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Treatment of Industrial Effluent of the Kaduna Refining and Petrochemical Company Using Rice Husk

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Authors' contributions

This work was carried out in collaboration between both authors. Author SAS designed the study, wrote the protocol and the first draft of the manuscript. Author MOI managed the field study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of the study was to test and assess the effectiveness of rice husk in the treatment of petroleum refinery effluents or waste water using the Kaduna Refining and Petrochemical Company (KRPC) as platform.
Place of Study: Kaduna Refining and Petrochemical Company Limited (KRPC) is located in the southern part of Kaduna State, Nigeria.
Methodology: The rice husk was obtained from a rice mill in the railway station market of Kaduna metropolis, and conditioned in accordance with standard procedures. Its characterization was carried out at the National Centre for Nanotechnology and Advanced Materials, Ondo state, Nigeria using X-Ray Fluorescence. The effluent from the refinery was sampled from the designated sampling point in the wastewater treatment plant following standard procedures and then treated with rice husk.

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Results: Revealed the ability of the rice husk to remove contaminants such as heavy metals, phenolic compounds, and anions from the effluent. It also reduced the effluent turbidity, total solid content, and chemical oxygen demand. The efficiency of rice husk decontamination capacity was lower than that of chemical treatment in Kaduna Refining and Petrochemical Company.

Conclusion: Rice husk can be considered a suitable material for the treatment of effluent water from Kaduna Refining and Petrochemical Company, which may reduce the hazard associated with these pollutants.

Keywords: Rice husk; characterization; effluent; contaminants; treatment.

1. INTRODUCTION

Environmental pollution may refer to an unfavorable alteration of our surroundings (local or global) by human actions, which directly or indirectly cause changes in energy patterns, radiation levels, chemical and physical constitution of organisms [1]. Following industrial revolution which has brought with it technological progress such as discovery of fossil fuel, nuclear reactors, and chemicals, the growth of pollution has since assumed global proportions [2]. Petroleum refining industries, as part of this development, produce significant quantities of wastewater from several processes including desalting, atmospheric and vacuum distillations, hydrocracking, catalytic cracking, catalytic reforming, as well as alkylation [3]. These effluents contain various contaminants including hydrocarbons, spent caustic soda, and cyanides. Typical petrochemical effluents have significant concentrations of suspended solids, organic matter, oil and grease, sulphide, ammonia, phenols, hydrocarbons, benzene, toluene, xylene, and polycyclic aromatic hydrocarbons [4].

Environmental pollution has become a major concern in developing countries in the last few decades. Major sources of water pollution are the untreated or partially treated industrial effluents and the petroleum refining industry among others is reputed globally as a major industry which contributes to water pollution [5]. The quality of discharged water from this industry is far from the desired level of acceptance into water ways. There is also observed ignorance of the harmful effects of releasing wastewater from these processes directly into the environment (farmlands, rivers) without proper treatment. In developing countries, only about 10% of the wastewater is treated. The rest is discharged directly into water bodies. These industrial wastes contain organic and inorganic impurities apart from higher biochemical oxygen demand, chemical oxygen demand, altered pH and other parameters [6].

The conventional processes that are applied for the treatment of petrochemical wastewater can only partially remove the contaminants [7,8]. Often, the existing regulations governing the reuse and/or discharge of petrochemical effluents require the adoption of advanced treatment techniques including membrane processes. Adsorption is one of the major unit operation used for removal of various pollutants from wastewater [9,10]. It offers flexibility in terms of selection of contacting devices and adsorbent material depending on the time, space and funds available for treatment of the wastewater. Low cost adsorbents prepared from rice husk, coconut shell, tamarind bean shells, fly ash, leaf litters, cashew nut shells, tea waste has been used effectively [11].

Nigeria is a net importer of rice with an annual local production of 3-4 million tons of paddy rice, about 20-25% of which is rice husk depending on the variety [12]. Rice husk, which is a layer protecting rice grain is the major by-product obtained from rice processing mill [13]. It consists of cellulose (32.24%), hemicelluloses (21.34%), lignin (21.44%), water (8.11%), extractives (1.82%) and mineral ash (15.05%) as well as high percentage of silica in its mineral ash, which is 94.5-96.34%. Rice husks are agricultural waste materials which have the advantage of treating the industrial effluents [14]. Several studies in different countries have been conducted on the efficiency of rice husk as an adsorbent which depends on dosage, contact time, and temperature [15-17]. However, no work has been done on the treatment of refinery effluent using rice husks in the area where the present study was carried out. Most researchers have targeted the use of agro-waste materials in the treatment of only one component or the other that form part of the pollutants from refinery effluent. In this light, this research targeted the use of rice husk in its natural form in the treatment of Kaduna Refinery Effluent.

2. METHODOLOGY

2.1 Study Area

The study area is the Kaduna Refining & Petrochemical Company Limited (KRPC). The Company is located in the southern part of Kaduna. It is in the business of refining crude oil into high quality petroleum products like premium motor spirit popularly known as petrol, automotive gas oil, lube base oil; manufacturing of petrochemical products like Linear Alkyl Benzene, toluene and packaging of products. The power plant and utility department of the company is responsible for treating the effluents generated as a result of these processes to the statutory quality specifications discharged into Romi River.

2.2 Materials

Materials used in preparation of the effluent treatment included; Rice husk, Kaduna Refinery effluent, distilled water, oven, beakers, jar test kit apparatus, spectrophotometer, X-ray Fluorescence (XRF), thermometer, oil and grease analyser, mortar and pestle, sieves, tap water, and weighing balance.

2.3 Methods

<u>2.3.1 Rice husk conditioning</u>

The rice husk was obtained from a rice mill at the Railway station market of Kaduna Metropolis. It was washed to remove unwanted materials, first with tap water and then distilled water several times. The washed rice husk was then placed inside an oven at 65-70^{o}C for several hours until constant weight was achieved. The dried husk

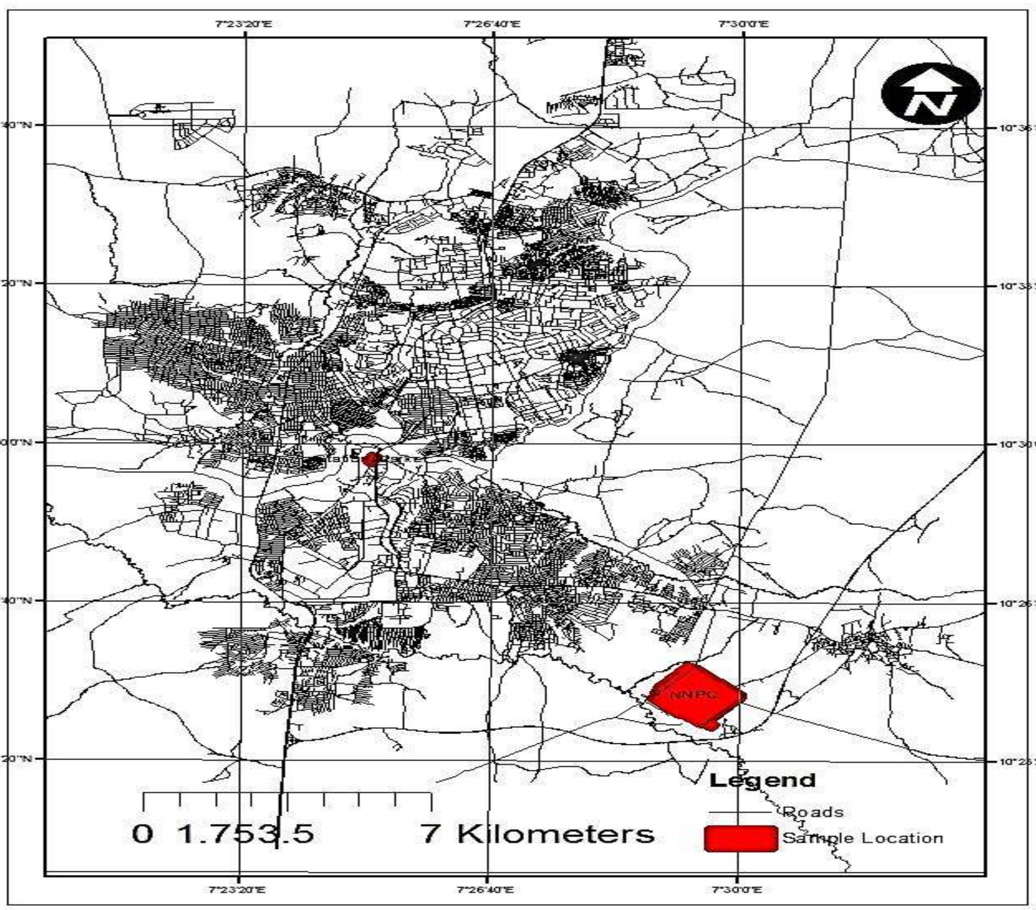

Fig. 1. Map of Kaduna Metropolitan Region showing the study area

was then crushed with a laboratory mortar and pestle to finer particles and sieved. The finer particles were stored in an air tight container for use in effluent water treatment. The choice of drying temperature was such that the husk should not be denatured.

2.3.2 Rice husk characterization

Portion of the processed rice husk was taken to National Centre for Nanotechnology and Advanced Materials, Akure, Ondo state, Nigeria for characterization using X-Ray Fluorescence (XRF). The XRF provided the elemental and oxide composition of the rice husk.

2.3.3 Effluent characterization

The effluent water from the refinery was sampled from the designated sampling point in the wastewater treatment plant following standard procedures [18]. The sampling was done by opening the sampling point valve and allowing the line to drain off for about two seconds. This was to ensure that the sample taken is the correct representation of the effluent water in the storage tank. The sampling can was then rinsed with the effluent water twice before collecting the water into it. This was followed by analysis at the Kaduna Refinery and Petrochemical Company's laboratory using Ultra Violet Spectrophotometer for the anion, Smart3 Colorimeter for the Cyanide and Phenol, and Atomic Absorption Spectrophotometer for the Metal determinations. This gave the detail pollutants present in the water before application of the processed rice husk in its treatment.

2.3.4 Effluent treatment

A quantity (500 ml) of the characterized effluent was then charged into a beaker where 5 g of the processed rice husk was charged and vigorously stirred for about two minutes and left to stand for half an hour while stirring every 10 minutes, then allowed to settle down for decantation. The decanted water was then characterized to see the extent of pollutants removal from the effluent. This procedure was repeated increasing the Rice Husk dosages to 10 g. The test can be run co-currently with the chemicals used in effluent treatment in the refinery for comparison.

The sample of untreated Effluent, which was collected, was carefully analysed at the Kaduna Refinery and Petrochemical Company's laboratory using Ultra Violet Spectrophotometer for the anion, Smart3 Colorimeter for the Cyanide and Phenol, and Atomic Absorption Spectrophotometer for the Metal determinations. The untreated effluent sample was treated with Rice Husk powder and analysed, and the results are presented below.

3. RESULTS

3.1 Rice Husk Treated Refinery Effluent Water

The mean value of the results obtained for both the untreated and treated effluent is presented in the Table 1. The results of the rice husk treated effluent were compared with the results of the untreated sample and the standard values.

3.2 Comparative Analysis of Refinery Effluent Treatment Using Rice Husk as against the Standard and KRPC Treated

The results of the Rice Husk treated Effluent and that treated by Kaduna Refinery Petrochemical Company (KRPC) using Poly Aluminium Chloride and Poly Vinyl Pyridine are presented in the Figs. 2-4. It can be seen in the Figs. 2-4 that concentration of most of the contaminants in the Rice Husk treated effluent though within specification are higher than that treated chemically in KRPC.

3.3 XRF Characterization of Rice Husk

The result of the XRF Characterization of Rice Husk is presented in Table 2. It can be seen that the Rice Husk contains aluminium and potassium oxides which are key oxides responsible for coagulation in water treatment. This could be a reason why the husk gives a good effluent.

4. DISCUSSION

Several cheap materials which are usually waste products have been employed in the removal contaminants in industrial wastes such as; agricultural waste [19,20], tea leaves and wood charcoal [21], rice hulls, bran, and husk [19,22], saw dust and mustard husk [23], cellulose [24], and many others.In this study, rice husk was used as the decontaminant. The pH of the rice husk treated and untreated effluent were acidic, though addition of rice husk improved the pH to about minimum value set(7.0 – 8.5) set by Nigerian Industrial Standards (NIS) [25]. The contaminants removal capacity of rice husk depends on pH, temperature, and composition

[15,22]. Hence the increase in pH seen in this study may be the reason for the effectiveness of rice husk, as seen in some studies [15,19]. Increase in pH has been shown to increase the removal of heavy metals especially cadmium by rice husk [22]. The treated effluent revealed the following characteristics; decreased turbidity, total dissolved solids (TDS), and suspended solids (SS) (Table 1). This is in agreement with [17], whose study revealed the ability of rice husk to greatly reduce the COD, turbidity, as well as TDS and SS concentrations. The chemical oxygen demand (COD) in this study was greatly reduced when treated with rice husk [6]. Reported the effectiveness of activated rice husk in removing heavy metals and reducing oxygen demand from waste water.The decrease seen in COD from treated effluent indicates the ability of rice husk to remove organic contaminants. Reduction in COD, heavy metals and anion concentration by rice husk has also been reported by [26]. The rapid reduction in COD seen may be as a result of decreased temperature observed in the treated effluent, as its removal process may be exothermic [26,27]. The phenolic compounds are carcinogenic. In this study, amount of phenols in treated effluent was reduced as reported by other authors. Rice husk and rice husk ash have been reported as effective adsorbent materials in removing phenol compounds from aqueous medium especially waste water [28,29].

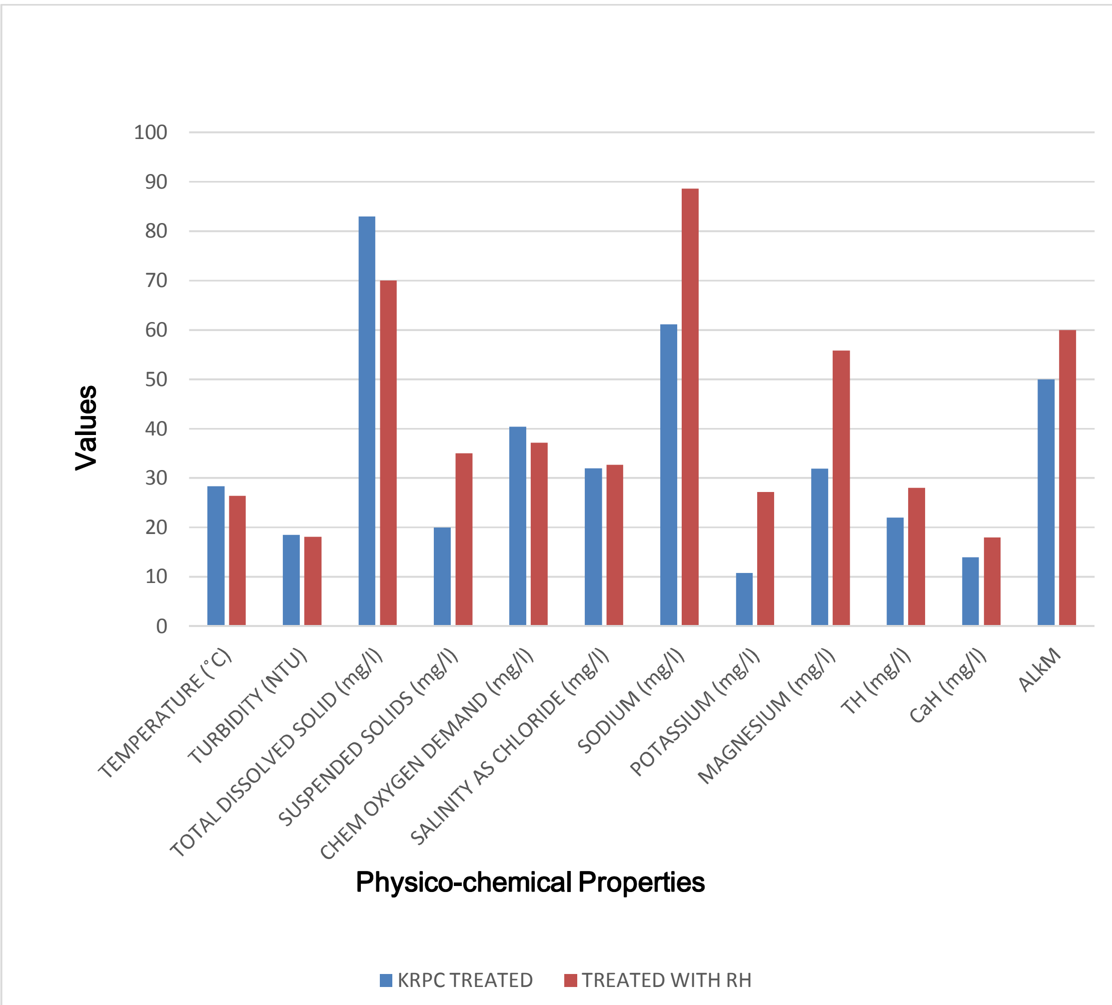

Fig. 2. Temperature, turbidity, and concentration of solids, anions and metals in KRPC and RH treated effluents (Each line on the vertical axis represents 10.00 units)

KRPC- Kaduna Refinery Petrochemical Company, RH- Rice husk, TH- Thorium, CaH- Calcium Hydride, ALkM- Alkalinity M

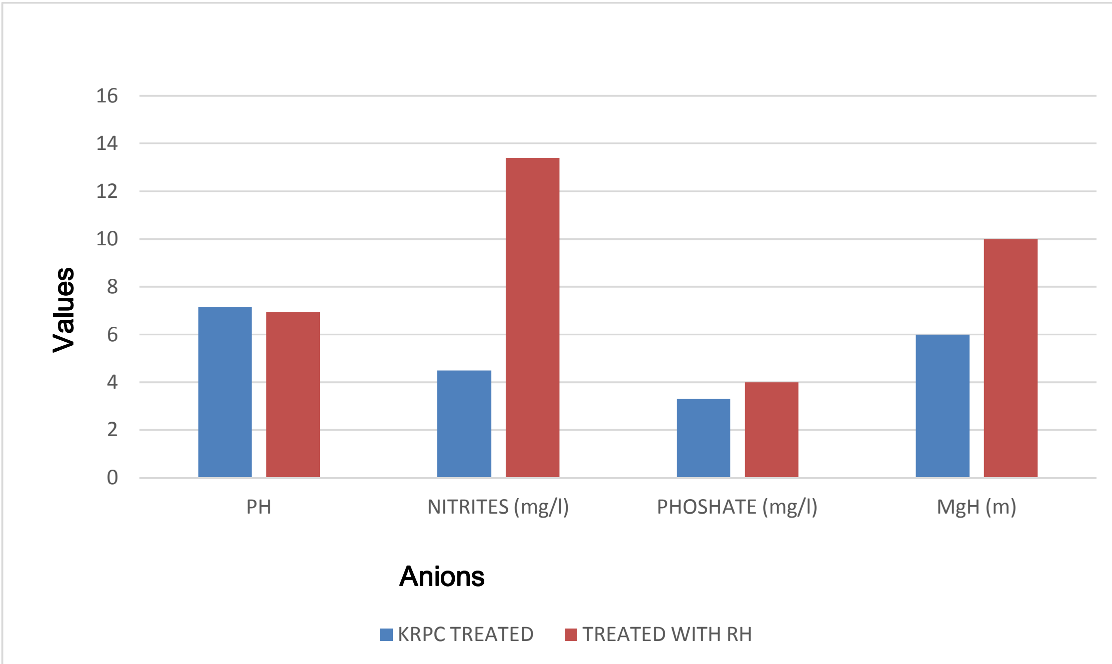

Fig. 3. pH value and concentration of Anions of KRPC and RH treated effluents (Each horizontal line represents 2 units)

KRPC- Kaduna Refinery Petrochemical Company, RH- Rice Husk, MgH- Magnesium Hydride

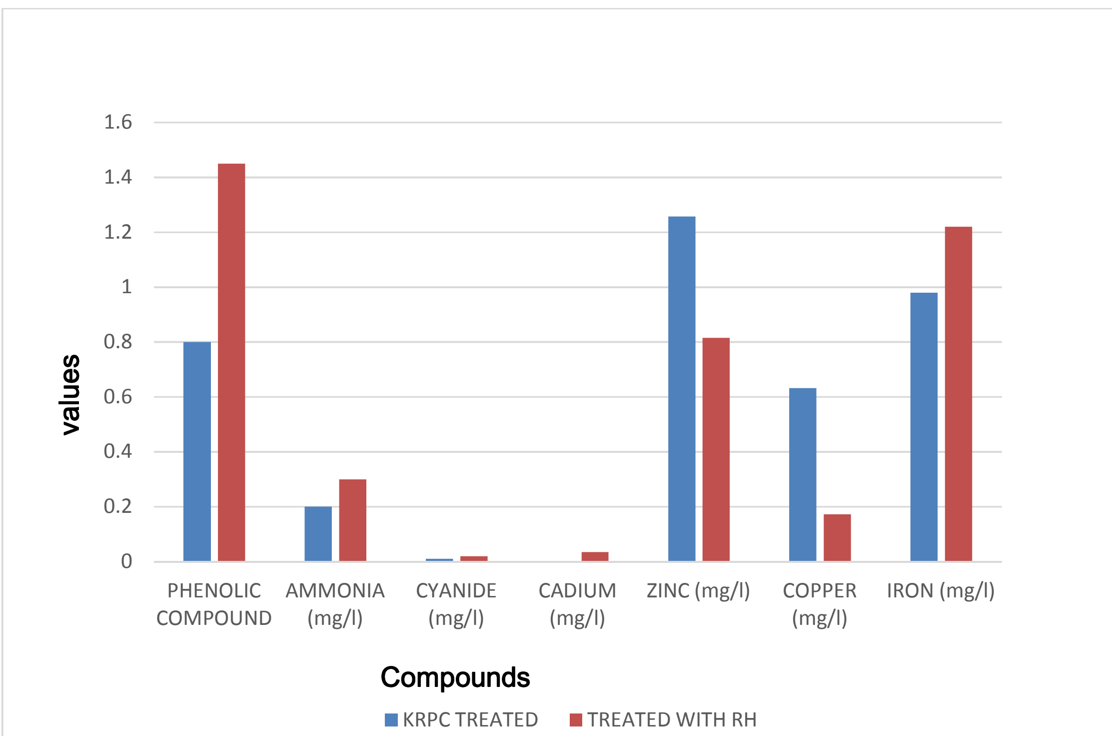

Fig. 4. Concentration of different compounds in KRPC and RH treated effluents (Each horizontal line represents 0.2 units)

KRPC- Kaduna Refinery Petrochemical Company, RH- Rice Husk

Table 1. Physico-chemical properties of rice husk treated refinery effluent compared with the untreated and standard values

S/N	Test	Standard values	Untreated	Treated
1	pH	7.0 - 8.50	6.38	6.94
2	Temperature (^{0}C)	36	28.2	26.4
3	Turbidity (NTU)	50	70.3	18.1
4	TS (mg/l)	NS	185	105
5	TDS (mg/l)	2000 (maximum)	130	70
6	S S (mg/l)	10 (minimum)	55	35
7	D O (mg/l)	NS	ND	
8	BOD (mg/l)	25	ND	
9	COD (mg/l)	60 (maximum)	201.7	37.17
10	Oil and grease (mg/l)	0.3	ND	ND
11	Phenolic compounds (mg/l)	0.1	1.76	1.45
12	Chloride (mg/l)	NS	48.7	32.7
13	Ammonia (mg/l)	1.0	0.7	0.3
	Anions			
14	Nitrates (mg/l)	NS	26.8	22.1
15	Nitrites (mg/l)	NS	13.6	13.4
16	Phosphate (mg/l)	NS	8.2	4
17	Sulphate (mg/l)	200	308	293
18	Sulphide H_2S (mg/l)	0.2	0.93	0.82
19	Conductivity	NS	128.4	0.3
20	Cyanide (mg/l)	0.05	0.03	0.02
	Metal			
21	Sodium (mg/l)	NS	70.0407	88.6203
22	Potassium (mg/l)	NS	15.5017	27.1561
23	Cadmium (mg/l)	0.05	0.0425	0.0345
24	Lead (mg/l)	0.05	<0.01	<0.01
25	Zinc (mg/l)	5	1.2579	0.815
26	Copper (mg/l)	0.05	0.6312	0.1726
27	Nickel (mg/l)	NS	<0.01	<0.01
28	Iron (mg/l)	0.03	2.3276	1.2206
29	Magnesium (mg/l)	NS	49.0296	55.814
30	TH (mg/l)	NS	32	28
31	CaH (mg/l)	NS	22	18
32	MgH (m)	NS	10	10
33	ALkP	NS	NIL	NIL
34	ALkM	NS	62	60

NS- Not stated, TH- Thorium, CaH- Calcium Hydride, ALkP- Alkalinity P, ALkM- Alkalinity M, DO- Dissolved Oxygen, SS- Suspended Solids, BOD- Biological Oxygen Demand, COD- Chemical Oxygen Demand, TDS- Total Dissolved Solids, TS- Total Solids

Heavy metals detected in the effluent were sodium (Na), cadmium (Cd), lead (Pb), zinc (Zn), and copper (Cu). Rice husk treated effluent revealed a reduction in the concentrations of the measured metals. This result confirmed the ability of rice husk to remove contaminants such as heavy metals from waste water. Using Rice Husk as refinery Effluent treatment agent will save the environment from the pollution it poses when it is burnt as the only means of disposal, make the effluent discharged into the river more environmental friendly especially the aquatic and above all save cost of effluent treatment. The rice husk in some cases is activated to make it very efficient for effluent treatment [6,30]. A review article reported the maximum adsorbent capacity of different metals gathered from several studies conducted on rice husk especially mercury, zinc, copper, cadmium, and arsenic [31]. Other studies have also reported the heavy metals removal capacity of rice husk from waste water [6,22]. The husk was shown not to contain dangerous materials in it as presented by the XRF result, hence adopting rice husk as effluent treatment agent will reduce the environment pollution it poses as a result of burning it.

Table 2. XRF characterization of rice husk

Element	Content (%)	Oxide	Content (%)
Mg	0.1901	MgO	0.3152
Al	0.1804	Al_2O_3	0.3409
Si	0.7948	SiO_2	1.7003
P	0.2602	P_2O_5	0.5962
S	0.3307	SO_3	0.8257
K	2.1736	K_2O	2.6183
Ca	0.8364	CaO	1.1703
Ti	0.4090	TiO_2	0.6822
V	0.0152	V_2O_5	0.0271
Mn	0.5184	MnO	0.6694
Co	0.0239	CoO	0.0304
Fe	4.6972	Fe_2O_3	6.7158
Ni	0.1094	NiO	0.1392
Cu	0.2541	CuO	0.3181
Zn	0.3187	ZnO	0.3967
W	0.5366	WO_3	0.6767
Rb	0.0861	Rb_2O	0.0942
Nb	0.0097	Nb_2O_5	0.0139
Mo	0.1323	MoO_3	0.1985
Sn	0.8052	SnO_2	1.0223
Sb	0.7045	Sb_2O_3	0.8451

5. CONCLUSION

The results obtained showed that rice husk is a good effluent water treatment material as most of the parameters are further reduced compared to specifications. Rice husk can be considered a suitable material for the treatment of effluent water from refinery (Kaduna Refinery) though it can be activated in order to achieve a better treatment. Use of rice husk may reduce amount of both agricultural waste and industrial waste, which may further reduce the hazard associated with these pollutants.

Further studies can be carried out using different temperatures, pH, as well as concentrations at same or similar study areas. Activated rice husk could also be used to achieve more effectiveness.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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