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The Determination andRemoval ofHeavy Metals (Fe, Man, As) From Ground Water Using Iron Oxide Coated Sand (IOCS)

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Abstract:*This study was undertaken to evaluate the performance of iron oxide coated sand (IOCS) as an adsorbent for the removal of heavy metals (Mn, Fe and As) from groundwater. The main parameters affecting this treatment process were examined namely the adsorbent dose, different adsorbent types and flow rate. River-bed sand of 0.5-0.85mm was collected, dried and coated with iron oxide. The coated sand was used as an adsorbent for the removal of Iron, Manganese and Arsenic from groundwater in column experiment. The uncoated sand was used as a control. The initial concentrations of Fe, Mn and As of raw groundwater collected from Bayelsa State of Nigeria, were found to be 5.423ppm for Fe, 0.092ppm for Mn and 0.001ppm for Arsenics. The water sample was spiked with 0.715ppm Arsenic to assess the efficiency of the adsorbent in removing heavy metals. The result showed that IOCS is a good adsorbent as compared with the uncoated sand (UCS). For the removal of Arsenic, it was observed that Arsenic was reduced from 0.715ppm to 0.020 ppm for IOCS and 0.073ppm for UCS. The adsorption of Iron (Fe) and Manganese (Mn) were found to increase with decreasing flow rate from 25ml to 5ml per minute respectively. Also, it was observed that as dosage of adsorbent increases, there was an increase in the percentage adsorption of Iron and Manganese from 5g to 25g adsorbent. In summary the coated sand showed better removal efficiency when compared to uncoated sand. Therefore, the column experiment demonstrated that heavy metals (Fe, Mn and As) can be effectively removed from groundwater using locally produced coated sand. The use of coated sand for heavy metal removal is far better than uncoated sand and that the study has shown that the locally produced adsorbent is not only for treatment of drinking water but also waste water and industrial affluent.*

Key words: *Heavy Metals, Adsorption, Iron oxide coated sand, IOCS, Flow Rate, Adsorbent Dosage*

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I. Introduction

In developing countries like Nigeria, groundwater is a major source of drinking water. Groundwater and other freshwater sources contain frequently undesirable and naturally occurring inorganic/organic contaminants and unfortunately, poverty prevents people from acquiring modern treatment technology. The study of Benjamin *et al*. (1996), was one of the first to investigate the removal of arsenic from water using a material coated with iron oxide. The surface of ordinary filter sand was coated with iron oxide using $FeCl_3 \cdot 6H_2O$ and heating the media to high temperature in a number of different steps to produce an amorphous iron oxide surface that was a good adsorbent for dissolved metals.

Iron and manganese oxides are well known effective adsorbentsfor heavy metal removal due to theirmicro porous structures and high surface areas. In addition, oxides of iron and manganese also possess hydroxide (- OH^-) functional groups (Han *et al.*, 2006). The presence of MnO_2 on the oxide surface has a catalytic effect on the removal of heavy metals (Phatui *et al.*, 2010). Previous studies showed that out of the 112 borehole water samples that were tested in Rivers and Bayelsa States of the Niger Delta region, 42 % (ranging from 2.0 to 10.2 mg/l) contain iron concentration above WHO Standard (Ujile *et al.*, 2007). Iron oxides have a relatively high surface area and surface charge, and often regulate free metal and organic concentrations in waters through adsorption reaction (Davis *et al.*, 1980, Yu *et al.*, 2010). Many researchers have used iron oxide to remove heavy metals and organic matters from tap water or waste water (Joshi *et al.*, 1996; Lo *et al.*, 1997 and Kondu *et al.*, 2007).

Some researchers have developed techniques for coating iron oxide on sand surface in order to overcome the difficulties of using iron oxide powder in water treatment. The Iron Oxide Coated Sand (IOCS) has been tested for removal of cationic as well as anionic species from synthetic and real wastes (Loi *et al.*, 2002; Petruesevski *et al.*, 2002). The results from those studies confirmed that the utilization of IOCS is worth developing for heavy metal removal from water (Loi *et al.*, 2002; Petruesevski *et al.*, 2002 and Gupta *et al.*, 2005).

Adsorptive filtration using sand coated with iron is a relatively new approach for treating metal-contaminated drinking water and numerous varieties are reported in the literature such as iron impregnated quartz sand and silica containing iron(III) oxide (Zerg, 2003) and iron oxide coated sand (IOCS) modified with sulfate (Vaishya and Gupta, 2006). In one study, Wong *et al.*(2003), studied the removal of heavy metal ions from aqueous solution using various adsorbents with minimal cost. He used various low-cost adsorbents like Fe_2O_3, Fe_3O_4, steel wool, magnesium pellets, aluminium pellets, zinc pellets, iron pellet, GAC for removal of heavy metal ions like cobalt and zinc from ground water. In another study, Choo, *et al.*,(2005), studied the removal of iron and manganese in ultra-filtration and also the process of membrane fouling. He also examined water to remove the residual chlorine due to pre-chlorination which is used as a convenient option for safe drinking water. The membrane fouling was caused due to the oxidation of iron and manganese which was also visualized thoroughly at microscopic level and steps for eradicating the degradation of membrane were proposed.

Bordoloi *et al*. (2011), studied the removal of iron from water using the ash produced from banana residue. Ashes from different materials i.e. dry banana leaf, pseudo stem, rice husk were produced by controlled combustion. Mechanism of removal included oxidation of iron at high pH or alkaline medium produced by potassium present in banana due to subsequent formation of potassium hydroxide. The study included analysis of chemical composition of banana ash and its efficiency in removal of iron from prefabricated water. Furthermore, it has been used in a low-cost household water purification model in which after treatment with ash, the water is filtered with a cotton cloth and use for drinking.

Chaturvedi (2012), studied the removal of iron for safe drinking water. He used the methods for iron removal from drinking water such as electro coagulation oxidation filtration, ion exchange, lime softening, adsorption by activated carbon, Birm media, greensand and pebble and mixture, ultra-filtration, etc.

Considering the high cost of procuring water treatment equipment and difficulty in operation, there is an urgent need for an inexpensive adsorbent that is simple and eco-friendly. Natural material like sand, is easily available and gives a cheap route of removal of heavy metals from groundwater. Its affordability and environmental friendliness would save a lot of costs on removal of heavy metals. Therefore, adsorption of Iron, Manganese and Arsenic using natural material has emerged as an option for developing economy like Nigeria. The aim of this study is to investigate the potential of using natural sand coated with metal oxide as an adsorbent for treatment of groundwater; to investigate the effect of flow rate and adsorbent dose on the removal efficiency and to contribute to the search for less expensive adsorbents for the elimination of contaminants from borehole water.

The Study Location

The study locations were Onopa and Akimfe, all in Bayelsa State (Fig. 1) and Plate 1.

II. Materials and Methods

The sand preparation involved the locally available river bed sand which was procured, washed and dried. The sand was sieved to obtain the size range of (0.5-0.85mm) using laboratory sieve and later soaked in 8% nitric acid solution overnight. This was rinsed with de-ionized water to pH = 7.0 and dried at 105°C to make it ready for coating.

Preparation of Iron Oxide Coated Sand

Iron oxide coated sand (IOCS), was prepared using a procedure described by Gupta *et al.*, 2005 and Joshi and Churdluri (1997) (Plates 2 and 3). This involved 200g of washed and dried river bed sand of particle size 0.5-0.85mm which was mixed with 80ml of a 2 M Ferric Chloride solution. 1.5ml of 10M NaOH was added to obtain pH 10.5 for 2 minutes. The mixture was then dried in an oven at 105°C for 24 hours. The coated sand was washed thoroughly with distilled water until clear water was visible. Finally, the mixture was dried at 105°C for 24 hours.

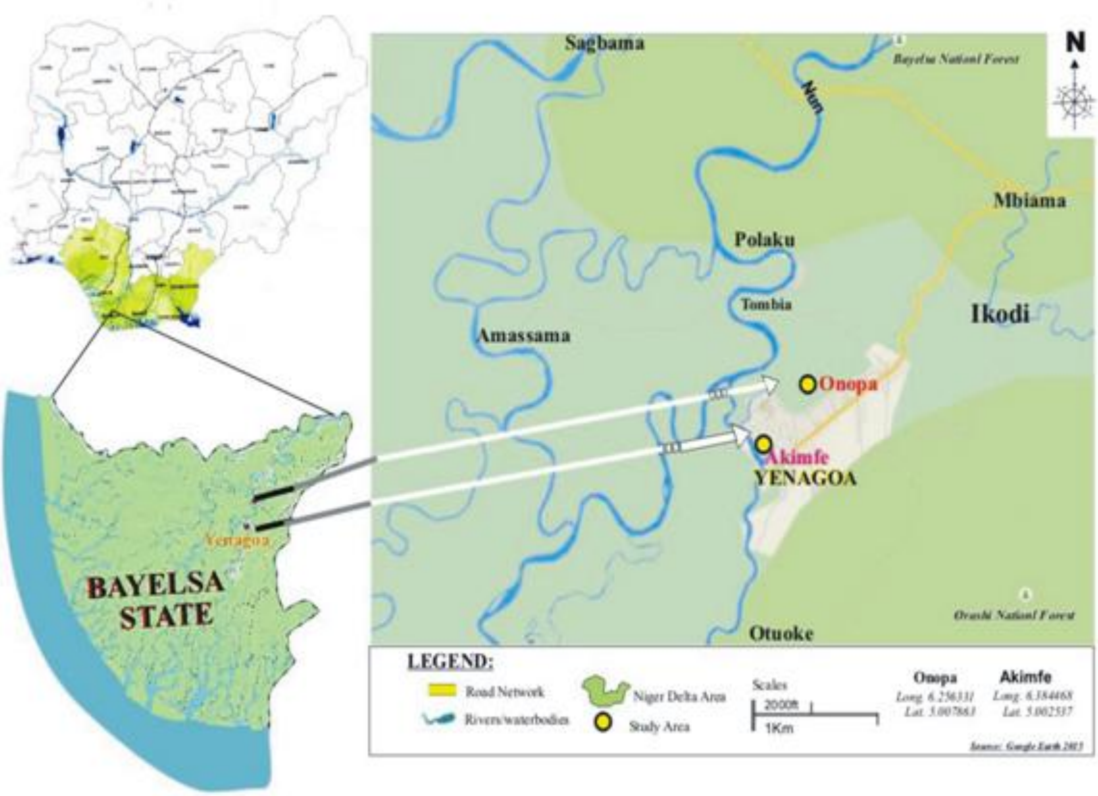

Fig. 1: Bayelsa State Showing the Study Locations at Akimfe and Onopa

Plate 1: Borehole (Sample A) location at Acme, Bagels State

Plate 2: Uncoated Sand (UCS)

Plate 3: Iron Oxide Coated Sand (IOCS)

III. Results

The results obtained in the removal of Iron, Mn and Arsenic by using IOCS and uncoated sand as adsorbentsare presented for the two adsorbent types (Table 1), while the results of mass of adsorbent dose for metal (sand) removal is given in Table 2. Looking at Table 1, the result showed that Arsenic had the highest percentage of removal, followed by Iron when using the uncoated sand. On the contrary, when using the IOCS, manganese is completely removed, followed by arsenic (Fig. 2).

The result also shows that the amount of metal contaminant removed, is also dependent on the mass of adsorbent used (Table 3). The higher the mass, e.g. 25gm against 5gm, the better the contaminant removal. This was observed for the two types of adsorbent (UCS or IOCS) (Fig. 2). The result of mass dose was also the same for manganese (Fig. 3) but showed better removal capacity for IOCS than UCS.

The result further shows that varying flow rate has an influence on how much contaminant is removed. Fig. 4 shows that a low flow rate of 5g/ml is optimum and better than flow rate of 25g/ml. As the flow rate increases to 25g/ml, the rate of removal takes a downward trend. This was observed for Iron and Manganese (Figs. 4 &5).

Table 1: Removal efficiency of different Adsorbents

/No.	Adsorbent Type	M etal	Initial Concentration	Final Concentration	% Removal	Flo w Rate
	Medium	Io n	Co (mg/l)	Ce(mg/ l)	% Qe	
	Uncoated Sand (UCS)	F e	5.423	0.629	8 8.40	10 ml/min
		M n	0.092	0.013	8 5.84	10 ml/min
		A s	0.715	0.073	8 9.79	10 ml/min
	Iron Oxide Coated Sand (IOCS)	F e	5.423	0.265	9 5.12	10 ml/min
		M n	0.092	0.000	1 00.00	10 ml/min
		As	0.715	0.020	97.20	10ml/min

Table 2: Effect of mass of adsorbent dose for iron removal

S/No.	Adsorbent Dose	Percentage Removal of Fe	
		UCS	IOCS
1	5g	56.12	81.20
2	10g	58.23	82.70
3	15g	64.18	87.11
4	20g	73.15	93.18
5	25g	74.6	96.50

Table 3: Effect of mass of adsorbent dose for Mn removal

S/N	Adsorbent Dose	Percentage Removal of Mn	
		UCS	IOCS
1	5g	56.50	78.13
2	10g	59.10	82.40
3	15g	65.08	94.60
4	20g	77.50	98.10
5	25g	82.10	99.35

Table 4: Effect of varying flow rate using column experiment

S/No.	Flow Rate	Percentage Removal of Fe	
		UCS	IOCS
1	5ml	89.41	100.00
2	10ml	88.40	98.10
3	15ml	87.02	95.49
4	20ml	83.14	93.43
5	25ml	81.15	91.82

Table 5: Effect of varying flow rate

S/No.	Flow Rate	Percentage Removal of Mn	
		UCS	IOCS
1	5ml	86.20	100.00
2	10ml	85.84	100.00
3	15ml	83.10	98.12
4	20ml	82.40	97.60
5	25ml	76.40	96.20

IV. Discussion

The result showed that Arsenic had the highest percentage of removal, followed by Iron when using the uncoated sand. This means that even the uncoated sand has a high capacityto purify water. This capacity varies from one metal to another as can be seen on Table 1 and Fig. 1. On the contrary when using the IOCS, manganese is completely removed, followed by arsenic. The complete removal of manganese shows superiority of IOCS as a purifying medium. The result further shows that, IOCS has a better removal capacity than uncoated sand. The column experiment confirms this (Fig. 1).

From the graph, it was observed that the percentage removal of Iron, Manganese and Arsenic are higher in iron oxide coated sand (IOCS) than the uncoated sand (UCS). The initial concentrationsfor Fe, Mn and As were: 5.423 ppm, 0.092 ppm and 0.001ppm respectively. The result showed that Arsenic was reduced from 0.715ppm to 0.073ppm for UCS and 0.715 ppm to 0.020ppm for IOCS. Although the Arsenic result is still above the WHO recommended permissible limitof 0.001ppm, this can be repeated. This suggests possible use of two to three column treatment system for an effective result.

The result shows that the mass of adsorbent used also determine the percentage of metal removed (Table 3). The higher the mass used, e.g. 25gm against 5gm, the better the contaminant removal. This was observed for the two types of adsorbent used (UCS or IOCS) (Fig. 2). However, IOCS further showed a far higher percentage removal than UCS. In other words, higher percentage removal was obtained with increasing mass of adsorbent. This finding is in agreement with those of many researchers who have used iron oxide to remove heavy metals and organic matter from tap water or waste water (Joshi *et al.,* 1996; Lo *et al*., 1997 and Kondu *et al.,* 2007). The results of this study corroborate previous studies which had confirmed that the utilization of IOCS is worth developing for heavy metal removal from water (Loi *et al.,* 2002; Petruesevski *et al*., 2002 and Gupta *et al*., 2005).

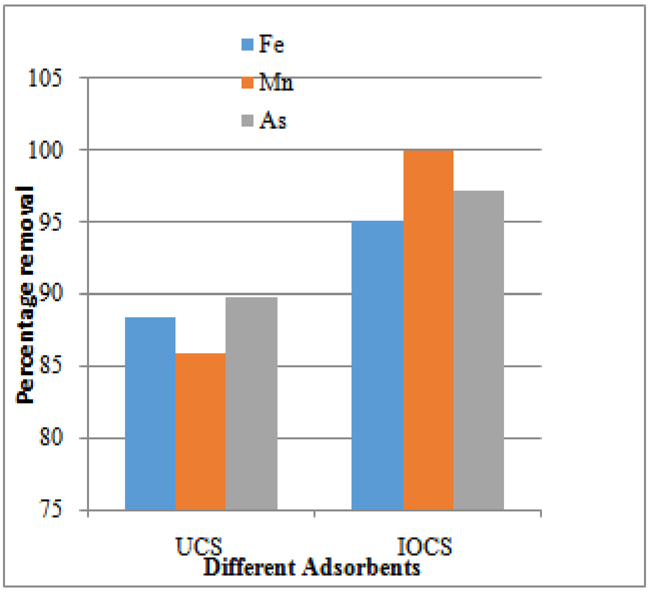

Figure 1: Effect of different adsorbents using Column Experiment

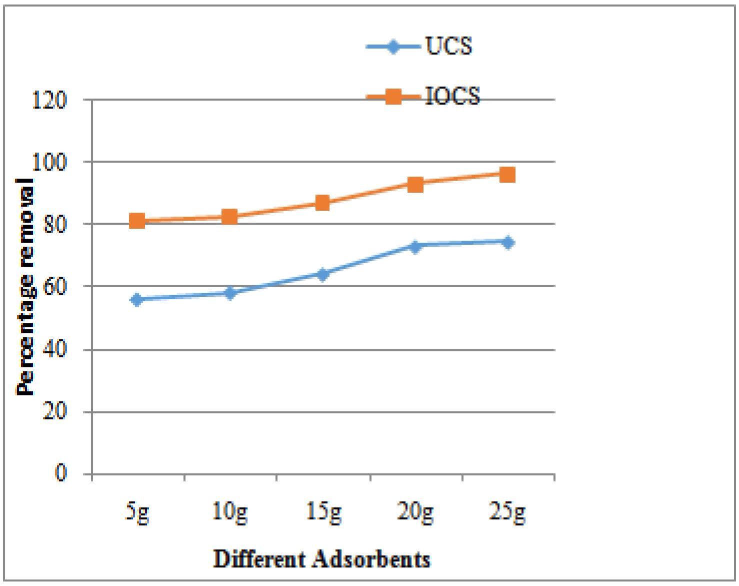

Figure 2: Effect of mass of adsorbent of Iron Removal

The mass of adsorbent used also determined the percentage of metal removed (Table 3). The higher the mass used, e.g. 25gm against 5gm, the more the contaminant removed. This was observed for the two types of adsorbent used (UCS or IOCS) (Figs. 2 and 3). However, IOCS further showed a far higher percentage removal than UCS. In other words, higher percentage removal was obtained with increasing mass of adsorbent. It is also evident that there is a clear gap between the coated sand and the uncoated sand. It can easily be inferred that the percentage removal of metal ions increased with increasing weight of coated sand. This is due to the greater availability of the exchangeable sites on surface area due to higher dose of the adsorbent.

The study on the flow rate showed that as the flow rate increased from 5ml to 25mml per minute, the percentage removal efficiency of iron decreased from 89.41% to 81.15% for uncoated sand and 100% to 91.82% for coated sand (Fig. 4); while that of manganese decreased from 86.20% to 76.40% for uncoated sand and 100% to 96.20% for coated sand (Fig. 5). The adsorption of iron and manganese were found to decrease with increasing flow rate from 5ml to 25ml per minute respectively in the two-treatment media.

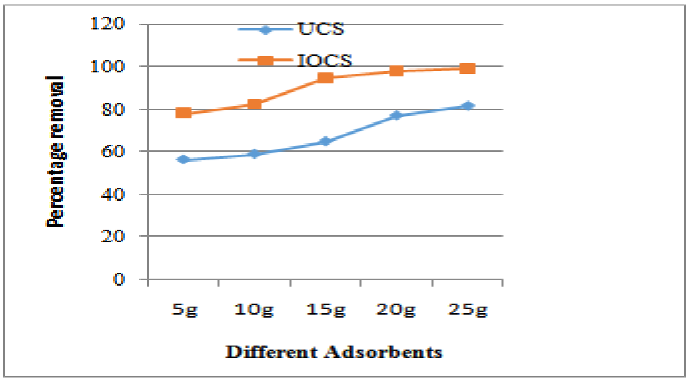

Figure 3: Effect of mass adsorbent for Manganese Removal

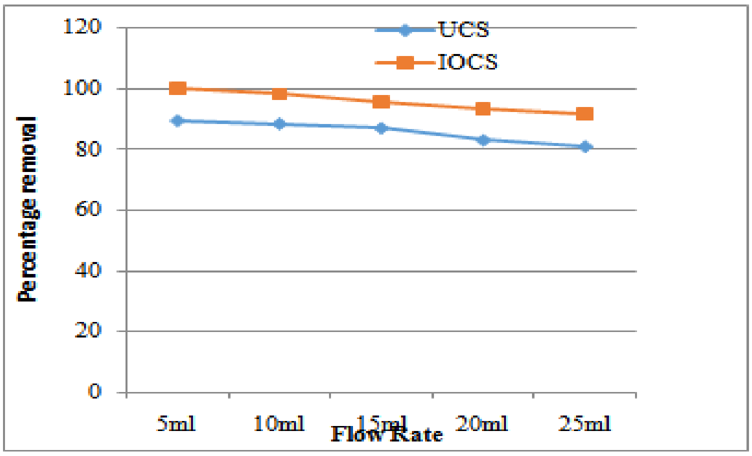

Figure 4: Effect of varying Flow Rate of Iron Removal

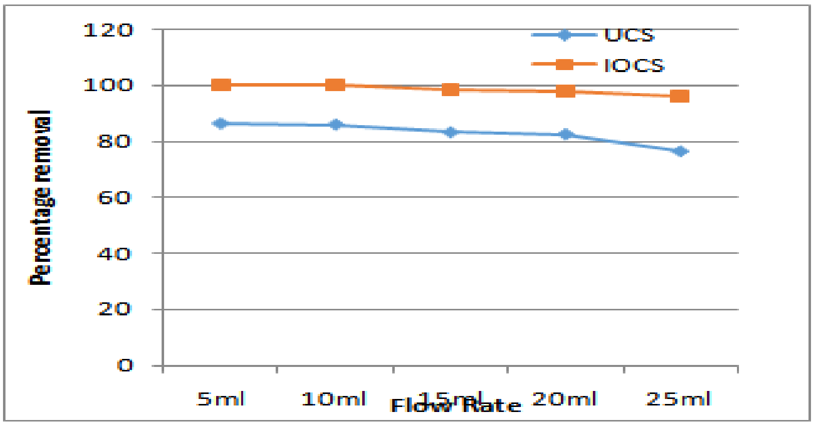

Figure 5: Effect of varying Flow Rate on Manganese Removal

V. Conclusion

It can be concluded that Iron oxide coated sand (IOCS) can be used to remove iron, manganese and arsenic effectively. The use of coated sand for heavy metal removal is far better than uncoated sand and that the study has shown that the locally produced adsorbent is not only for treatment of drinking water but also waste water and industrial affluent.

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