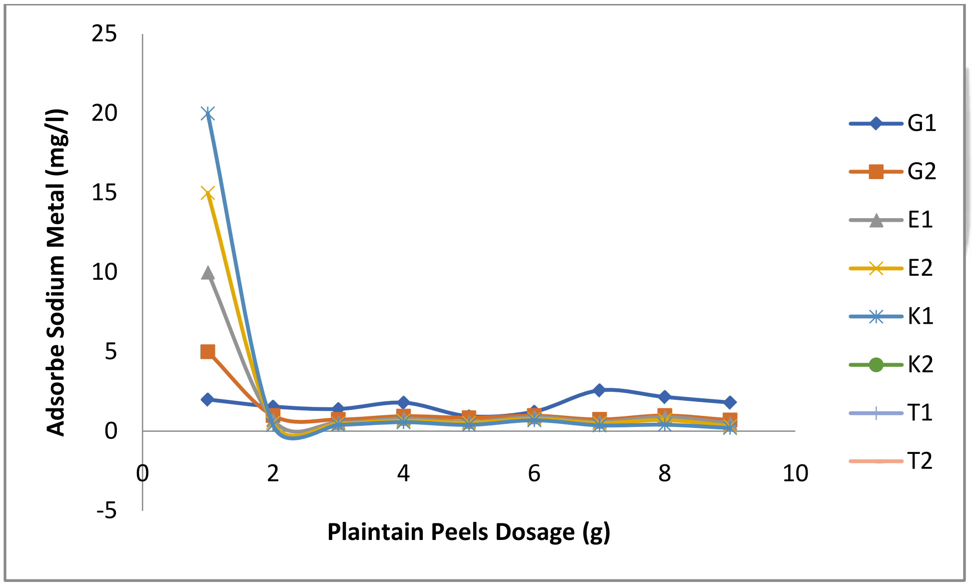


Figure 4.19: Effect of Plantain Peels Adsorbent Mass on Na Removal

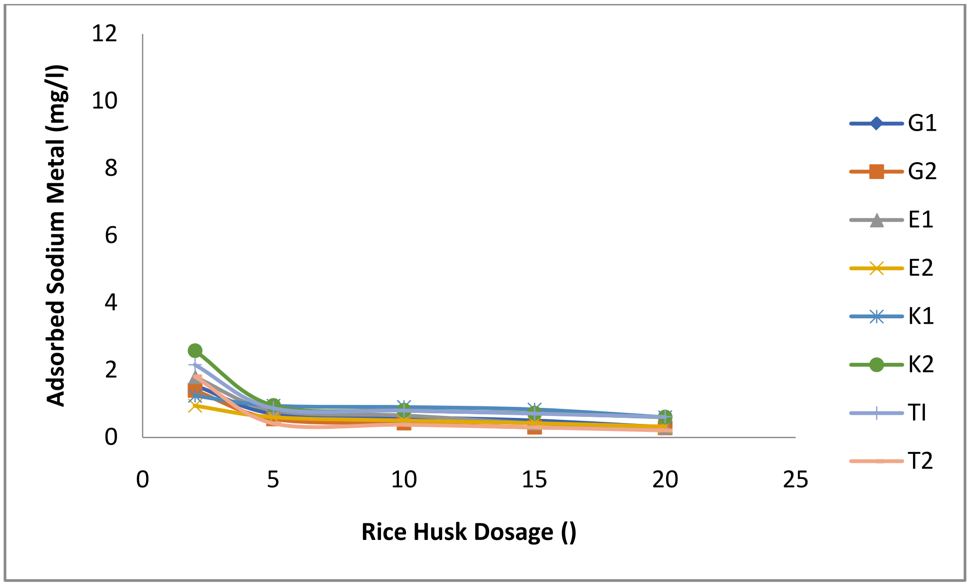


Figure 4.20: Effect of Rice Husk Adsorbent Mass on Na Removal

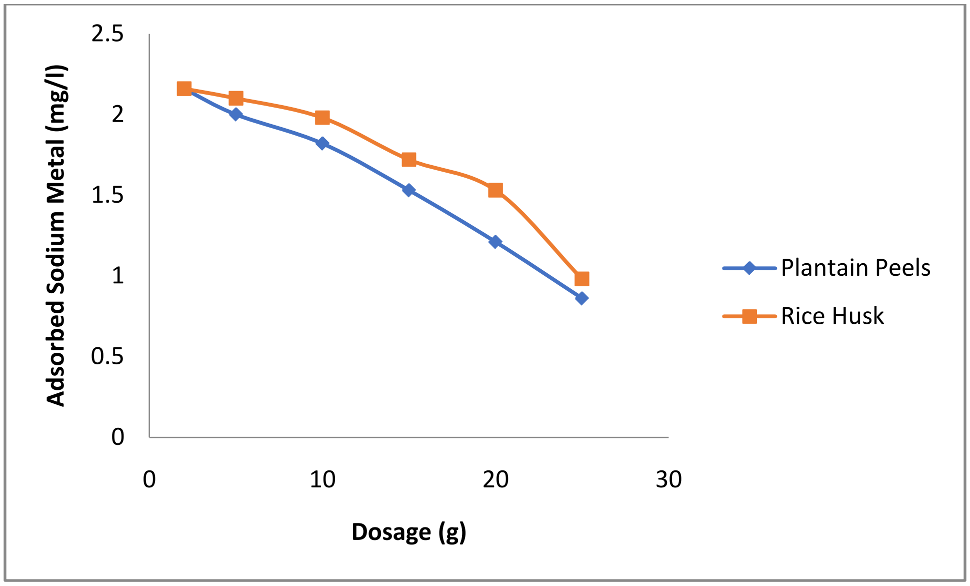


Figure 4.21: Effect of Adsorbents Mass on Na Removal

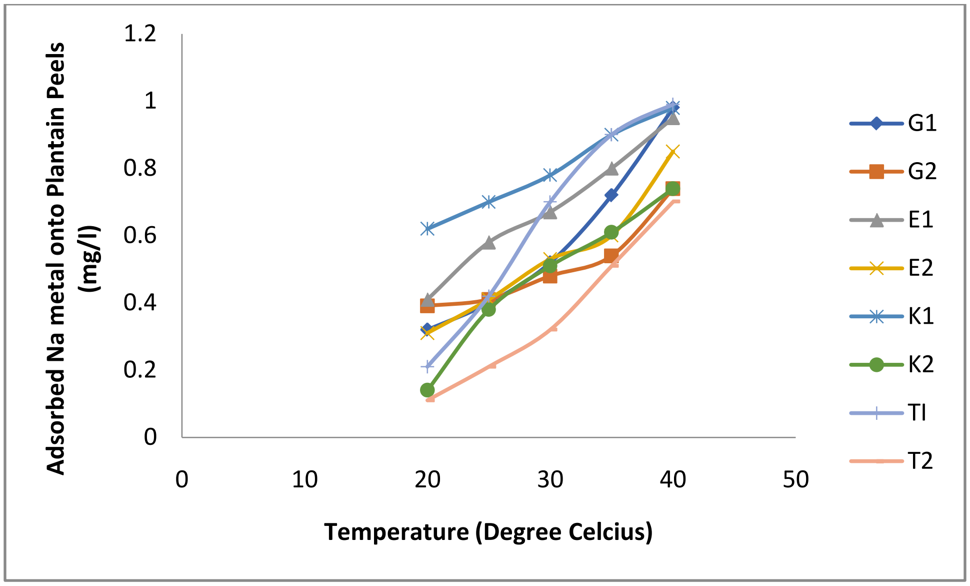


Figure 4.22: Effect of Temperature on Na Adsorption onto Plantain Peels Particles on the eight sites

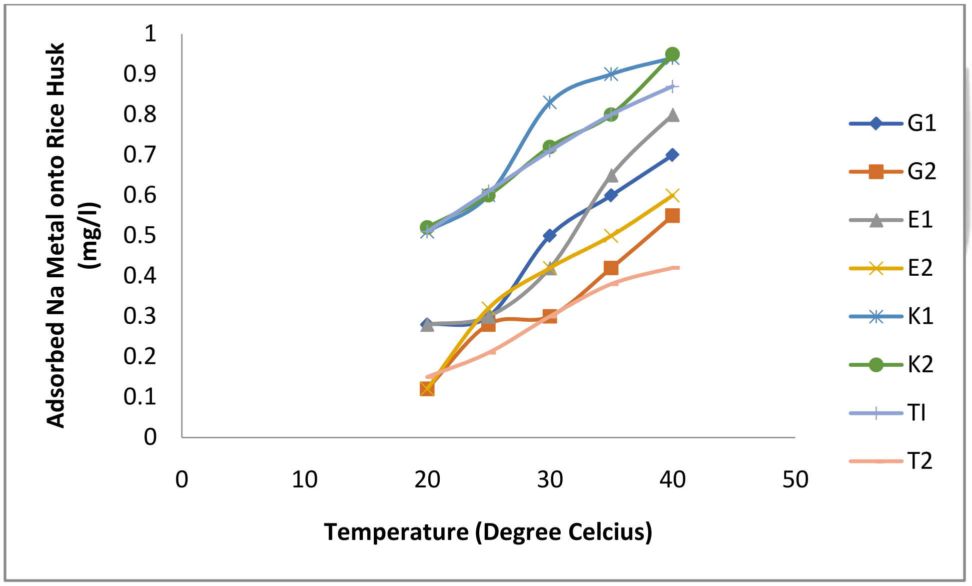


Figure 4.23: Effect of Temperature on Na Adsorption onto Rice Husk Particles on the eight sites

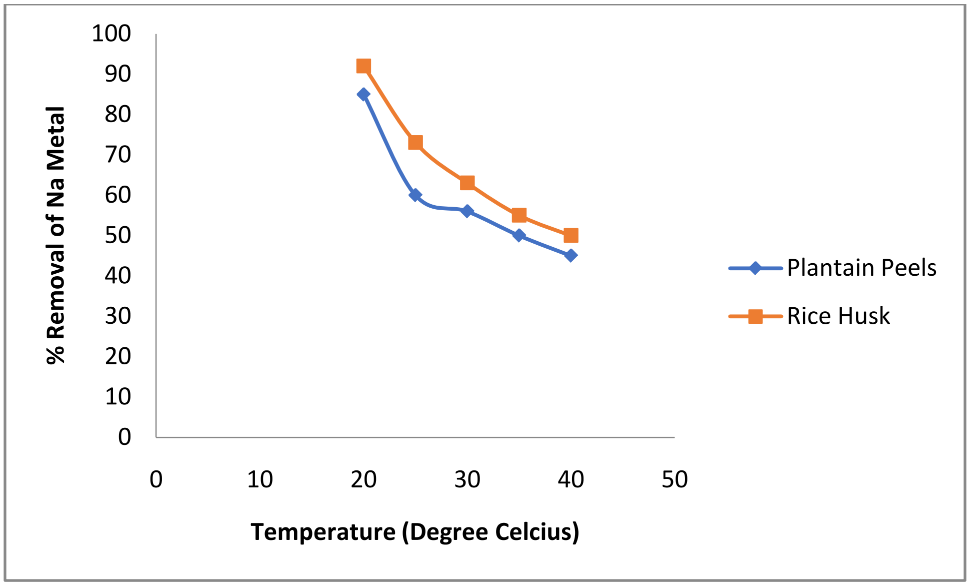


Figure 4.24: Effect of Temperature on Na Adsorption onto Adsorbents Particles on the eight sites

The adsorption of Na ion in aqueous solution by Plantain Peels or rice husk differs. However, there was remarkable reduction of metal concentration in the solution, indicating that particles of Plantain Peels and rice husk are promising adsorbents for metal removal in aqueous solution. Figure 4.19 shows the amount of Na ion adsorbed by Plantain Peels particles from the solution at various initial concentrations of the metals. Also, Figure 4.20 shows the metal adsorbed by rice husk particles in same solution. Thus in both cases, increase in initial concentration of metal in solution decreases the amount of metals removed by particles of Plantain Peels and rice husk. Thus, the concentration of Na adsorbed by Plantain Peels from the solution at equilibrium decreased from their initial values of the different locations to very small amounts in mg/l when its concentration was increased from 10mg/l to 50mg/l. In the same vein, similar situation was observed with rice husk particles. Thus at equilibrium, the concentrations of Na adsorbed by the rice husk particles decreased from initial values to smaller amounts in mg/l for the eight sites measured respectively as concentration in the solution was increased from I 0mg/I to 50mg/I.

The reductions in concentration of adsorption of metal by the adsorbents were attributed to the increased amount of contaminants in the solution. Thus, it implied that there was not enough space for the adsorbent to take up more of the metals at the given dosage. Ademiluyi and Ujile (2013) observed similar trend while investigating the capacity of activated bamboo carbon for removal iron (II) ion from its solution; and reported that the reduction in percentage adsorption was due to availability of more reactive sites on the pore of adsorbent. In another study, the fixed weight of adsorbent dosage was attributed to be the reason for decrease in percentage removal of metals in solution (Kumer *et al.*, 2010). Kumer *et al*., (2010) further explained that increase in initial concentration of metal ion (Pb) in solution also improved interaction between lead ion and the adsorbent.

4.2.2 Effect of Adsorbents Dosage on the Adsorption of Na Metal

The effect of Plantain Peels and rice husk dosage on the removal of Na ions has been investigated. The adsorption of Na metal from aqueous solution containing 10mg/I concentration each of the metals was investigated at different dosage of Plantain Peels and rice husk particles of weights 2, 5, 10, 15 and 20g in 100 ml of the solution. Again, like the effect of initial concentration, each experimental analysis of Plantain Peels and rice husk particles were left in the solution until equilibrium was attained. The amount of Na ions adsorbed by the particles of Plantain Peels and rice husk at equilibrium is shown in Figures 4.21. The effect and comparison of Plantain Peels and rice husk dosage on the adsorption of Na ions from the solution is presented in Figures 4.21. It was observed that increase in adsorbent dosage of both Plantain Peels and rice husk particles consequently increased the adsorption of the metals. This trend had also been reported in many studies for the removal of heavy metals by either rice husk, Plantain Peels or other modified particles of plants (Kumar *el al*., 2010; Chowdhury *et al.,* 2012; Ademiluyi and Ujile, 2013 and Sharma *et al*., 2016). Kuniar *et al*., (2010) attributed the high percentage removal at increased adsorbent dosage to overlapping of adsorption sites due to over-crowding of adsorbent particles, while Ademiluyi and Ujile (2013) attributed it to increase in effective surface area and conglomeration of the adsorbent.

On comparison as shown in Figure 4.21, rice husk particles adsorbed the Na ions in solution than Plantain Peels particles at all doses. In the finding, both Plantain Peels and rice husk particles have high affinity to Na ion.

The adsorption of Na ion in aqueous solution by Plantain Peels or rice husk differs. However, there was remarkable reduction of metal concentration in the solution, indicating that particles of Plantain Peels and rice husk are promising adsorbents for metal removal in aqueous solution. Figure 4.19 shows the amount of Na ion adsorbed by Plantain Peels particles from the solution at various initial concentrations of the metals.

4.2.3 Effect of time on the adsorption of Na ion onto Temperature

The effect of temperature on the absorption process studied of varying temperature (20^{o}C – 40^{o}C). The result is presented in Figures 4.22 to 4.24 on the various locations and also compared with the type of adsorbents. As shown in Figures 4.22 and 4.23, there is generally increase in adsorption of Na metal ion onto the surface of the plantain peels and rice husk adsorbents respectively on all the locations sampled. This indicates that the adsorption process is exothermic (Ifelebuegu *et al.*, 2018; Tian *et al.*, 2009). Na ion can exhibit the inclination to migrate to the bulk of the solution from the solid phase as the temperature of the solutions increases (Karaca *et al.*, 2004). Low energy requirement for Na ion decreases as a result of high temperature on the surface of adsorbents particles. Similarly, Figure 4.24 indicates the comparison of adsorbents on the percentage removal of Na ion in solution. However, rice husk adsorbent adsorbed more of the metal ion in solution than plantain ion, although both are good adsorbents. (Mall *et al.*, 1998; Kose and Kivanc, 2011) reported that adsorbents sites for adsorption function depending on the variation of temperature, hence the reason why rice husk adsorbed more Na ion than plantain peels.

4.3 Adsorption Kinetics

The adsorption kinetics was carried out for a period of 5hrs at initial 20mg/l initial concentration of Na ion and 20g dose of the plantain peels and rice husk adsorbents at 1hr interval and the results fitted into the kinetics of pseudo-1st and 2nd order, Elovich and intra-particle diffusion kinetics as shown in Figures 4.25 to 4.28.

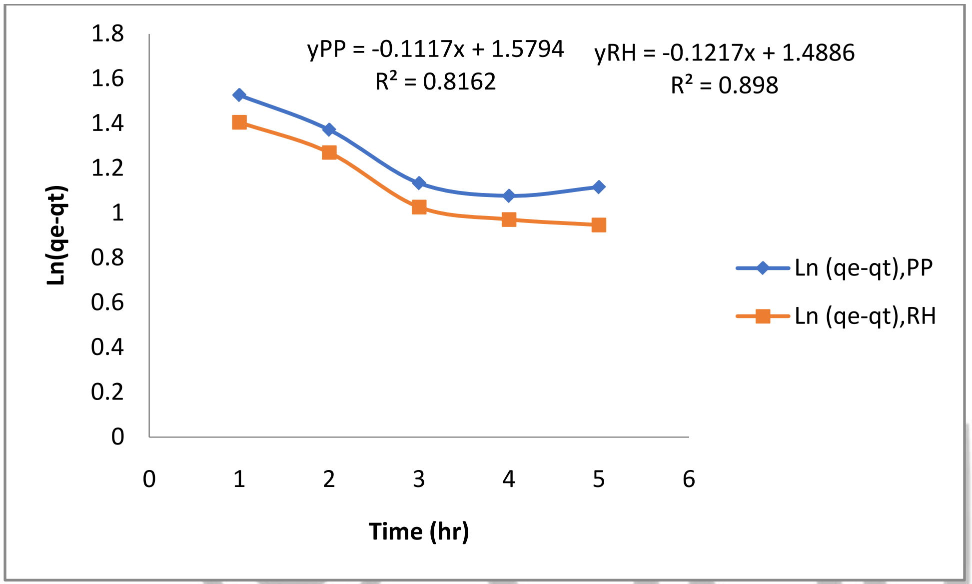


Figure 4.25: Pseudo-1st Order Kinetics with Plantain Peels and Rice Husk Adsorbent

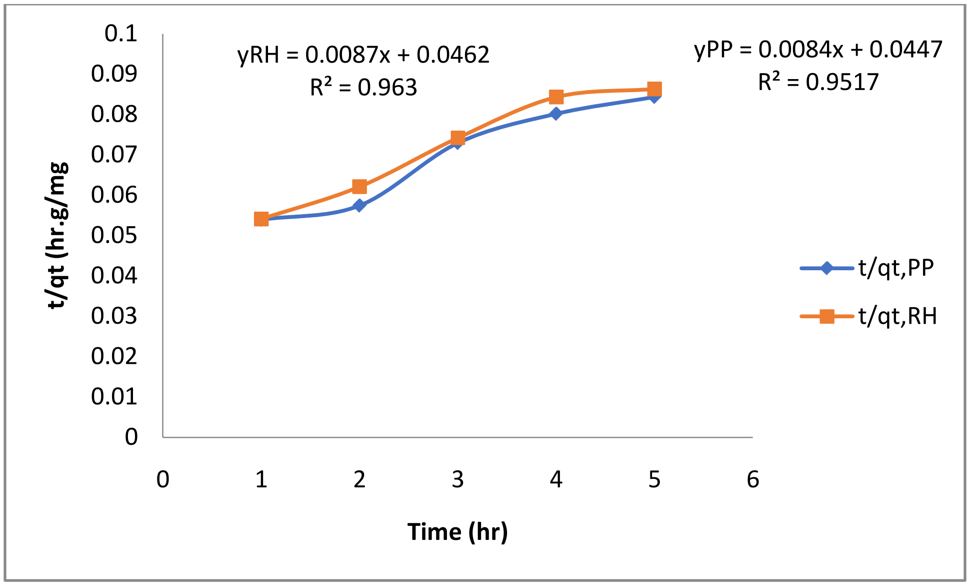


Figure 4.26: Pseudo-2nd Order Kinetics with Adsorbents

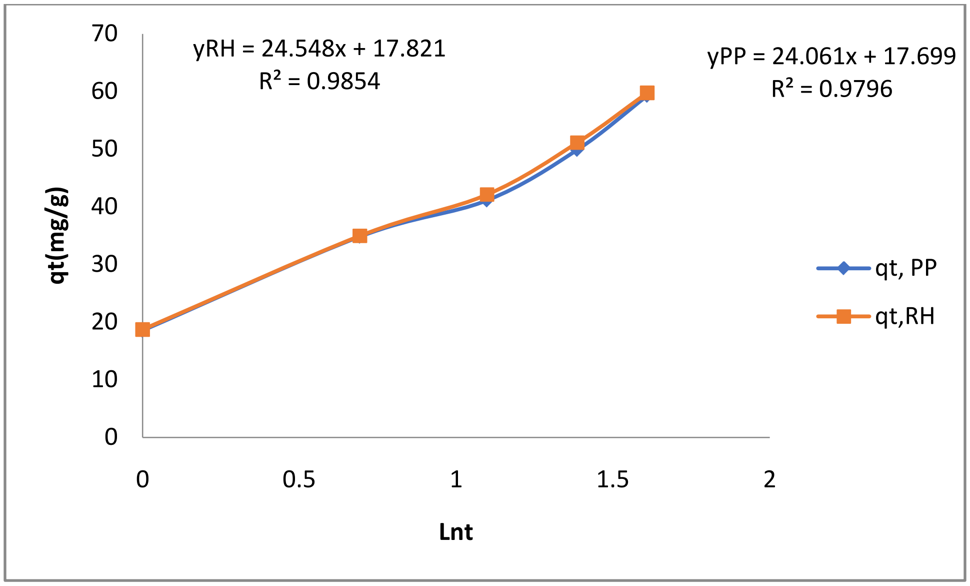


Figure 4.27: Elovich Kinetics Kinetics with Adsorbents

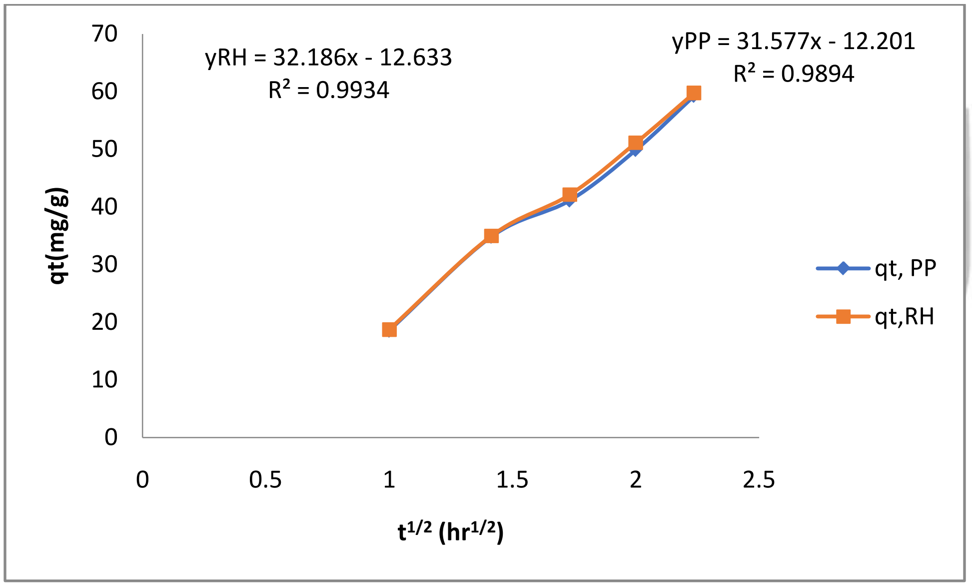


Figure 4.28: Intra-Diffusion Kinetics of Na Metal onto Adsorbents Particles

The kinetics of adsorption of Na ion in solution onto plantain peels and rice husk particles has been performed. Thus, the kinetic describing the adsorption process had been utilized as depicted in Figures 4.25 to 4.28. The linear plots revealed that the adsorption of Na ion did not only occurs on the surface of the adsorbents but also due to chemisorption and diffusion, the adsorption of Na ion plantain peels and rice husk particles as applied to the Pseudo First Order kinetics is shown in Figure 4.25. The first order rate constant with respect to the Na ions differs with respect to adsorbents. Thus, the first order rat constant, k1 is 0.1117hr^{-1} for plantain peels and 0.1217hr^{-1}for rice. Also, the predicted equilibrium adsorption capacity by the Pseudo First Order kinetics plantain peels and rice husk are respectively 4.852mg/g and 4.431mg/g

In the same vein, as shown in Figure 4.26, the second order rate constant, k2 for Na ions using plantain peels and rice husk particles is given as 0.0058 g/mg.hr and 0.00164 g/mg.hr respectively. Again, the predicted equilibrium adsorption capacity by the Pseudo Second Order kinetics for Na ions with plantain peels and rice husk particles are 119mg/g and 115mg/g respectively. This is further demonstrated by the R-squared values on the figures. Similar observation on comparison of First and Second Order Pseudo Kinetics has been reported in recent studies (Li *et al*., 2016; Sharma *et al*., 2016 Azizi *et al*., 201 7 and Kulkami *et al*., 2017).

Figure 4.27 is the elovich kinetics plot with initial rate of adsorption α for Na ions using plantain peels and rice husk particles as 50.161mg/g.hr and 50.779mg/g.hr respectively. Again, the predicted surface coverage and activation energy for chemisorption for Na ions with plantain peels and rice husk particles are 0.0416g/mg and 0.0407g/mg respectively.

The linear plots on Figure 4.28 showed the plots for intra-particle diffusion describing the diffusion of Na ions into the particles of plantain peels and rice husk adsorbents. The intra-particle diffusion plot alongside the Pseudo First and Second Order Kinetics was used to ascertain the mechanism and rate controlling step of the adsorption process. Thus, in both particles, the linear lines do not pass through the origin for adsorption of Na ions. Though, there was effect of diffusion and chemisorption, but the failure of the linear plots to pass through the origin implied that the adsorption was not controlled by intra-particle diffusion. This was also observed by other studies for adsorption of heavy metal in aqueous solution (Ademiluyi and Ujile, 2013; Li *et al*., 2016 and Kulkarni *et al*., 2017). However, the diffusion rate constant, K_d for adsorption of Na ions onto particles of plantain peels and rice husk are 31.577 mg/g.hr$^{-0.5}$ and

32.186 mg/g.hr$^{-0.5}$ respectively. Finally, the R-squared values on the plots for the pseudo first and second order kinetic model as well as the intra-partiele diffusion model revealed that the pseudo second order model fits better with experimental data. Therefore, the pseudo second order kinetics is the rate controlling step for the adsorption process.

4.4 Adsorption Isotherm

The adsorption isotherm was studied by varying the initial concentration of Na ions in the underground water with 20g dose of plantain peels and rice husk particles in 100 ml of aqueous solution at room temperature of 25 °C. The batch adsorption process was left in the solution until equilibrium was attained at each initial concentration of the metals. The Langmuir and Tempkin isotherm were used to study the adsorption process of adsorbents particles.

4.4.1 Langmuir Isotherm

The Langmuir isotherm for adsorption of Na ions in solution onto plantain peels and rice husk particles is shown in Figures 4.29a and 4.29b.

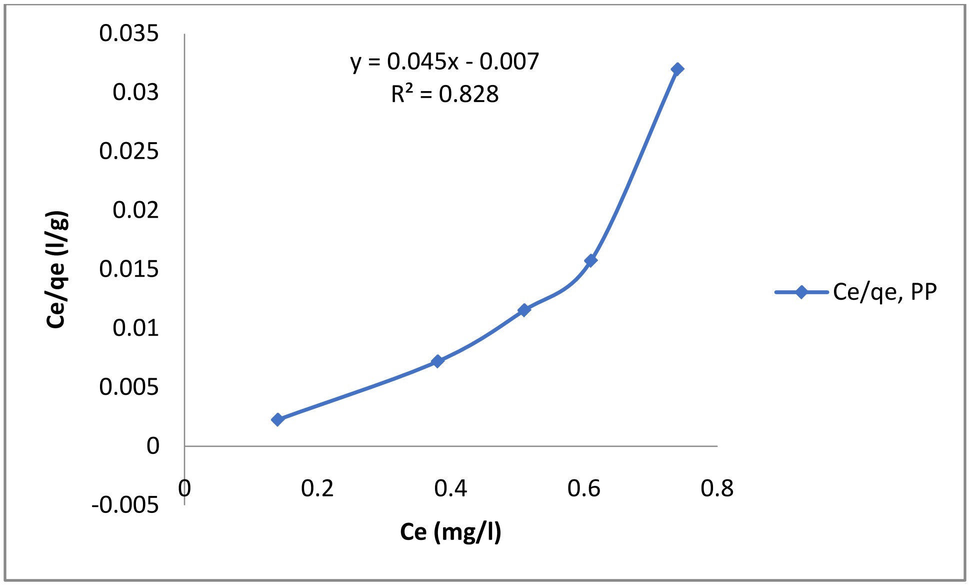


Figure 4.29a: Langmuir Isotherm for Na using Plantain Peels

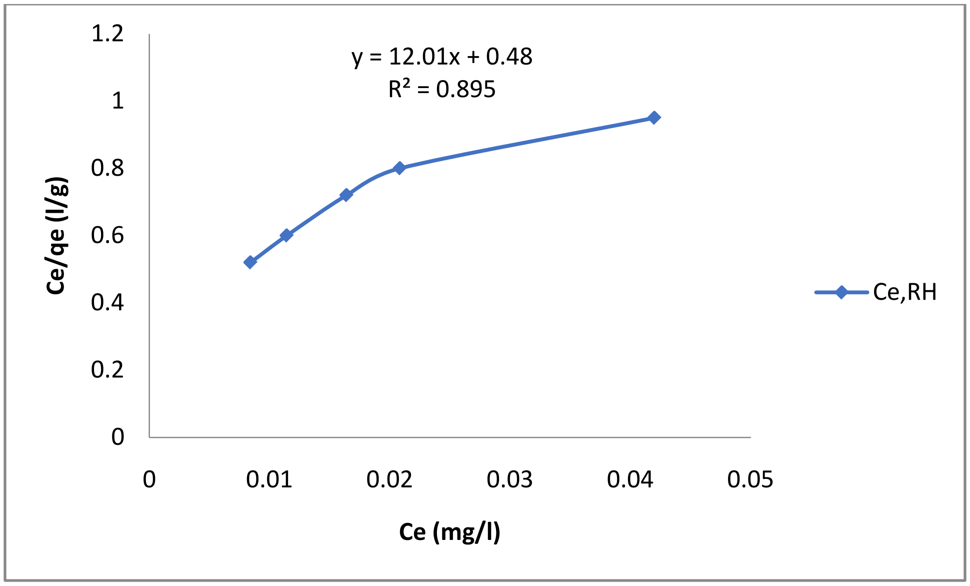


Figure 4.29b: Langmuir Isotherm for Na using Rice Husk

The plot of the ratio of concentration in solution to the concentration adsorbed onto the adsorbent (Ce/qe) versus the concentration in solution (Ce) at equilibrium shows a linear relation, which depicts that Langrnuir isotherm model can be used for this study. It is clearly shown on the plots that the rate of adsorption increased as concentration of metals in solution at equilibrium increases. Thus, increase in the amount of metal in solution speeds up the uptake rate. The linearity of the plots in the Figures 4.29a and 4.29b indicates that the Langmuir model explained what exactly transferred in the physical phenomena during the adsorption process. The adsorption capacity, q_m of plantain peels and rice husk for Na ion are respectively 22.22 mg/g, 0.0832 mg/g and Langmuir constant for the adsorption for the adsorbents too are 5.845 l/mg and 25l/mg respectively for the plantain peels and rice husk. However, the correlation coefficient R^2 for the three Na metal ions is between 0.814 and 0.816 across the two adsorbents, which implied that the isotherm is consistent with Langmuir model. Thus, the constant parameters in the Langmuir isotherm model and the R-squared values for two adsorbents are presented in Table 4.13. Kumar and Shrivastava (2015) reported 6.84mg/g with neem adsorbent and 4.63mg/g with rice husk adsorbent, for the removal of Na ion from wastewater. Also, Sharma et al. (2016)

reported a value of 7.2993mg/g for same chromium ion adsorption from wastewater using a mixture of tea and garlic.

4.4.2 Freunlich Isotherm

The Freundlich isotherm for adsorption of Na ions in solution onto plantain peels and rice husk particles is shown in Figures 4.30a and 4.30b.

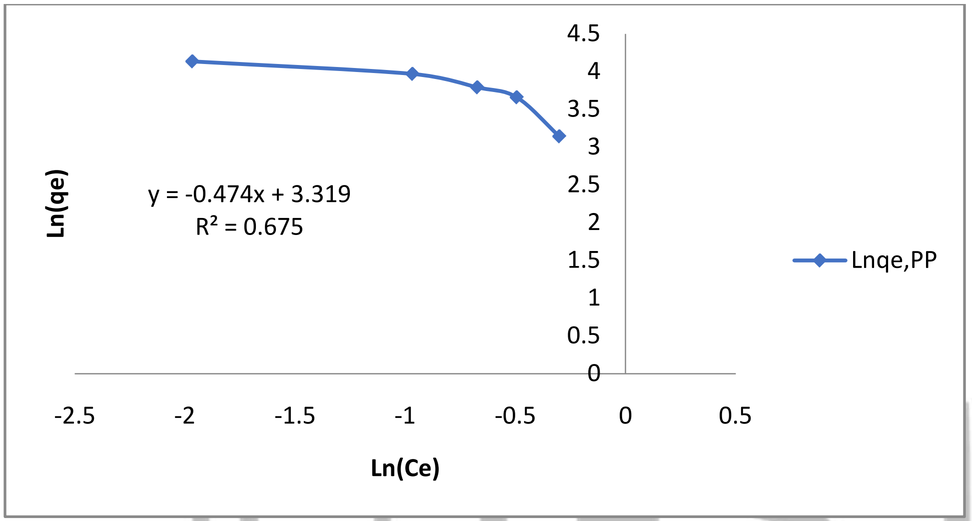


Figure 4.30a: Freundlich Isotherm for Na using Plantain Peels

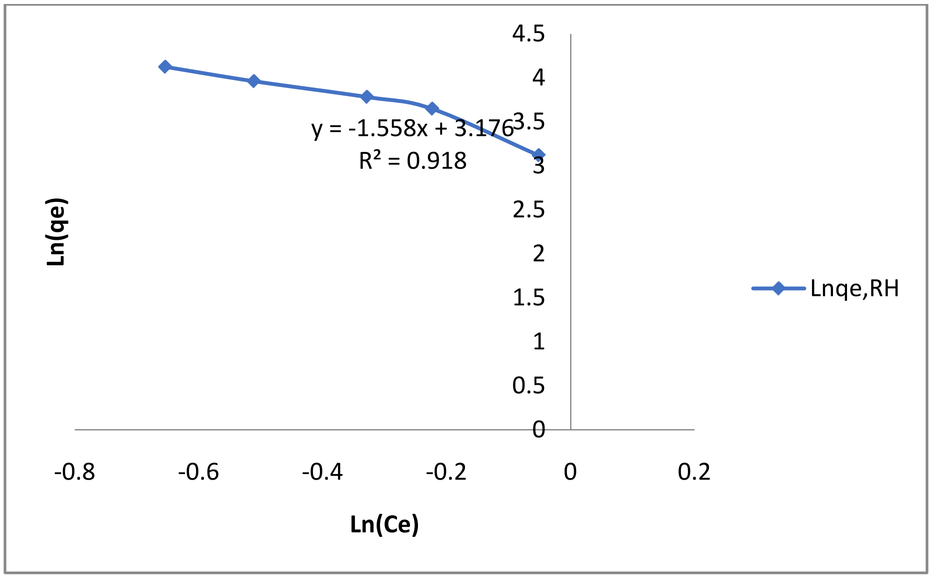


Figure 4.30b: Freundlich Isotherm for Na using Rice Husk

The Freundlich isotherm model for adsorption of Na ion in solution onto plantain peels and rice husk particles is shown in Figures 4.30a to 4.30b. The Freundlich isotherm model showed decrease in concentration of Na metal uptake by the adsorbents. The adsorption intensity relating to the plantain peels and rice husk particles as obtained from Table 4.13 are respectively -2.1 and -0.64 while the freundlich isotherm constant of adsorption (k_f) was 27.65 and 23.956. Similarly, the correlation coefficient R^2 for the three Na metal ions is between 0.675 and 0.919 across the two adsorbents. This was revealed through the correlation coefficient indicated in the figures. This observation has also been reported by Sharma *et al*., (2016) for adsorption of Na ion from wastewater onto mixture of rice husk particles.

4.4.3 Tempkin Isotherm

The Tempkin isotherm for adsorption of Na ions in solution onto plantain peels and rice husk particles is shown in Figures 4.31a and 4.31b.

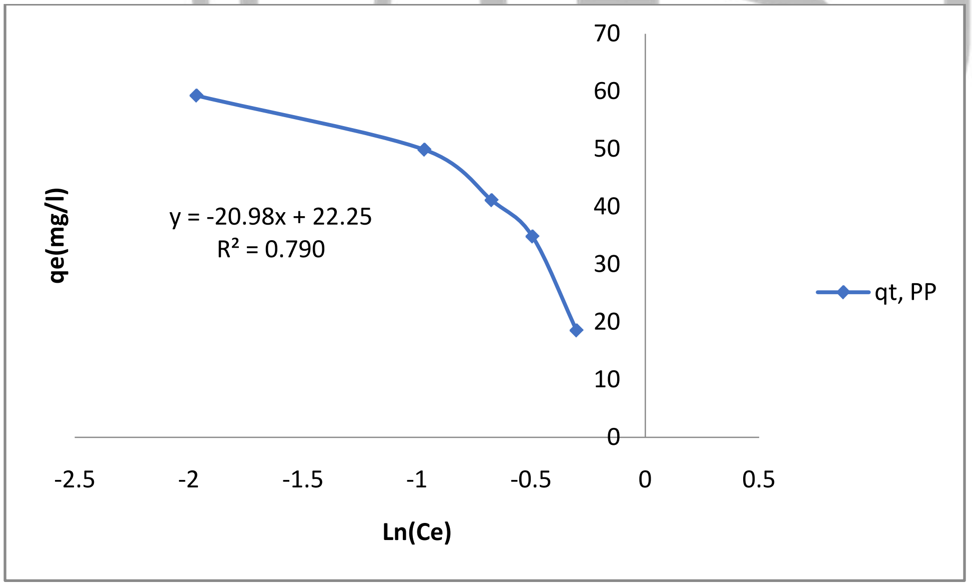


Figure 4.31a: Tempkin Isotherm for Na using Plantain Peels

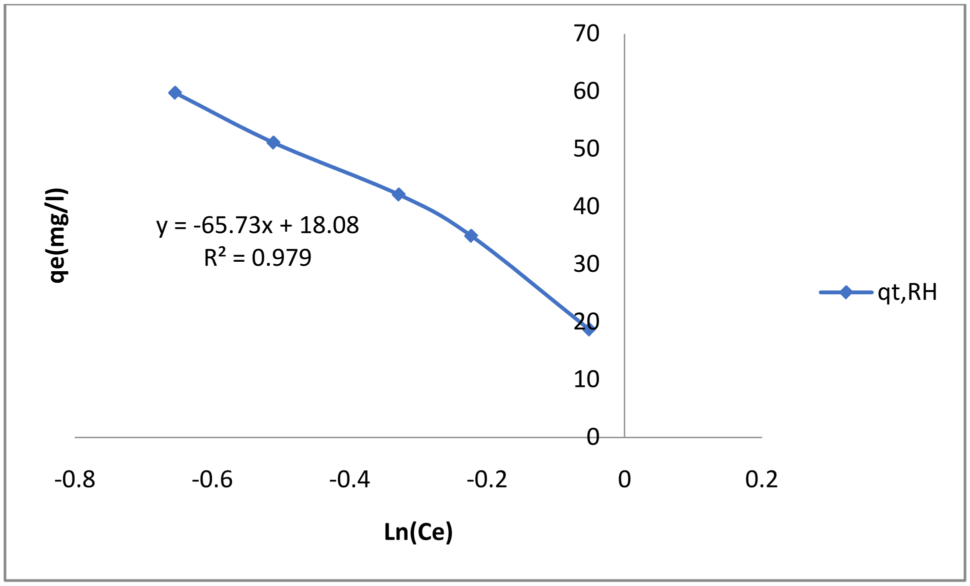


Figure 4.31b: Temkin Isotherm for Na using Rice Husk

The Temkin isotherm model for adsorption of Na ion in solution onto plantain peels and rice husk particles is shown in Figures 4.31a to 4.31b. The Temkin isotherm model showed decrease in concentration of Na metal uptake by the adsorbents. The adsorption heat (B) relating to the plantain peels and rice husk particles as obtained from Table 4.13 are respectively are -20.989 J/mol and -65.73J/mol. Similarly, the Temkin isotherm equilibrium binding constant (A_T) for adsorption of Na ion onto plantain peels and rice husk were 0.3463l/mg and 0.759l/mg, while the adsorption isotherm constant (b_T) was -0.0396 and -0.126 respectively. The Temkin isotherm model in this study was also as efficient as the Langmuir isotherm and equally be used for the study of adsorption process of Na ion. This was revealed through the correlation coefficient indicated in the Table 4.13 and Figures 4.31a and 4.31b

4.4.4 Dubinin-Radushkevich Isotherm

The Dubinin-Radushkevich isotherm for adsorption of Na ions in solution onto plantain peels and rice husk particles is shown in Figures 4.32a and 4.32b.

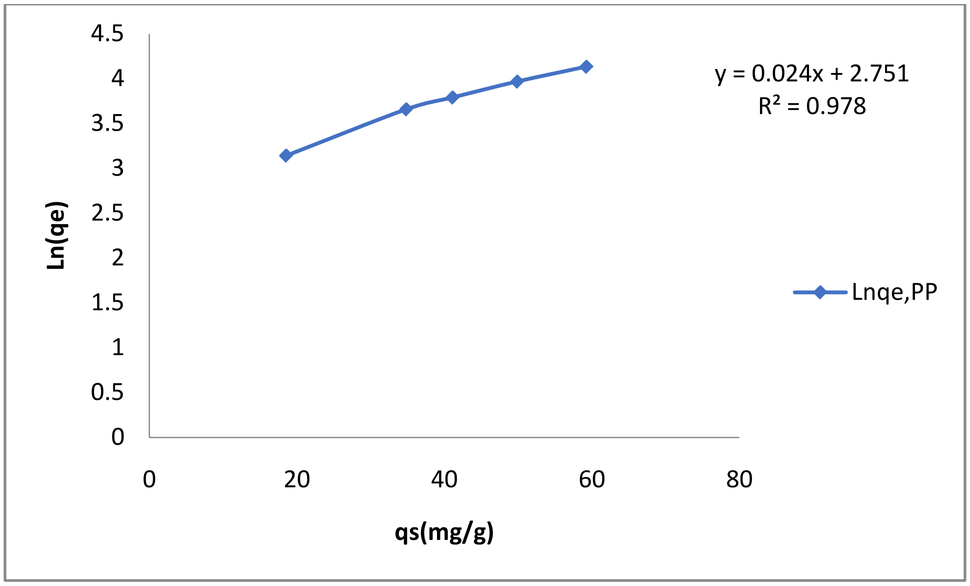


Figure 4.32a: Dubinin-Radushkevich Isotherm for Na using Plantain Peels

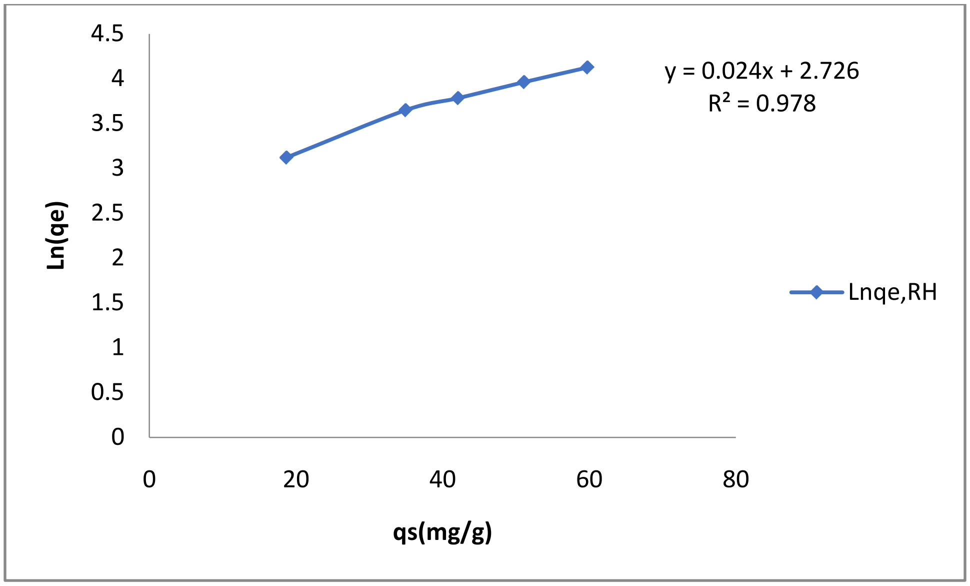


Figure 4.32b: Dubinin-Radushkevich Isotherm for Na using Rice Husk

The Dubinin-Radushkevich isotherm model for adsorption of Na ion in solution onto plantain peels and rice husk particles is shown in Figures 4.32a to 4.32b. The Dubinin-Radushkevich isotherm model showed decrease in concentration of Na metal uptake by the adsorbents. The Polanyi potential (ε) relating to the plantain peels and rice husk particles as obtained from Table 4.13 are respectively are 2.8 kJ/mol and 3.1kJ/mol. Similarly, the Dubinin-

Radushkevich isotherm constant (β) for adsorption of Na ion onto plantain peels and rice husk were 6.28E-7 mol^2/kJ^2 and 5.22 mol^2/kJ^2

4.4.4 Separation Factor

The separation factor for the adsorption utilizing Langmuir isotherm has been studied

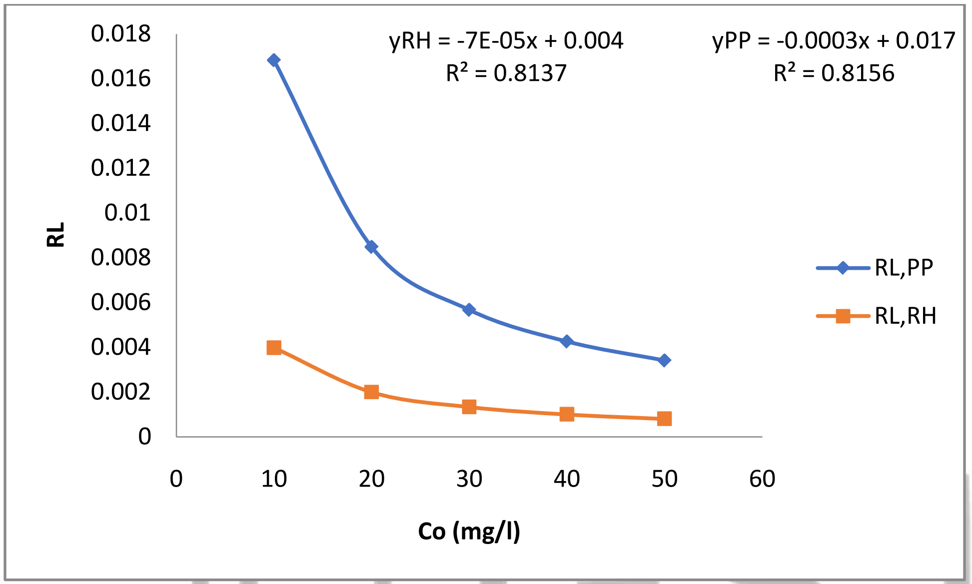


Figure 4.33: Separation Factor of Adsorbents in Solution

The possibility of material to be used as adsorbents can be ascertained from the Langmuir isotherm model. This dimensionless factor called separation factor R_L has been studied to determine the separability of the metals from the solution. The plot of separation factor RL against the initial concentration of Na ions for Plantain Peels particles and rice husk is shown in Figure 4.33. The separation factor decreases as the initial concentration of the metal were increased. Importantly, the values of the separation factor were less than unity, but greater than zero (0<RL< 1). This means the adsorption process is favourable and irreversible as opined by Sharma *et al*., (2016). From initial concentration of 10mg/l to 50mg/l, the separation factor was obtained as 0.0168 to 0.0034 and 0.004 to 0.0008 for Na using plantain peels and rice husk adsorbents.

4. Conclusion

The research work evaluation of possible contaminates in underground water was carried out. Two absorbents were made from locally sourced materials of plantain peels and rice husk. These materials were sourced, of dried, grinned and activated with 0.1M HCl/HNO_3 at temperature of 60^0C to formed activated carbon of the materials, used as absorbents. The contaminated samples areas were located in four Local Government Area of Ogoni land of Gokana, Eleme, Khana and Tai each producing two sites for samples collections. These samples were analyzed i.e. physiochemical analysis in the chemical, petrochemical engineering laboratory, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Rivers State. The analysis produces about 21 parameters see Appendix I. Analysis of the samples interms of application of the absorbents on the absorption of contaminants on the sampled areas were invested. From the result, the absorbents were able to be effective on certain pollutants namely: turbidity, total suspended solids, nitrates, ammonia, dissolved, oxygen and sodium, while no effects was shown on the absorption of the remaining contaminants viz: TDS, conductivity, pH, Cl, total hardness,SO_4^{2-} etc.

The performances of the absorbents on the absorption process was also discussed and from the discussion, it is proven that rice husk absorbent is highly efficient and effective and thus better performed for most absorption of the pollutants them plantain peels absorbents, though both absorbents are good for the absorption process.

In the eight locations sampled, the pollutants present were below limits of WHO, hence these locations were not polluted with these contaminants. The aim of the research work was achieved as I was able to examined about 21 contaminants in the eight (8) locations, compared their concentrations with standard from WHO/united nations and see also the performances of the locally formulated absorbents on the absorption of the pollutants in the underground water sampled.

Adsorption isotherms and kinetics for the adsorption of Na ion on the surface of adsorbents were studied and the results stated in tables 4.12 and 4.13 and also Figures 4.18 to 4.33.

REFERENCES

Al.Anber, M. A. (2011). Thermodynamics Approach in the absorption of heavy metals; Intech open Access publisher: London, UK.

Aliewe, A., & Al-Khatib, I.A. (2014). Hazard and Risk Assessment of Pollution on the Groundwater Resources and Residents, Health of Salfit District, Palestine, *Journal* of hydrology: Regional studies, 4(1), 472-486.

Anthany, S., & Harison, P. (2002). Groundwater Contaminates and Contaminant Source Project Work, Department of Health Services, University of California, USA: Davis, Califormia. available online at http://bgs.uk/hydrogeology/argoss

Balouch, A., Kolachi, M., Talpur, F. N., Khan, H. & Bhanger, M. I. (2013). Sorption Kinetics, Isotherm and Thermodynamic Modeling of Defluoridation of Ground water using Natural Absorbents. Am. J. Annal. Chem. 4: 221-228.

Banks, W.S.L., & Battigeli, D.A. (2002). Occurrence and Distribution of Microbiological Contamination and Enteri Viruses in Shallow Groundwater in Baltimore and Harford countries, Maryland (CDF). Baltimore, MD: USGS water-Resources Investigation Report, 01-4216.

BARNES, L. J. (2011). *Simultaneous Microbial Removal of Sulphate and Heavy Metals from Waste Water* (Proc. EMC91: Non-ferrous Metallurgy - Present and Future), Elsevier, Amsterdam.

BEAR, J. (2014). *Use of Models in Decision Making* (Dracos & Stauffer, eds), BALKEMA

BGS (British Geological Survey) (2001). Assessing risk to groundwater from on-site sanitation.

Bhutiani, R., Kulkarni, D. B., Khanna, D. R., & Gautam, A. (2016). Water Quality, Pollution ource Apportionment, and Health Risk Assessment of Heavy Metals in Groundwater of an Industrial Area in North India. *Expo. Health*, 8(1), 3-18.

Biglari, H., Chavoshani, A., Javan, N., & Mahvi, A. H. (2016). Geochemical Study of Groundwater Conditions with Special Emphasis on Fluoride Concentration, Iran. *Desalin. Water Treat*. *57*(47).

Biswas, A. K. (1998). Water Resources. Environmental Planning, Management and Development. Tata McGraw- Hill Publishing Company Limited, New Delhi.

Boujelben, N., Bouhamed, F., Eloyear, Z., Bouzid, J., & Feki, M. (2013). Removal of phosphates ions from aqueous solutions using MO_2-Coated sand and brick. Desalin. Water. Treat., 52: 2282-2292.

Bouwer, H. (2007). Groundwater Recharge with Sewage Effluent. *Water Science and Technology*, 23: 2099-2108.

Canter, L.W., Knoz, R.C., & Fairchild, D.M. (2011). *Groundwater Quality Protection*. Lewis publishers; Chelsea, Michigan, 562.

Casey, D., Ne,etz, P.N., & Nneyo, D.H. (2013). Sampling Frequency for Water Quality Monitoring: Measures of Effectiveness. *Water Resource Res*., 19(5), 1109-1110.

Chapelle, F.H. (2014). *Groundwater* microbiology and geochemistry. John Wiley & Sons. New York 424.

Chen, S., Jiao, X., Gai, N., Li, X., Wang, X., Lu, G., Piao, H., Rao, Z., & Yang, Y. (2016). Perfluorinated Compounds in Soil, Surface Water, and Groundwater from Rural Areas in Eastern China. *Environ. Pollut*. 211:124-131.

Cherry, J.A. (2003). Migration of Contaminants in Groundwater at a Lanafill: A Case Study. *Journal Hydrology* 13(0.5), Elsevier, Amsterdam 1-198.

Chilton, J. (2016). Groundwater: Water Quality Assessment – A guide to use of Biota, sediments and water in Environmental monitoring, 2nd Edition UNESCO/WHO/UNEP.

Chilton, P.J., Lawrenier A.R., & Stuart, M.E. (2005). The Impact of Tropical Agriculture on Groundwater Quality in: H. Nash and G.J.H. McCall (Editions): *Groundwater Quality*, Chapinsm & Hall: London, 113-122.

Chorus, I., & Bartram, J. (2000). *Toxic Cyanobacteria in Water: A Guide to their Public Health Consequences, Monitoring and Management*. E & FN Spon published on behalf of London. Erzgebirge through Precipitation and Floculation, Wasser 84, 117-129.

Corey, J.C., Kaback, D.S., & Looney, B.B. (2012). In Situ Remediation System for Groundwater and Soil, United States Patent 5,263,795.

Dabrowki, A. (2001). Absorption-From theory to practice. Delv. Colloid. Interface Sci. 93:135-224.

Dada, A., Olalekan, A., & Dada, O. (2012). Langmuir, Freundlich, Tempkin and Dubinin-Radushkevich Isotherms Studies of Equilibrium sorption of Z_n unto phosphoric Acid Modified Rice Husk. J. Appl. Chem 3:38-45.

Deshmukh, K. K., & Aher, S. P. (2016). Assessment of The Impact of Municipal Solid Waste on Groundwater Quality Near Sangamner City using GIS Approach. *Water Resour. Manage.* **30**, 2425-2443

Foo, K. Y. & Hameed, B. (2010). Insights into the modeling of absorption Isotherm systems. Chem. Eng. J., 156:2-10.

Foster, S.S.D. (2006). Groundwater Pollution Protection in Developing Countries. In: G Mathese. S.S.D. Foster and A.C. Skinner (Eds). Theoretical background, hydrogeology and hydrogeology, Heise, Hannover, 167-200.

Foster, S.S.D. Gale, I.N., & Hespanhol, I. (2014). Impacts of Wastewater use and Disposal on Groundwater. Technical Report WD/94/55, British, Geological survey key worth, UK. 32

Fruchter, J.S. (2016). Creation of a Subsurface Permeable Treatment Barrier using in Situ Redox Manipulation" (Proc. Int. Topical Mtg on Nuclear and Hazardous Waste management, Spectrum 96), American Nuclear Society, La Grange Park, Illinois, 2 (2016) 1306-1310.

Geake, A.K., Foster, S.S.D., Nakamatsu, N., Valenzuela, C.F., & Valverde, M.L. (2006) *Groundwater Recharge and Pollution Mechanisms in Urban Aquifers of Arid Regions.* Hydrogeological Report 86/11, British Geological Survey, Wallingford, UK, 55 .

Geraphty, J.J., & Miller, D. W., (2015). *Fundamentals of Groundwater Contamination*. Short Course Notes, N. Y, 75.

Golke, U., Otto, A., & Kiessig, G. (2015). Water Treatment of Mining Waste Waters.

Gworek, B., Dmuchowski, W., Koda, E., Marecka, M., Baczewska, A. H., Bragoszewska, P., Sieczka, A., & Osinski, P. (2016). Impact of Municipal Solid Waste Lubna Landfill on Environmental Pollution by Heavy Metals. *Water*. **8(10)**, 470, 1-16.

Hafner, S. C., Harter, T., & Parikh, S. J. (2016). Evaluation of Monensin Transport to Shallow Groundwater After Irrigation with Dairy Lagoon Water. *J. Environ. Qual. 45*(2), 480-487.

Hinchee, R.E., Means, J.L., & Burris, D.R., (2015).Bioremediation of Inorganics. International Atomic Energy Agency, (2008). Characterization of Radioactively Contaminated Sites for Remediation Purposes, IAEA-TECDOC-1017, Vienna

Houtson, N. D. & Yang, R. T. (1997). Theoretical basis for the Dubinin-Radushkevitch (D.R) absorption Isotherm equation Absorption, 3:189-195.

International Atomic Energy Agency, (2008). Factors for Formulating Strategies for Environmental Restoration, IAEA-TECDOC-1032, Vienna

International Atomic Energy Agency, Application of Radiation Protection.

International Atomic Energy Agency, IAEA, 2011: Technical options for the remediation of groundwater contaminations, INIS Clearing house, IAEA, Wagramer Str., Austria: Vienna.

Kinniburgh, D.G. & Miles, D.L. (2003). Extraction and chemical analysis of interstitial water from soils and rocks. *Environ. Sci. Technol., 17*, 362-368.

Linderbaum, J. (2012). Identification of Arnmonia in groundwater using stable Ntrogen and Boron Isotopes in Nam Du, Hanoi, *Master's Thesis,*, Department of Geology Lund University, Lund; Siveden.

Marecek, P.& Novak, J., (2013).WASSERBAUER, V., Mathematical Modelling of the Influences of the Straz Tailings Ponds on the Groundwater.

Mezenner N.Y & Bensmaili, A. (2009). Kinetics and Thermodymic study of Phosphate absorption on iron hydroxide-egg shell waste chem. Eng. J. 147: 87-96.

Nara, S., Hajiudin, Z., Glyn, A., Hayly, V., Brooke, S., & Jacqueline, F. (2013). Groundwater Risk Assessment Model for well field protection. Open Access Journal water 2013, 5:1419-1439.

NDES: Niger Delta Environmental Survey Report, 1 & 2, 2001

Pickens, J.F., Cherry, J.A., Grisak, G.E., Merritt, W.F., & Risto, B.A. (2008). A multi-level device for groundwater sampling and piezometric monitoring. *Groundwater, 16,* 322-327.

Pionke, H.B., Sharma, M..L., & Hirschberg, K.J. (1990). Impact of Irrigated Horticulture on Nitrate Concentrations in Groundwater. *Agriculture, Ecosystems and Environment,* 32:119–132.

Principles to the Cleanup of Contaminated Areas, Interim Report for Comment, IAEATECDOC-987, Vienna

Quin, X. (2009). Critical review in absorption Kinetic models J. Zhejiang Univ., 10: 716-724.

Ross, N. (2010). Cleaning the Waters a Fraise on Water Quality Solutions, Nairobi: Kenya. Rotterdam, 11(4), 3-9.

Salman, A.S., Ahmed, A.A., Amr, E.G., & Hassan, S. (2019). Evaluation of Human Risk of Surface Water and Groundwater Contaminated with Cd and Pb in the southern El-Ming Government, Egypt. *Drinking* water engineering and science, 12, 23-30.

Salt, D.E. (2015). Phytoremediation, a Novel Strategy for the Removal of Toxic Metals from the Environment using plants, Bio/Technology 13(4), 8-474.

Sudarshan, K. (2019). Groundwater and vulnerability Assessment. *Water Environment Research,* 89(10), 1560-1577.

Sumner, M., & McLaughlin, M. (2006). Adverse Impacts of Agriculture on Soil, Water and Food Quality, in: Naidu R et al., compilers. *Contaminants and the Soil Environment in the Australasia Pacific Region,* Kluwer Academic Publishers, Dortrecht, The Netherlands. 125–181.

Tempkin, M. & Pyzher, N. (1940). Heavy metals removal and Isotherms study. Acta Physiochim, URSS, 12: 217-222.

Thompson, T., Fewell, J., Jackson, D., Apple Yard, S., Bartram, J., & Kingston, P. (2014). Chemical WHO Press, WHO: Switzerland: Genera.

Ujile, A. A. (2003). Modeling Groundwater Contaminants due to Transient Sources of Pollutants, *PhD Dissertations*, RSUST, Nigeria.

Ujile, A. A. (2007). Modeling Leachate Transport in a Sanitary Landfill System-Niger Delta as a Case Study. *Journal of Solid Waste Technology & Management*. www.solid-waste.org 33(4).

Ujile, A.A. (2013) Evaluating groundwater contamination process and developing framework for qualitative management in part of Nigeria. International journal of innovative research in science, engineering and technology, 2(8): 3890-3900.

United Nations, The 2004 population estimates and population growth rate from World Bank Atlas 1996 population projections (medium variant) for 2025 and 2050 United Nations. 1996

Uduakohong, A. E & Augustine, O. I. (2020). Kinetics, Isotherms, and Thermodynamic modeling of the Absorption of phosphates from model waste water using Recycled Brick Waste. *Processes*, 8:665

Weil, R.R; Weismiller, R.A & Turner, R.S (1990). Nitrate Contamination of Groundwater Under Irrigated Coastal Plain Soils, *Journal of Environmental Quality*, 19:441–448.

WHO (2001). *Water health and human rights*, World Water Day 2001. Available online at http://www.worldwaterday.org/thematic/hmnrights.html#n4.

WHO (2004). *Guidelines for Drinking-water Quality*, 3rd ed., Volume 1: Recommendations, World Health Organization, Geneva.

WHO (2006). *Guidelines for Drinking-water Quality*, 1st Addendum to the 3rd ed., 1: Recommendations, World Health Organization, Geneva.

WHO (2006). *Protecting Groundwater for Health: Managing the Quality of Drinking water*

WHO (2011). *Guidelines for Drinking-Water Quality* (4th ed., vol. 3). WHO Press, World Health Organization, Switzerland.

WHO (in preparation). *Protecting Surface Waters for Health: Managing the Quality of Drinking Water Sources*, World Health Organization, Geneva and IWA Publishing: London. World Health Organization, London and New York, 416

World Health Organization (2008). Guidance for drinking water quality. Recommendations, 3rd edition; world health organization Switzerland: Genera,1, 515.

World Health Organization (WHO) (2009). Contaminant Present in Underground Water, Italy: Rome.

World Health organization, WHO (2006). Protecting Groundwater for Health. In: Oliver, S. Gey, H, & Chilton, J. & Ingrid, C. (Eds). *Managing* the quality of drinking water *source*: IWA publishing: Padstow, Cornwall, UK.

WRI (World Resources Institute) 1987 *World RESOURCES 1986: An Assessment of the Resource Base that Supports the Global Economy*. Basic Books Inc., New York.

Yakout, S. & Elsherif, E. (2010). Batch Kinetic Isotherm and Thermodynamic Studies of Absorption of Strontium from Aqueous Solutions onto low Cost Rice Straw Based Carbons Carbon Sci. Technol., 1:144-153.

Yauan, X., Xia, W., An J., Yin, J., Zhou, X., & Yang, W. (2015). Kinetic and thermodynamic Studies on the Phosphates Removal by. Dolonnite Mineral, J. Chem., 2015:1-8.

Zhou, J., Yang, S., Yu, J. & Shu, 2. (2011). Novel hollow microspheres of hierarchical Zn-Al Layered double hydroxides and their enhanced absorption capacity for phosphate in H_2O. Journal of Hazard Materials, 192: 114-1121.