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Adsorption Equilibrium Study

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Highlights

Study of Adsorption Kinetics

Physical Analysis of Drinking Water

Discovering Thoughts, Inventing Future

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Chemical and Physical Analysis of Drinking Water from Shallow Wells and Bore Holes in Thovalai and Vilavancode Taluk

By M. Alice Margret, A. Amal Raj & T. Citarasu
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Abstract- A study was conducted in Thovalai and Vilavancode Taluks in Kanyakumari District of Tamil Nadu to evaluate the Status of drinking water from shallow wells and bore-holes with respect to different physic-chemical parameter Temperature, pH, turbidity, alkalinity, hardness, salinity, fluoride, chloride total dissolved solids, dissolved oxygen, BOD, electrical conductivity total nitrogen, nitrate, sulphate ,ammonia, phosphate, total phosphorus, sodium, potassium and oxidation and reduction potential water samples were collected from different places from the taluks. Results reveal that almost all the Physic-Chemical parameter including the elemental investigations of the shallow wells and bore-holes have values within the range of permissible levels for drinking water. It was found that most of the parameters are within the permissible levels as described by WHO (1984).

Keywords: *shallow well, bore holes, thovalai taluk, physico-chemical parameters.*

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Chemical and Physical Analysis of Drinking Water from Shallow Wells and Bore Holes in Thovalai and Vilavancode Taluk

M. Alice Margret [α], A. Amal Raj [σ] & T. Citarasu [ρ]

Abstract- A study was conducted in Thovalai and Vilavancode Taluks in Kanyakumari District of Tamil Nadu to evaluate the Status of drinking water from shallow wells and bore-holes with respect to different physic-chemical parameter Temperature, pH, turbidity, alkalinity, hardness, salinity, fluoride, chloride total dissolved solids, dissolved oxygen, BOD, electrical conductivity total nitrogen, nitrate, sulphate ,ammonia, phosphate, total phosphorus, sodium, potassium and oxidation and reduction potential water samples were collected from different places from the taluks. Results reveal that almost all the Physic-Chemical parameter including the elemental investigations of the shallow wells and bore-holes have values within the range of permissible levels for drinking water. It was found that most of the parameters are within the permissible levels as described by WHO (1984).

Keywords: shallow well, bore holes, thovalai taluk, physico-chemical parameters.

I. Introduction

Water is the most important component for the existence of all human beings animals and plants. The important sources of water are rain, sea, surface water is essential source of water supply throughout the world. It is used in irrigation, industries and domestic uses continue to increase where perennial surface water sources are absent[Marriappan 2005] Kanyakumari district of the state of Tamilnadu, and the southernmost tip of India. Peoples of thin district depends on bore-hole water or shallow wells for domestic and agricultural purpose Appraisal of ground water quality from bore-hole and shallow wells for drinking is the objective of present study.

II. Materials and Methods

a) Area of the study

There are four taluks in Kanyakumari district namely Agasteeswaram, kalkulam, Thovalai and Vilavancode. The study was conducted in two taluks of Kanyakumari district in South India namely Thovalai and Vilavancode. A part of our research study the water from Thovalai and Vilavancode was analysed.

b) Collection of samples

Bore-well water samples were collected from five villages Aralvaimozhi(B_1), Boothapandy(B_2), Erachakulam(B_3), Esanthimangalam(B_4) and Thovalai(B_5) of Thovalai Taluk. Bore-well water Samples were collected from villages Anducode(B_6), Midalam(B_7), Pacode(B_8), Paloor(B_9) and Palukal(B_{10}) of Vilavancode Taluk.

Similarly shallow well water samples were also collected from the above said villages and are labeled as Aralvaimozhi(S_1), Boothapandy(S_2), Erachakulam(S_3), Esanthimangalam(S_4) and Thovalai(S_5) of Thovali Taluk and Anducode(S_6), Midalam(S_7), Pacode(S_8), Paloor(S_9) and Palukal(S_{10}) of Vilavancode taluk. Samples were collected in Plastic container and brought to the laboratory for analysis.

i. Analysis of Physico-Chemical parameters

The standard methods [APHA 2005,Trivedi 1984] and standard Procedures were followed for the analysis of water.

III. Results and Discussion

The results obtained from analysis of borewell water samples of 5 villages of Thovalai and Vilavancode Taluk are results obtained from analysis of shallow well

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water samples of 5 villages of Thovali and vilavancode Taluk are given in Table 2. The results are compared with WHO(1983). The results are alsssso analysed graphically as shown in figures 1 to 10.

a) pH

The pH values varied from 6.5 to 6.8 for B_1 to B_5, 6.4 to 6.8 for B_6 to B_{10} (Table 1), 6.4 to 6.9 for S_1 to S_5, 6.5 to 6.8 for S_6 to S_{10} (Table 2). The limit of pH value for drinking water is specified[WHO, ISI] as 6.5 to 8.5. The pH of both bore-well water and shallow well water is almossst neutral. The pH of water is influenced by geology of catchment areas and buffering capacity of water.

b) Temperature

The temperature was found to be the range between 26 to 28°C during study.

c) Turbidity

The turbidity values varied from 7.1 to 7.7 for B_1 to B_5, 7.0 to 7.8 for B_6 to B_{10} (Table 1), 5.0 to 5.4 for S_1 to S_5, 5.4 to 5.8 for S_6 to S_{10} (Table 2). The limit of turbidity value for drinking water is specified as 5 to 10 NTU. The observed turbidity values are within the permissible levels.

d) Alkalinity

The mean value of alkalinity in the bore-well water of Thovalai and Vilavancode talluks are respectively. The standard desirable limit of alkalinity in drinking water is 120 mg/L. The maximum permissible level is 600 mg/L. The mean value of alkalinity exceeding the desirable limit in all stations.

e) Calcium and Magnesium

Calcium concentrations were found to vary from 50 to 71 for B_1 to B_{10} (Table 1) and 50 to 57 mg/L for S_1 to S_{10} (Table 2). The upper limit of Calcium Concentration in drinking water is specified as 75 mg/L (ISI, 1983). The observed values in all the five villages of both taluks of bore-water and shallow well water are and well within the desirable limits.

Magnesium samples varied from 1.2 to 1.8 mg/L and the values are the permissible limit of WHO(30 mg/L).

f) Chloride

Ground water contamination is identified from chloride content. The values of chloride observed for B_1 to B_5 is 225 to 235 (Table 1) and B_6 to B_{10} is 232 to 262(Table 2) and for S_1 to S_5 is 203 to 208(Table 1) and S_6 to S_{10} is 71 to 80(Table 2). The values are within the permissible limits.

g) Total dissolved solids

The desirable limit of TDS is 500 mg/L as prescribed by ISI. The TDS values for both bore water sample and shallow well water sample in all the stations of Thovalai and vilavancode Taluk are low because there is no pollution by any waste water.

h) Dissolved Oxygen

Dissolved Oxygen values of water samples varied from 6 to 7.6 mg/L. Ther is no standard[Ashvin 2013] for dissolved oxygen for water quality assessment.

i) Fluoride

The desirable limit of fluoride is 1 to 1.5 mg/L for drinking water. In this samples were found to have 0.7 to 0.82 for B_1 to B_{10} and 0.4 to 0.61 for S_1 to S_{10}. Fluoride content is an important factor in the development of normal bones and teeth. [Preeti Gupta 2009].

j) Bio-Chemical Oxygen Demand

BOD values ranged from 4.1 to 5 for B_1 to B_5 (Table 1) and 4.6 to 5.4 for B_6 to B_{10} (Table 2) and 7 to 7.6 for S_1 to S_5 (Table 1) and 5.1 to 5.8 for S_6 to S_{10} (Table 2). The values are within the permissible levels (WHO 1983).

k) Electrical Conductivity

Electrical Conductivity values for Bore-well water and shallow well water and ranges from 600 to 740 micromho/cm^2 and 600 to 630 micromho/cm^2. The values are within the permissible limits.

l) Nitrate

The nitrate values of sample varied from 0.6 to 0.98 for B1 to B_5 and 0.4 to 0.5 for S_1 to S_5 and 0.64 to 0.8 for B_6 to B_{10} and 0.4 to 0.5 for S_6 to S_{10}. These values are within the permissible limits.

m) Sulphate

The sulphate concentration varied between 5.2 to 6.7 for B_1 to B_{10} and 4.2 to 4.8 for S_1 to S_{10} samples and the values were found within the permissible limit.

n) Phosphate

The phosphate content in the study area was found in the range of 0.84 to 0.96 for B_1 to B_5 and 0.8 to 0.94 for S_1 to S_6 and 0.84 to 0.96 for B_6 to B_{10} and 0.51 to 0.64 for S_6 to S_{10}. These values are within the permissible limits.

o) Sodium (NA^+) and Potassium(K^+)

Sodium concentrations were found in between 18.4 to 19.9 mg/L for B_1 to B_{10} and 14.3 to 16.2 mg/L for S_1 to S_2.

Potassium concentrations were found in between 10.4 to 15 mg/L. The concentration of sodium and potassium in the water samples are within the permissible limits.

p) Oxidation and Reduction Potential

The value of oxidation and Reduction Potential of both bore well water and shallow well ranges from 600 to 630 mV and 540 to 590 mV.

The low oxidation reduction potential value of shallow well water than bore well water indicates that more oxygen is present in bore –hole water.

Table 1 : Chemical and physical parameters of bore hole water samples of Thovalai and Vilavancode Taluk

Parameters	Taluk									
	Thovalai					Vilavancode				
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
Temperature (°C)	27	27	26	26	27	27	26	27	26	27
pH	6.8	6.7	6.8	6.6	6.5	6.7	6.4	6.8	6.8	6.7
Turbidity (NTu)	7.7	7.3	7.1	7.6	7.7	7.8	7	7.2	7.2	7.6
Alkalinity(mg/L)	174	173	170	176	174	190	190	188	187	181
Hardness Ca(mg/L)	50	51	51	52	51	68	65	70	71	70
Mg(Mg/L)	1.4	1.4	1.2	1.3	1.3	1.6	1.8	1.5	1.4	1.45
Salinity(mg/L)	71	78	78	73	74	70	80	71	72	72
Fluoride(mg/L)	0.8	0.7	0.7	0.8	0.7	0.8	0.78	0.7	0.81	0.82
Chloride(mg/L)	225	225	230	220	235	250	232	258	260	262
Total dissolved solids(mg/L)	64	61	62	70	68	62	63	68	70	69
Dissolved oxygen(mg/L)	6	6.3	7	6.8	6.4	5.4	6	5.5	5.2	5.1
BOD(mg/L)	4.8	4.9	4.1	5	4.8	4.6	5.4	4.6	4.8	4.9
Electrical conductivity	680	685	680	700	685	600	740	620	635	620
Total Nitrogen	4.2	4.3	4.2	4.4	4.6	4	4.2	4.6	4.4	4.2
Nitrate(mg/L)	0.6	0.6	0.64	0.68	0.61	0.8	0.64	0.76	0.78	0.8
sulphate(mg/L)	6.1	6.4	6.1	6.7	6.1	5.2	5.4	6.1	6.2	5.8
Ammonia(mg/L)	6.8	7	7.2	7.2	7.6	7.4	5.2	7.3	7.4	7.4
phosphate(mg/L)	0.84	0.86	0.94	0.9	0.88	0.8	0.94	0.86	0.88	0.8
Total phosphorus(mg/L)	0.65	0.7	0.72	0.68	0.74	0.6	0.7	0.64	0.64	0.6
Sodium(mg/L)	19.2	19.6	19.4	19.6	19.2	18.8	19.9	18.6	18.4	18.8
Potassium(mg/L)	14.8	14.7	15	14.9	15.1	12.9	13	14.8	14.4	13.4
Oxidation-Reduction Potential	625	620	620	600	625	620	610	630	615	620

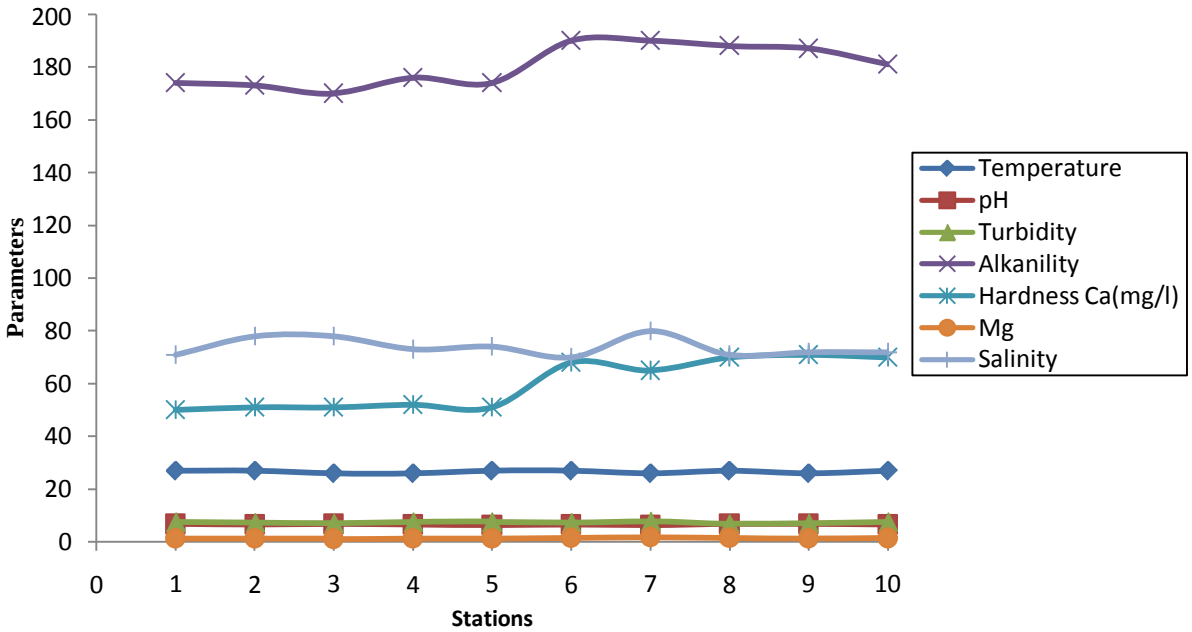
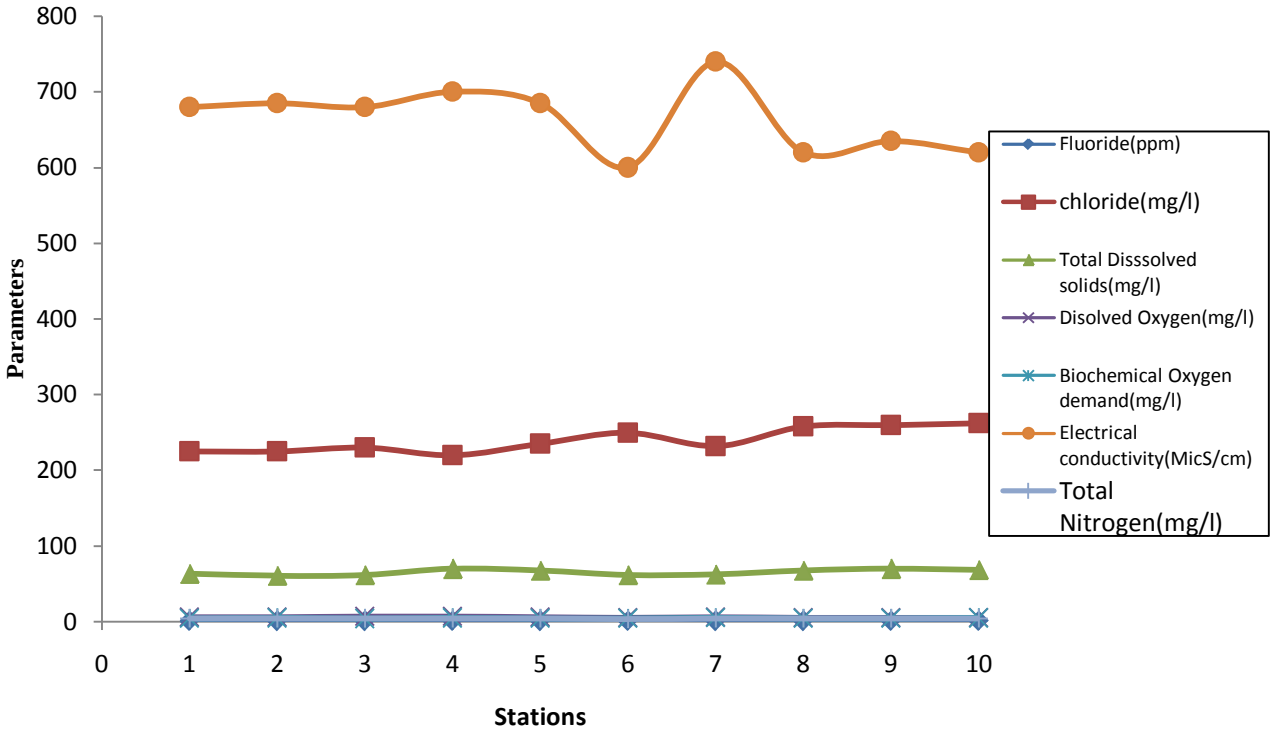


Figure 1



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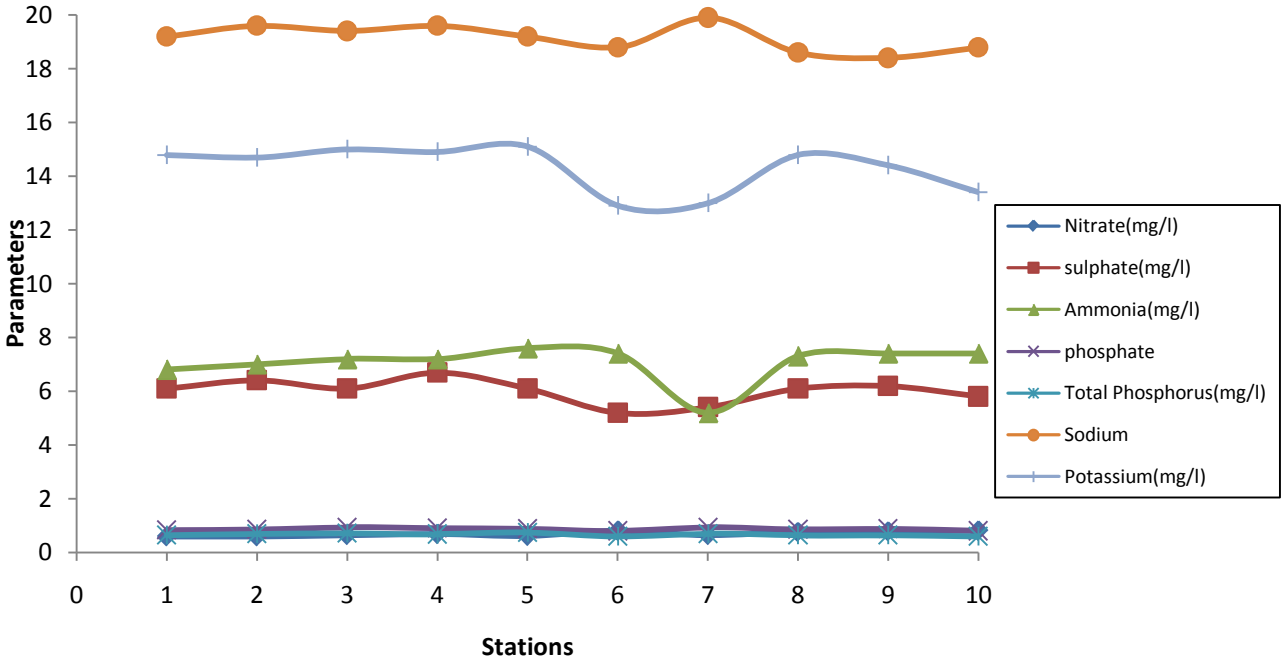

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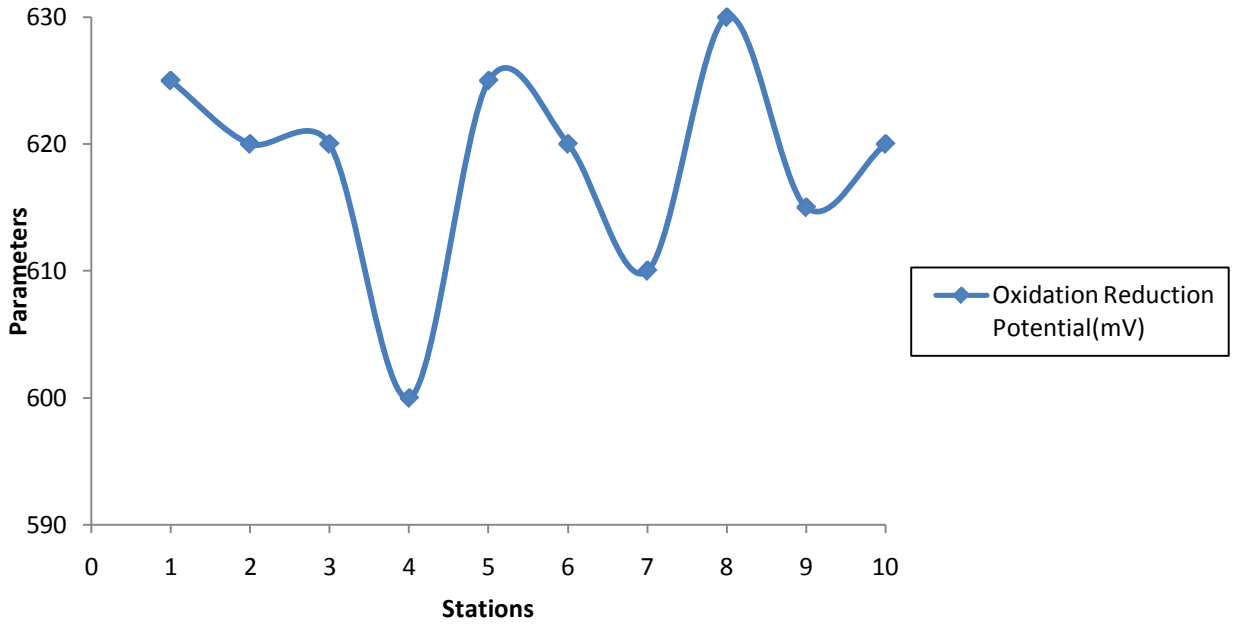
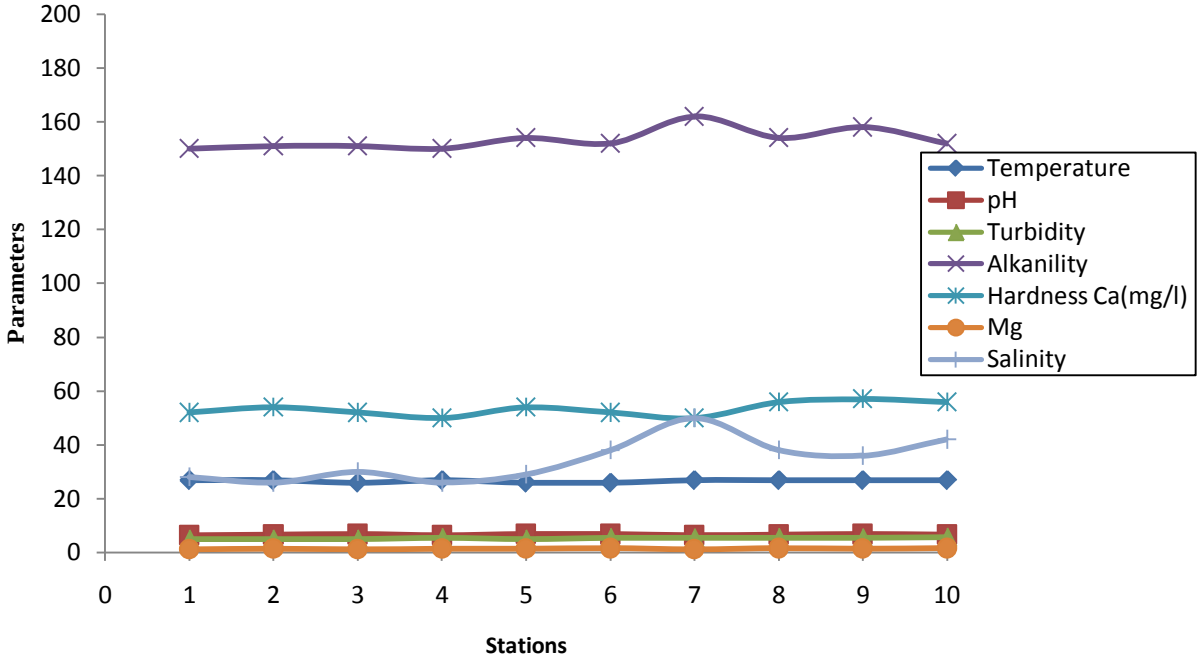


Figure 4

Table 2 : Chemical and physical parameters of different shallow well water samples of Thovalai and Vilavancode Taluk

Parameters	Taluk									
	Thovalai					Vilavancode				
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
Temperature (°C)	27	27	26	27	26	26	27	27	27	27
pH	6.4	6.6	6.8	6.4	6.9	6.8	6.5	6.6	6.8	6.6
Turbidity (NTu)	5	5.1	5.1	5.4	5.1	5.4	5.5	5.4	5.6	5.8
Alkalinity(mg/L)	150	151	151	150	154	152	162	154	158	152
Hardness Ca(mg/L)	52	54	52	50	54	52	50	56	57	56
Mg(Mg/L)	1.3	1.4	1.32	1.38	1.48	1.6	1.28	1.6	1.5	1.58
Salinity(mg/L)	28	26	30	26	29	38	50	38	36	42
Fluoride(mg/L)	0.6	0.6	0.58	0.61	0.6	0.4	0.51	0.48	0.42	0.41
Chloride(mg/L)	205	208	206	205	203	210	221	212	220	218
Total dissolved solids(mg/L)	36	36.5	37	36.8	36.9	37	35	36	37	36
Dissolved oxygen(mg/L)	7	7.1	7.4	7	7.6	7	6.2	7.2	7.3	7
BOD(mg/L)	5.2	6	5.1	6.2	5.1	5	5.1	5.8	5.6	5.6
Electrical conductivity	620	600	615	610	600	600	630	625	620	620
Total Nitrogen	3.8	3.9	4	3.6	3.8	4	4	3.8	4.2	4.1
Nitrate(mg/L)	0.5	0.5	0.4	0.4	0.5	0.4	0.51	0.42	0.48	0.5
sulphate(mg/L)	4.4	4.8	4.62	4.5	4.3	4.4	4.2	4.6	4.8	4.8
Ammonia(mg/L)	5	4.9	4.8	5.1	4.85	4.8	5	4.8	4.7	4.6
phosphate(mg/L)	0.6	0.62	0.51	0.52	0.64	0.7	0.4	0.64	0.66	0.6
Total phosphorus(mg/L)	0.53	0.54	0.58	0.53	0.58	0.5	0.5	0.48	0.48	0.5
Sodium(mg/L)	15.7	15.8	16	16.2	14.3	15.8	16.1	15.6	15.4	15.6
Potassium(mg/L)	11.8	11.6	11.7	11.8	11.4	11.4	10.4	11.8	11.6	11.6
Oxidation-Reduction Potential	590	580	540	540	576	560	580	585	590	560



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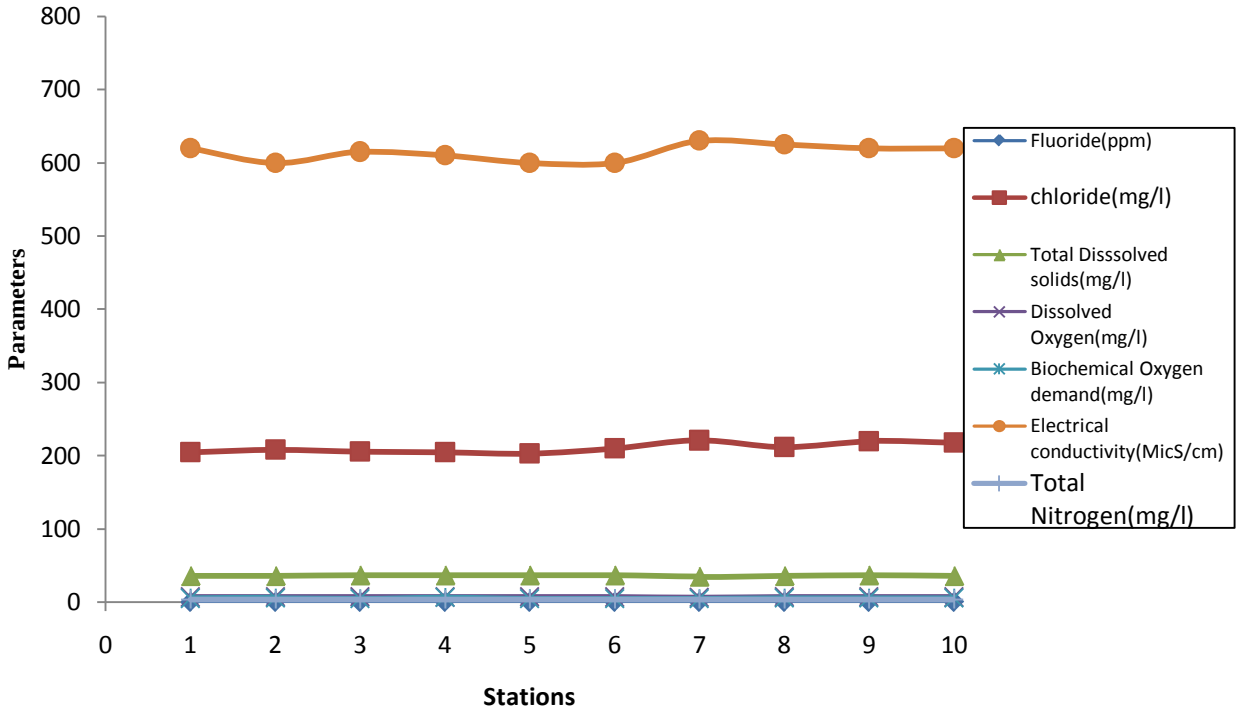

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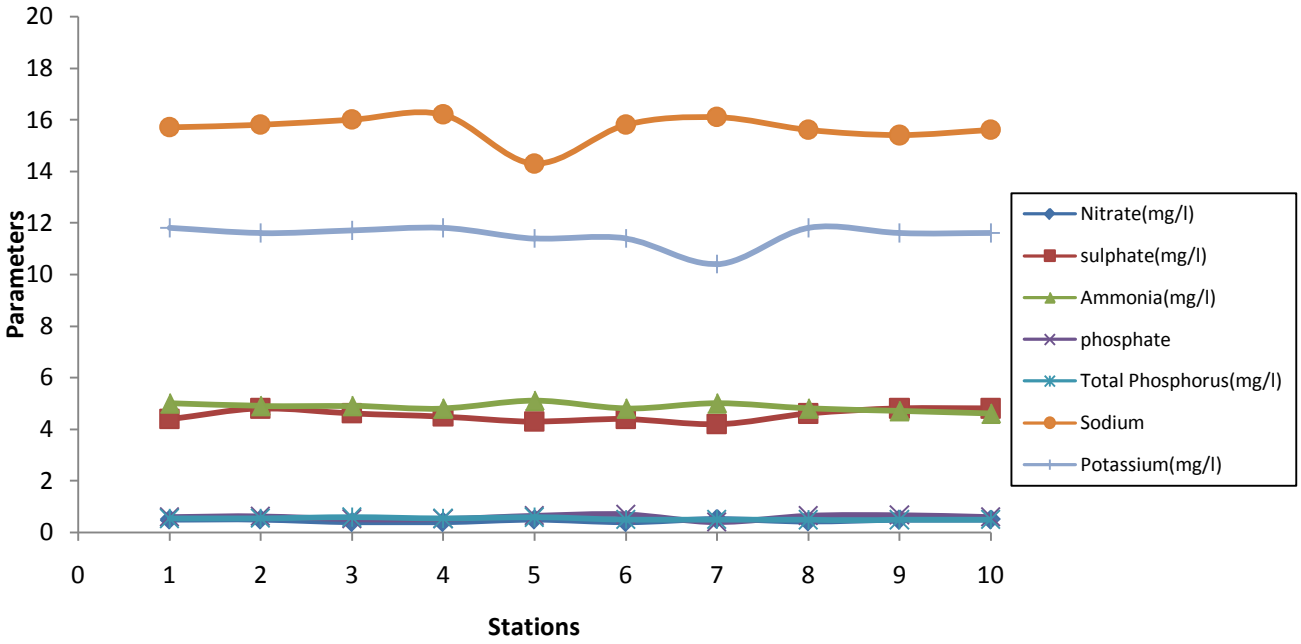

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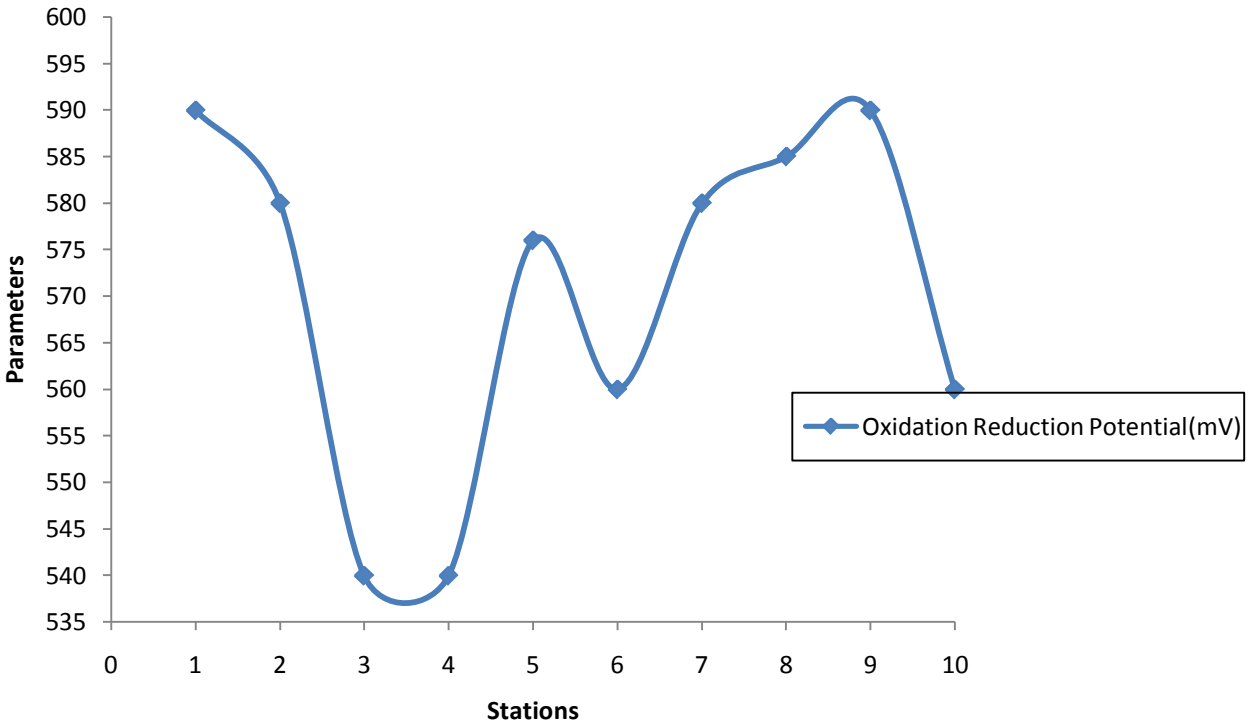

Figure 8

IV. Conclusions

The physico-chemical analysis of bore-hole water samples from five different villages in Thovalai and Vilavancode Taluk, shallow well water sample from five different villages in Thovalai and Agatheesvaram taluk were carried out. Most of the parameters are well within the permissible limits. It is concluded that both bore water and shallow well water can be used for domestic purpose.

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Adsorption Equilibrium Study of Lead and Zinc on Rice Husk from Aqueous Solution

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Abstract- In this study the adsorption property of rice husk of varied particle sizes (150 µm and 500µm) was examined in the removal of lead and zinc in synthetic solution. The adsorption was done in batches; the effect of concentration, temperature, pH and contact time was examined on the adsorption and the data were fitted into different models such as Langmuir, Freundlich, Temkin, Lagergren pseudo first order and Ho's pseudo second order. The adsorption was best fitted into the Langmuir and Lagergren models. The adsorption per unit mass was optimum at 150 mg/L, at 20°C, pH 7-8 and 30 minutes. The rice husk showed a good potential in removing lead and zinc of waste water.

Keywords: *metal adsorption; synthetic water; rice husk; varied sizes.*

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Strictly as per the compliance and regulations of :

Adsorption Equilibrium Study of Lead and Zinc on Rice Husk from Aqueous Solution

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Abstract- In this study the adsorption property of rice husk of varied particle sizes (150 µm and 500µm) was examined in the removal of lead and zinc in synthetic solution. The adsorption was done in batches; the effect of concentration, temperature, pH and contact time was examined on the adsorption and the data were fitted into different models such as Langmuir, Freundlich, Temkin, Lagergren pseudo first order and Ho's pseudo second order. The adsorption was best fitted into the Langmuir and Lagergren models. The adsorption per unit mass was optimum at 150 mg/L, at 20°C, pH 7-8 and 30 minutes. The rice husk showed a good potential in removing lead and zinc of waste water.

Keywords: metal adsorption; synthetic water; rice husk; varied sizes.

I. Introduction

Effective removal of lead and zinc ions in effluents as a result of industrial, agricultural and mining is a problem; because they find their way into water bodies and their activities are persistent in the environment and are very toxic, and usually manage to get into potable water. Lead accumulation in the human body has been the major cause of dysfunction of kidney, liver, central nervous system, anaemia, high blood pressure, depression and reduced intelligence quotient in children [1; 2]. Zinc accumulation in the human body leads to electrolyte imbalance, nausea, anaemia and lethargy [3]. Lead and zinc metal removal in waste water has been effected by several methods in the time past including chemical precipitation [4], filtration [2], ion exchange [5], reverse osmosis [1], coagulation/flocculation [6] and adsorption [7]. All these methods have their demerits which include high cost of operation, which is not sustainable by small scale industries and also clean up of chemical treatment is difficult if not almost impossible. However out of the all the available methods of effluent treatment, biosorption seems to be the cheapest, fastest and most effective method of remediation of waste water.

Recently some materials have been used for biosorption in waste water remediation which include sugar cane bagasse [8], maize tassel [9], brick [10], clay [7], alumina [11], bark [12] zeolite tuff [13]. Others include walnut shell [6], pineapple peel [14], wheat bran, corn cob and human hair [4], coconut husk, bean chaffs [2], coal [15], kaolinite, illite [16], egg shell and activated carbon [17]. However much attention is focused on bio--adsorbent as a standard. Adsorbents have the advantage of being biodegradable, thus are environmentally friendly and remove toxicants by adsorption, ion exchange and metabolic reaction but a little attention is paid on rice husk which is a universal waste product in zinc and lead remediation of waste water. The few researchers that have examined the potential of rice husk did not examine the effect of variation of particle sizes on the adsorption process.

Hence this research examines the effect of varied particle sizes on adsorption of lead and zinc on using various particle sizes of the rice husk and also the efficiency in remediating waste water, also to examine the effect of change of pH, temperature, adsorbate concentration and time on adsorption capacity of rice husk.

II. Materials and Methods

The rice husk was purchased in the market in Abeokuta in Ogun state south west Nigeria and was washed in tap water, distilled water and de-ionized water respectively after which it was spread on polythene materials in the laboratory to air dry and later oven dried for 24 hours at 105°C, it was then ground and sieved into various particle sizes viz; 150 and 500 micron sizes. All reagents and standards were purchased from Sigma Aldrich Germany. Lead chloride and zinc chloride were used to prepare the lead and zinc standard solutions respectively. The 1000 mg/L standards were prepared by first preparing 0.1 molar of sodium acetate solution. The 0.1 molar sodium acetate solution was used to prepare the 1000 mg/L of the stock standard solution. The 100 mg/L solution was produced from the 1000 mg/L stock by dilution with de-ionized water. 0.5 g of the 500 micron size rice husk was placed in a 100 ml screw cap bottle and 50 mL of the 100 mg/L standard of the lead solution was added to it and was then place in temperature controlled water bath with shaker and was shaken for 30 minutes. It was then filtered and the filtrate was analysed on the atomic absorption spectrometer (AAS). The procedure was done in triplicates and the mean concentration was obtained. The procedure was repeated for 150 micron size and analysed by AAS.

The extent of metal ion uptake on 0.5 g of biosorbent of both micron sizes was examined with 50

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mL test solution of lead and zinc respectively, with concentrations between 100-250 mg/L for 30 minutes. They were filtered with whatman filter paper and the filtrate was analysed with AAS.

Effect of temperature was examined on 0.5 g of biosorbent of both micron sizes with 50 mL test solution of lead and zinc respectively, between 40- 80°C for 30 minutes, after which they were filtered with whatman filter paper and the filtrate was analysed with AAS.

Time variation effect on biosorption was examined on 0.5 g of biosorbent for both micron sizes with 50 mL test solution of lead and zinc respectively, between 30 – 150 minutes and were filtered with whatman filter paper and the filtrate was analysed with AAS.

Effect of pH was examined on biosorption on 0.5 g of biosorbent of both micron sizes with 100 mg/L of 50 mL test solution of lead and zinc respectively, between pH 3 - 9, after which they were filtered with whatman filter paper and the filtrate was analysed with AAS.

III. Result and Discussion

a) Effect of Concentration

The adsorption of zinc ion in synthetic solution was examined with increase in zinc concentration on rice husk of 150 and 500 micron sizes. it was observed that the amount of ions adsorbed increased with increase in concentration though not stepwisely as the concentration increased from 150 – 300 mg/L, which seems to suggest that the adsorption increased as the concentration increased, also the adsorption per unit mass was maximum at the highest concentration for both particle sizes. The adsorption in 150 and 500 micron sizes showed similar trends and the t-test showed that there was no significant deference between the adsorption by the two particle sizes. The effect of varied concentration of zinc on rice husk varied particle sizes is as shown in figure 1.

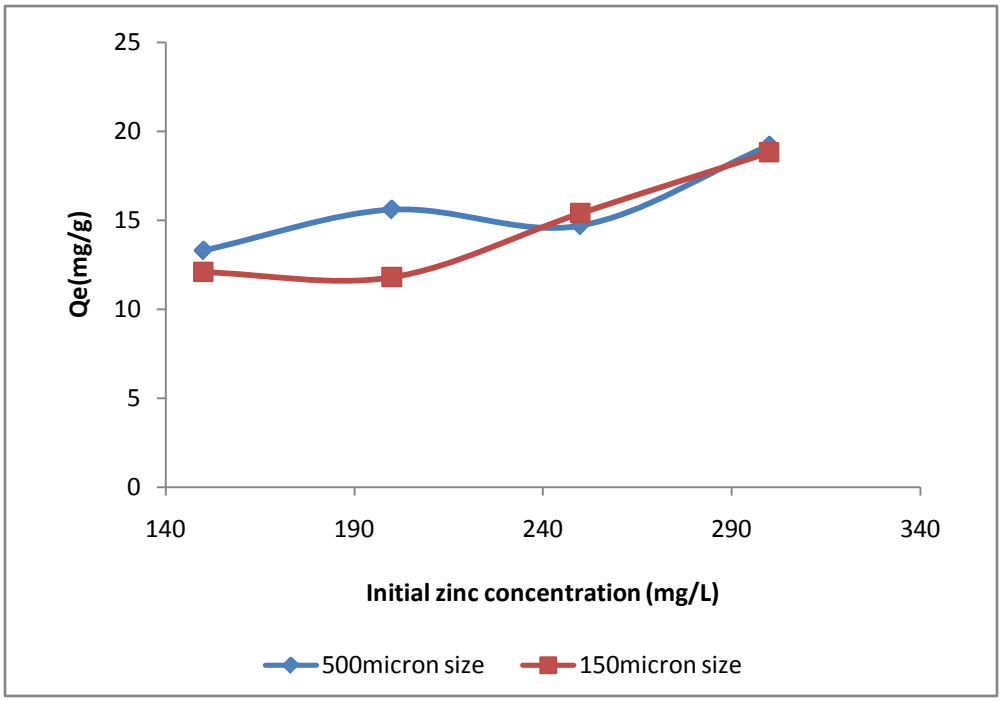

Figure 1 : Showing effect of varied concentration of zinc on rice husk of varied particle sizes

The effect of increased concentration was examined on lead biosorption, on both particle sizes. As the concentration increased, it was observed that the adsorption increased with increase in lead concentration though not stepwisely in 500 micron size, but was stepwise on 150 micron size rice husk. The adsorption per unit mass was maximum at the 300 mg/L concentration for both particle sizes. Nevertheless the paired t-test of adsorption of both particle sizes showed that there was no significant difference between the adsorption of both particle sizes. The effect of varied initial lead concentration on rice husk of varied particle sizes is as shown in figure 2.

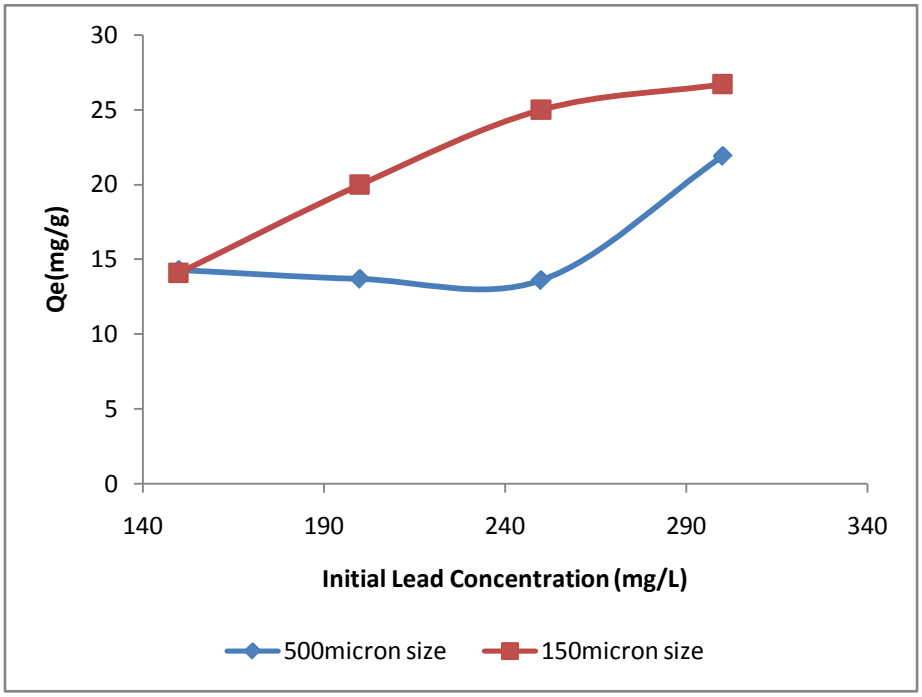

Figure 2 : showing effect of varied concentration of lead on rice husk of varied particle sizes

The Langmuir adsorption isotherm was examined on zinc solution on the 150 and 500 micron sizes of rice husk respectively, the Langmuir model assumes the adsorption of an ideal gas on the ideal surface occurs only on a fixed number of sites, each molecule forms a monolayer sorption on each site and no interaction is between adjacent sites. The Langmuir adsorption is based on the equation.

$$\frac{Ce}{qe} = \frac{1}{KL} - \frac{aL}{KL}Ce$$

Where Ce is the concentration of the adsorbate solution at equilibrium (unit in mg/L) and qe is the mass of adsorbate adsorbed per unit mass of the adsorbent at equilibrium (unit in mg/g) [9]. When $\frac{Ce}{qe}$ is plotted against Ce the slope is $\frac{aL}{KL}$ which is the theoretical saturation capacity (unit in mg/g) and the intercept of the slope is $\frac{1}{KL}$. KL is the equilibrium constant. The result is as tabulated below.

Table 1: Langmuir adsorption isotherm of zinc on rice husk

Rice Husk Size	R^2	$\frac{aL}{KL}$	$\frac{1}{KL}$
500micron size	0.931	0.06	0.42
150micron size	0.737	0.05	1.52

From the table above we could observe that Langmuir adsorption isotherm was obeyed as the correlation coefficients (R^2) were above 0.5, while $\frac{aL}{KL}$ in both cases, the saturation capacity were very low, while the intercept were also low.

The Langmuir adsorption isotherm was also obeyed for lead in 150 and 500 micron sizes of rice husk and the result obtained is as tabulated below.

Table 2 : Showing Langmuir adsorption isotherm of lead on rice husk

Rice Husk Size	R^2	$\frac{aL}{KL}$	$\frac{1}{KL}$
500micron size	0.886	0.07	–0.21
150micron size	0.799	0.04	0.034

From the table above, we could observe that Langmuir adsorption isotherm was obeyed as the regression coefficients (R^2) were above 0.5 while $\frac{aL}{KL}$ the saturation capacity were very low while the intercept was very low.

The Freundlich adsorption isotherm of the adsorption of zinc on rice husk of particle sizes 150 and 500 micron sizes were also examined. The Freundlich model is used for heterogenous surface energy system and with highly interactive species. The Freundlich model is represented by the equation.

$$q_e = KCe^{1/n}$$

Where Ce is the concentration of the adsorbate solution at equilibrium (unit in mg/L) and qe is the mass adsorbed per unit mass of the adsorbent at equilibrium

(unit in mg/g), K is an indicator of the adsorption capacity, and n is the adsorption intensity which varies with heterogeneity of the material [9: 18]. When qe is plotted against Ce the slope is K and the power of the slope equation gave 1/n.

The result of the Freundlich isotherm is as tabulated in table 3 below.

Table 3 : Showing Freundlich isotherm of Zinc on rice husk

Rice Husk Size	R^2	K	n
500micron size	0.507	9.35	7.83
150micron size	0.449	5.06	4.12

It could be observed from the table above that the regression coefficient (R^2) were very low (<0.5), which is an indication that the Freundlich isotherm was not obeyed, nevertheless n is less than 10 which is an indication that the adsorption was favourable, the K was also low which is an indication of adsorption capacity of the adsorbent is low, but it is quite promising.

The Freundlich isotherm for adsorption of lead on 500 and 150 micron sizes of rice husk, are as tabulated in table 4 below.

Table 4 : Showing Freundlich isotherm of Lead on rice husk

Rice Husk Size	R^2	K	n
500micron size	0.05	13.30	24.51
150micron size	0.002	21.4	–0.005

It could be observed from the table above, that the regression coefficient was very low (<0.5) which is an indication that Freundlich isotherm was not obeyed, however, n was high an indication that the adsorption on the adsorbate was favourable; K was also high which is an indication that adsorption capacity was high.

The Temkin adsorption isotherm of the adsorption of zinc on rice husk of particle sizes 150 and 500 micron sizes were examined. The Temkin model is represented by the equation.

$$q_e = \left(\frac{RT}{b}\right) lnA + \left(\frac{RT}{b}\right) lnCe$$

where

q_e = equilibrium mass adsorbed per unit mass

R = gas constant = 8.314 J $K^{-1}mol^{-1}$

T = Temperature in Kelvin = 303K

Ce = equilibrium concentration in mg/L

B = Temkin isotherm constant (J mol^{-1})

A= Equilibrium binding constant corresponding to the maximum binding energy (L/mg).

The plot of lnCe against qe gives a linear graph whose slope is $\left(\frac{RT}{b}\right)$ and intercept is $\left(\frac{RT}{b}\right) \ln A$ which can be used to obtain A [19].

The Temkin isotherm of zinc on 500 and 150 micron sizes of rice husk is as tabulated in table 5 below.

Table 5 : Showing Temkin isotherm of zinc on rice husk.

Rice Husk Size	R^2	A	b
500micron size	0.480	44.37	1247
150micron size	0.446	0.798	700

It could be observed from the table 5 above that the regression coefficients were low, an indication that the Temkin isotherm was not obeyed; however the isotherm constant in both cases were high.

The Temkin isotherm of lead on 500 and 150 micron sizes of rice husk is as tabulated in table 6 below.

Table 6 : Showing Temkin adsorption isotherm of lead on rice husk

Rice Husk Size	R^2	A	b
500micron size	0.058	1.5E7	3232
150micron size	0.003	4.3E62	16,465

It could be observed from the table 6 above that the regression coefficients were low, an indication that the Temkin isotherm was not obeyed; however the isotherm constant in both cases were high, an indication that lead interaction with adsorption sites at that temperature were high.

b) Effect of pH

The effect of varied pH (3, 5, 7, 8 and 9) was also examined on the adsorption of zinc on rice husk of both micron sizes, the initial concentration at various pH was 100 mg/L. It was observed that the zinc adsorption per unit mass on adsorbent was low in acidic pH but increased stepwisely to the neutral pH on both micron sizes, but maintained a crest to the basic pH examined in this research. Which seems to suggest that acidic pH does not favour adsorption of zinc on rice husk, whereas it is more favourable at neutral and basic pH. The neutral pH seems to be the optimum pH for the adsorption. The t-test for paired result was conducted on the mass adsorbed per unit mass of adsorbent of the two particle sizes indicated no significant difference. The effect of varied pH on the adsorption of zinc on rice husk is as shown in Figure 3 below.

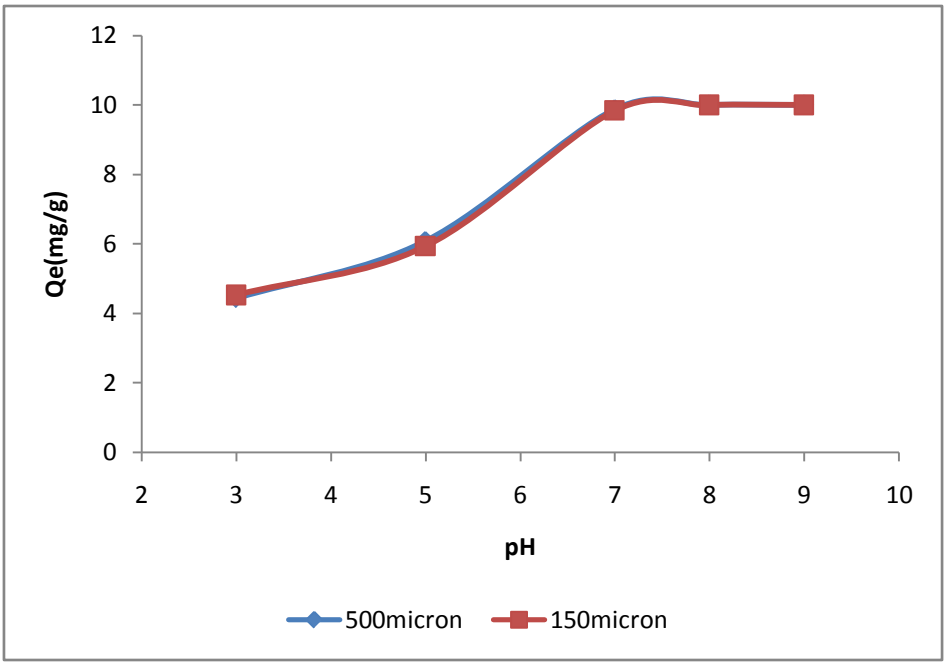

Figure 3 : Showing the effect of varied pH on the adsorption of zinc on rice husk

The effect of varied pH on adsorption of lead was also examined on 500 and 150 micron sizes of rice husk, for pH (3 - 9) and the initial concentration was 100 mg/L for all pH. The effect of changes in pH is not as pronounced as in the case of zinc, as the mass adsorbed per unit mass increased only slightly from acid to neutral pH. However pH 7 seems to be the optimum for 500 micron size of rice husk, while the pH 8 seems to be the optimum for the 150 micron size of rice husk; which seems to suggest that the reduced H^+ ion in neutral and basic pH led to increased adsorption but not significantly. The results of the adsorption of 500 and 150 micron sizes were compared and the paired t-test was conducted and it showed that there was no significant difference between the two results. The effect of varied pH on adsorption of lead on rice husk of varied particle sizes is as shown in Figure 4 below.

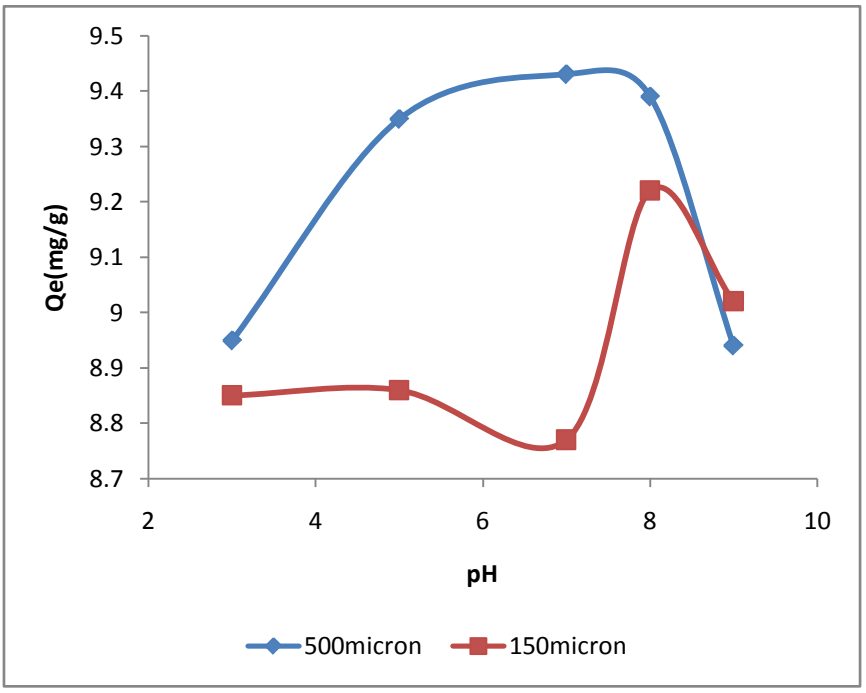

Figure 4 : Showing the effect of varied pH on adsorption of lead on rice husk

c) Effect of time on adsorption

The effect of increase in time was examined on adsorption of lead on rice husk, the effect was examined with 100 mg/L lead solution at 30, 60, 120 and 150 minutes respectively on rice husk of 500 and 150 micron sizes respectively. It was observed that on the 500 micron size of the rice husk, that the mass adsorbed per unit mass increased between 30 and 60 minutes but thereafter decreased at 120 and 150 minutes respectively, this seems to suggest that the optimum time for adsorption of lead on rice husk is the 60 minutes, the mass adsorbed per unit mass was lowest at the 150 minutes, which seems to suggest that longer contact time encouraged desorption of lead on rice husk at the 500 micron size. The trend was different on the 150 micron size of the rice husk, the mass adsorbed per unit mass was about the same for both 30 and 60 minutes of contact, and at 120 minutes the mass adsorbed per unit mass was maximum, however it dropped again at 150 minutes, this seems to suggest that the optimum contact time for the 150 micron size rice husk is 120 minutes, but higher contact time tends to encourage desorption. The graphical representation of effect of increase in contact time on lead adsorption on 500 and 150 micron sizes of rice husk is as shown in figure 5 below.

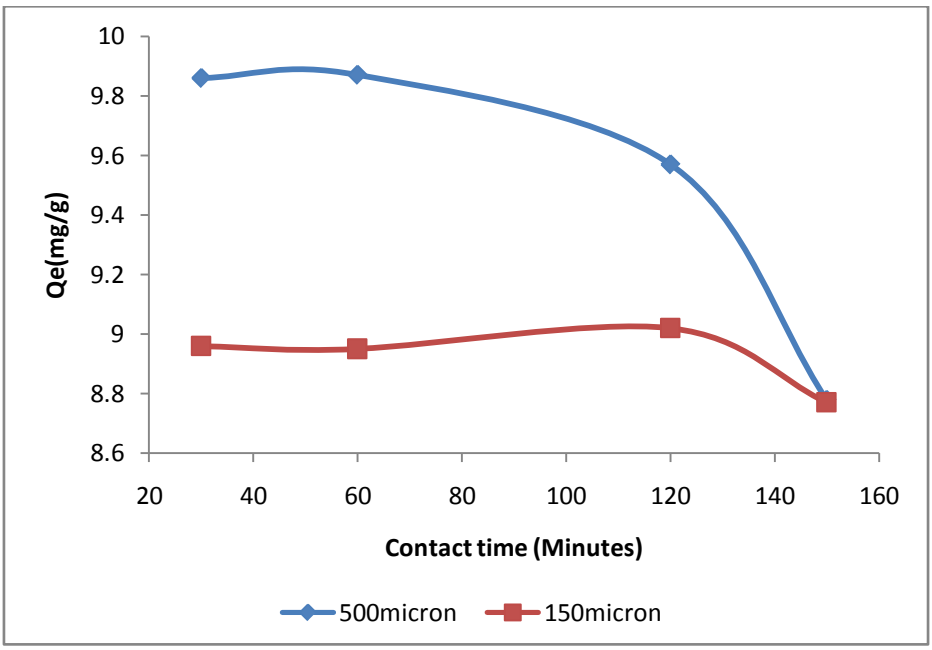

Figure 5 : Showing the effect of varied contact time on adsorption of lead on rice husk of varied particle sizes

Similarly, the effect of increase in time was examined on adsorption of zinc on rice husk of varied particle sizes, the effect was examined with 100 mg/L zinc solution at 30, 60, 120 and 150 minutes respectively on rice husk of 500 and 150 micron sizes respectively. It was observed on the 500 micron size that the mass adsorbed per unit mass increased steadily as the contact time increased from 30 to 120 minutes but dropped at 150 minutes; this seems to suggest that increase in contact time increased adsorption between 30 and 120 minutes. 120 minutes seems to be the optimum contact time but a further increase in time beyond the 120 minutes encouraged desorption of zinc at the 500 micron size of rice husk. But the trend was different on the 150 micron size rice husk as mass adsorbed per unit mass decreased steadily from the 30 to 120 minutes respectively but increased sharply at the 150 minutes contact time, 150 minutes was the optimum for the 150 micron size of rice husk; this seems to suggest that increased contact time does not favour adsorption on the 150 micron size of rice husk between 30 and 120 minutes but was optimum at the 150 minutes. The graphical representation of the effect of contact time on adsorption of zinc on rice husk of varied particle sizes is as shown in figure 6 below.

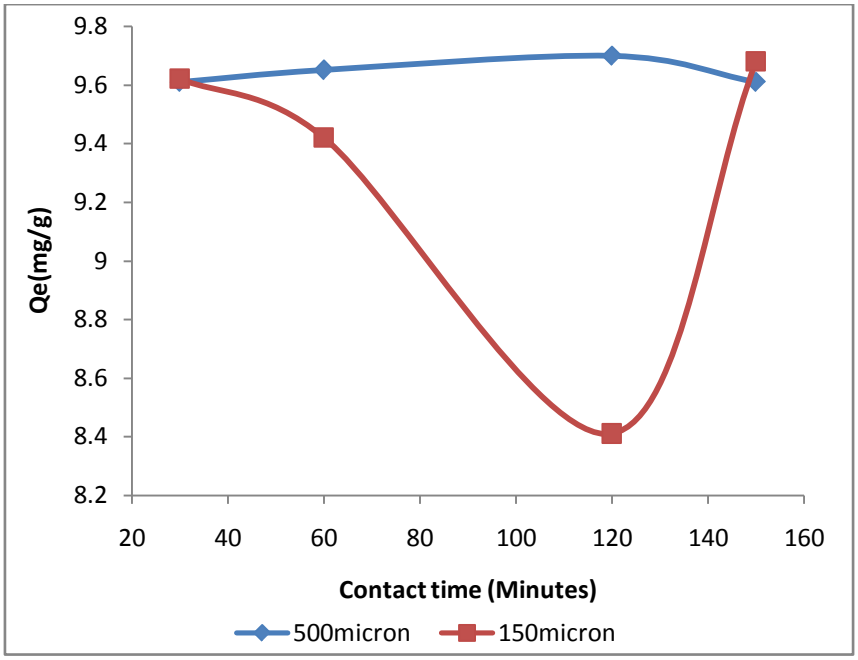

Figure 6 : Showing the effect of varied contact time on adsorption of zinc on rice husk of varied particle sizes

The data of lead adsorption in varied contact time were examined using the Lagergren first order and Ho's second order kinetics; this is an indication of the molecularity of the sorption mechanism and the rate controlling step. The Lagergren model is a pseudo first order kinetic and is guarded by the equation

$$\ln(Co–Ct) = Kt + A$$

where Co = Initial concentration of the adsorbate solution.
Ct = Concentration of the adsorbate at time t
t = time in minute
K = Sorption rate constant.
A = intercept. [9].
And the Ho's is a pseudo second order kinetic and is guarded by the equation

$$\frac{1}{qe} = Kt + A$$

Where qe = the amount adsorbed by the adsorbent per mass of the adsorbent at equilibrium,
K = Sorption rate constant
A = intercept [9].

The result of Lagergren kinetic of lead on rice husk of 500 and 150 micron sizes is as shown in table 7 below.

Table 7 : Showing Largergren kinetic of lead on rice husk

Rice Husk Size	R^2	K	A
500micron size	0.772	8.0×10^{-4}	4.63
150micron size	0.417	2.0×10^{-4}	4.51

From the table above, we observe that the 500 micron size of rice husk obeyed the Lagergren kinetics, as the correlation coefficient was high (0.772) and the rate constant was very low and the intercept is high. But for 150 micron size was quite different as the correlation coefficient was very low (0.417) an indication that the Lagergren model was not obeyed and the rate constant was very low but the intercept is high.

The result of Ho's kinetic of lead on rice husk of 500 and 150 micron sizes is as shown in table 8 below.

Table 8 : Showing Ho's kinetic of lead on rice husk

Rice Husk Size	R^2	K	A
500micron size	0.798	1.0×10^{-4}	9.62×10^{-2}
150micron size	0.190	1.0×10^{-5}	1.11×10^{-1}

From the table above, we observe that the 500 micron size of rice husk obeyed the Ho's kinetics, as The correlation coefficient was high (0.798) and the rate constant was very low and the intercept is very low as well. But for 150 micron size was quite different as the correlation coefficient was very low (0.190), an indication that the Ho's model was not obeyed and the rate constant was very low but the intercept is equally very low.

In the same vein the data of zinc adsorption at varied time was examined on Lagergren pseudo first order model and the result of the model is as tabulated in the table 9 below.

Table 9 : Showing Lagergren kinetic of zinc on rice husk

Rice Husk Size	R^2	K	A
500micron size	0.0364	$2.0x10^{-5}$	4.567
150micron size	0.4248	$6.3x10^{-3}$	4.209

We observe from the table above that the Lagergren model was not obeyed on both particle sizes, as the correlation coefficients were very low, and the rate constant in both cases too were very low, but the intercept in both cases were high.

The Ho's model of the data of zinc adsorption on rice husk of varying particle sizes is shown in the table 10 below.

Table 10 : Showing Ho's kinetic of zinc on rice husk

Rice Husk Size	R^2	K	A
500micron size	0.0364	$2.0x10^{-6}$	$1.04x10^{-1}$
150micron size	0.0798	$4.0x10^{-5}$	$1.05x10^{-1}$

We observe from the table above that the Ho's model of kinetic was not obeyed, as the correlation coefficients were very low and the rate constant were very low as well, the intercept of in both cases were also very low.

d) Effect of temperature on adsorption

The effect of increase in temperature was examined in lead adsorption on rice husk of 500 and 150 micron sizes at 100mg/L of lead solution between 20°C - 80°C; it was observed that for both micron sizes the adsorption per unit mass were higher at lower temperature as compared to higher temperature; which seems to suggest that lower temperature favours adsorption on rice husk, hence the adsorption seems exothermic. The paired t-test of the two data obtained for the two particle sizes showed that there was no significant difference between the two results. The graphical representation of the adsorption of lead on rice husk of 500 and 150 micron sizes are as shown in the figure 7 below.

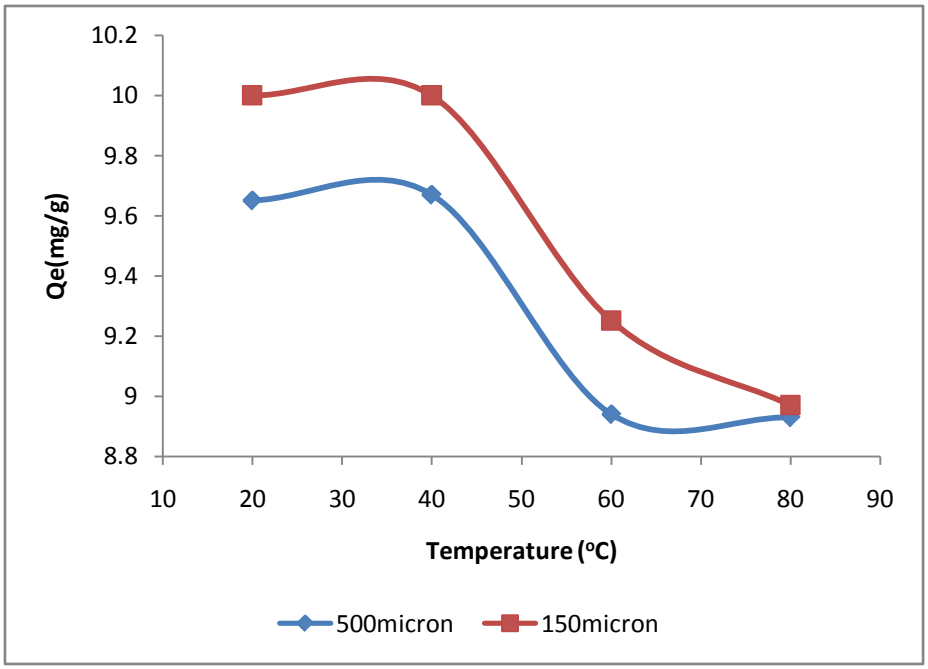

Figure 7 : Showing the effect of varied temperature on adsorption of lead on rice husk of varied particle sizes

The effect of increase in temperature was examined in zinc adsorption on rice husk of 500 and 150 micron sizes at 100 mg/L of lead solution between 40 – 80°C; it was observed that both sizes seems to favour adsorption of lead on rice husk at higher temperature and was optimum at 60°C. the adsorption per unit mass was higher at 60°C, which seems to suggest that the adsorption of lead on rice husk is endothermic. The paired t-test of the two data obtained for the two particle sizes showed that there was no significant difference between the two results. The graphical representation of the effect of temperature on adsorption of lead on rice husk of 500 and 150 micron sizes are as shown in the figure 8 below.

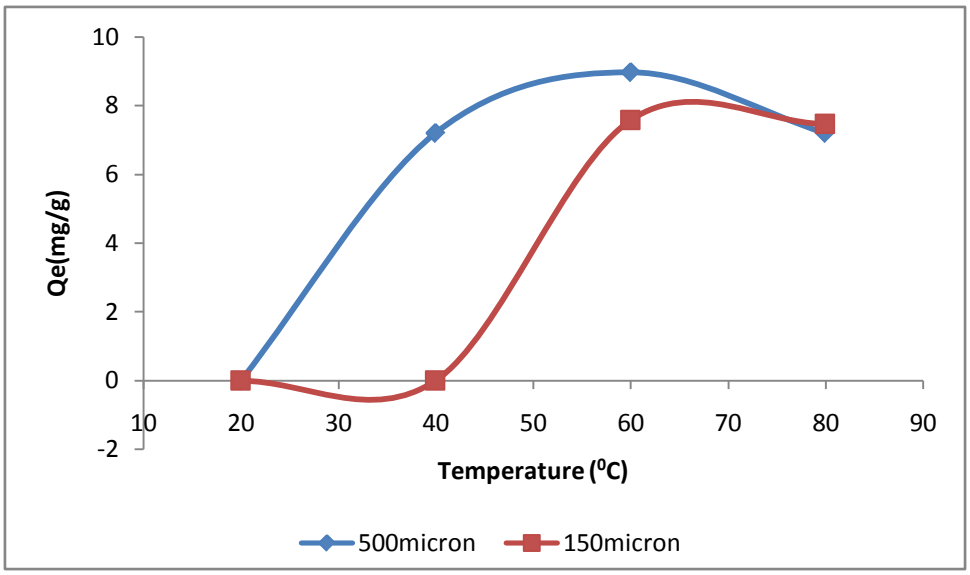

Figure 8 : Showing the effect of varied temperature on adsorption of Zinc on rice husk of varied particle sizes

IV. Conclusion

In general, the result showed that rice husk is a good biosorbent for lead and zinc in waste water remediation, with a very high mass adsorbed per unit mass under atmospheric conditions, albeit rice husk showed greater affinity for the removal of lead than zinc in all the conditions examined and the adsorption seems to be exothermic rather than endothermic as the adsorption was favoured by lower temperature. Neutral and basic pH favoured the adsorption in most of the cases as compared to the acidic pH. Increase in contact time did not have any significant difference in the level of adsorption for all the contact time considered. The smaller particle sizes seems not to obey the Lagergren pseudo first order kinetic nor the Ho's pseudo second order kinetic while the larger particle size tends to obey the Lagergren pseudo first order and Ho's pseudo second order kinetic. Relatively Langmuir and Largergren isotherm were obeyed by both particle sizes at varied concentration and contact time respectively. It is noteworthy to state that rice husk is a good adsorbent for lead and zinc in waste water with good efficiency even at small quantity.

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Contamination of Toxic Heavy Metal in Locally Made Plastic Food Packaging Containers

By Saimah Khan & Abdul Rahman Khan
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Abstract- Human exposure to toxic heavy metals creates a major health hazards. The main objectives of our study was to examine the concentration of toxic heavy metals like Lead (Pb), Copper(Cu), Nickel(Ni), Zinc(Zn), Manganese(Mn), Chromium(Cr) and Cadmium(Cd) in locally made food containers purchased from various districts of U.P (India). All samples are analyzed at 60±2°C for 2hrs in different simulating solvents as per BIS, IP, USP and other guidelines by using atomic absorption spectrophotometer(AAS). The results shows that leaching of heavy metals occur in all samples and follows the order:

Pb(1.9-0.0001 ppm) > Cu(1.61-0.0001 ppm) >Ni(1.31-0.001 ppm) > Zn(1.02 -0.001 ppm) > Mn(1.01-0.0001 ppm) > Cr(0.14-0.0001 ppm) > Cd(0.01-0.0001 ppm).

Keywords: food containers, concentrations, heavy metals, toxic, health, plastic.

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I. Introduction

Plastic containers used for food packaging are made from plastics based on the following polymers: polyethylene(low and high density), polypropylene, polyvinyl chloride, polystyrene etc. All plastics, apart from basic polymer, contain additional chemical compounds called additives (plasticizers, antioxidants, stabilizer, curing agent, colouring agent etc) which are added in small amount to attain certain desired properties. The final processed plastic is slightly different material as compared to the virgin polymeric plastic. These additives possess mobility and likely to transfer some low molecular weight non polymeric components into the packaged content under the influence of physicochemical factors such as sunlight, temperature, type of solvents (based on nature of food) and pH of the stored material[1-8].Thereby contaminating the food with the risk toxic health hazard to the consumer. Therefore, the guidelines for the proper use of plastic have been formulated all over the world and BIS formulate the national standard[9-17]. According to this, metal content should not be more than 1ppm and Cd should not be more than 0.1ppm. Therefore, it is necessary to determine the concentration of heavy metals such as Zn, Ni, Mn, Cu, Cr, Cd and Pb in locally made food containers to safeguard the health of a consumer.

Various studies have done on leaching of heavy metal from food containers and found that the concentration of heavy metal is beyond the allowed limit[5,18]. Since heavy metals cannot be metabolized easily by the human body because it is five times more dense than water. Therefore, it can be accumulated in the body and when their concentration cross their permissible limit, can become harmful and causes toxic health hazards such as disorders in mental function, kidney, nervous system, respiratory system and many other physiological activities of the body cells and other organs[19-23].

Due to large consumption of plastic in India, several small scale industries forming plastic food container in irregular way by using harmful additives which are usually above their allowed limits and these product are generally not tested by regulatory agencies for safety of consumer. This leads to reduced quality of product. In the regard, this research was designed to determine the concentration of heavy metals like Zn, Ni, Mn, Cu, Cr, Cd and Pb in local made food container which were purchased from various districts of U.P., India.

II. Material and Methods

Thirty samples of five different brands of food containers were purchased from various districts of U.P, India, for the assessment of heavy metals (Zn, Ni, Mn, Cu, Cr, Cd and Pb). The food containers were washed thoroughly with sterilized double distilled water prior to leaching. Based on nature of food, five different food simulating solvents are used and these are Double distilled water, Acetic acid (3% v/v), Ethanol (8% v/v), Sodium chloride (0.9% w/v) and Sodium carbonate (5% w/v). The food containers were exposed in 100ml of each simulating solvents in a sterile beaker at a ratio of 1 cm^2 /2 ml. The samples were kept at 60 ±2° C for 2 hours. Parallel sets having simulating solvents only served as basal control were also run under identical conditions. The stimulant solvents (100ml) were taken in a beaker and digested in a fuming chamber using concentrated nitric acid. The digested samples were make up to 10ml using 0.1N HNO_3. The quantitative analysis of final digested samples were done by using Perkin-Elmer-500 atomic absorption spectrophotometer (AAS). The instrument was first calibrated with standard solution prepared from stock solution as provided by Merck. The metals concentration of different leachates of samples were determined in triplicate and the result is given as a mean ±SD. The heavy metals concentration

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of different samples are presented in ppm. The concentration of metal should not be more than 1ppm (Cd should not be more than 0.1ppm) according to BIS,IP,USP and other regulatory agencies.

III. Results and Discussion

The results showed that all samples were found to contain Zn, Ni, Mn, Cu, Cr and Pb in varying concentrations are given in Figure 1 to 5.

* The mean concentration of Zn which is above allowed limit (1ppm) in the samples follows the order: *S2 (1.02 ppm in 3% acetic acid) > S4 (1.006 ppm in 0.9% NaCl) .*

* The mean concentration of Ni which is above allowed limit (1ppm) in the samples follows the order: *S4(1.31 ppm in double distilled water) > S3(1.21ppm in double distilled water) > S2(1.102ppm in 3% acetic acid) > S2(1.08ppm in 0.9% NaCl) >S5 (1.02ppm in 5% Na_2CO_3) > S5(1.01 ppm in 3% acetic acid).*

* The mean concentration of Mn which is above allowed limit (1ppm) in the samples follows the order: *S5(1.01ppm in 0.9% NaCl) > S2(1.008ppm in double distilled water) > S3(1.001 ppm in double distilled water).* The concentration of Mn was not detected in case of 8% Ethanol.

* The mean concentration of Cu which is above allowed limit (1ppm) in the samples follows the order: *S5(1.61ppm in 3% acetic acid) > S4(1.30 ppm in 0.9% NaCl) > S4(1.02 ppm in double distilled water).*

* Except in case of 0.9% NaCl, all samples were found to contain Cr under permissible limit. The highest mean concentration of Cr(0.14ppm) was detected in case of 3% acetic acid.

* The mean concentration of Pb which is above allowed limit (1ppm) in the samples follows the order: *S1(1.9 ppm in double distilled water) > S3(1.2 ppm in 3% acetic acid) > S5 (1.1 ppm in 5% Na_2CO_3) > S1 (1.04ppm in 5% Na_2CO_3) > S1(1.029 ppm in 8% ethanol) > S2(1.002ppm in 3% acetic acid).*

* All samples were found to contain Cd under allowed limits (0.01 ppm).

The differences were significant between mean concentrations of metals in different food containers samples in double distilled water ($P<0.05$), 3% acetic acid($P<0.05$), 8% ethanol($P<0.05$), 0.9% NaCl($P<0.05$) and 5% Na_2CO_3 ($P<0.05$).

Thus, the result shows that higher percentage of leaching of heavy metals above allowed limit follows the pattern:

Pb(1.9-1.002ppm) in S1 > Cu(1.61-1.02ppm) in S5,S4 > Ni(1.31-1.01ppm) in S4,S3,S2,S5 > Zn(1.02-1.006ppm) in S2,S4 > Mn(1.01-1.001ppm) in S5,S2,S3.

Percentage of leaching in different food stimulant solvents shows the pattern:

Double Distilled Water > 3% Acetic Acid > 0.9% NaCl > 5% Na_2CO_3 > 8% Ethanol.

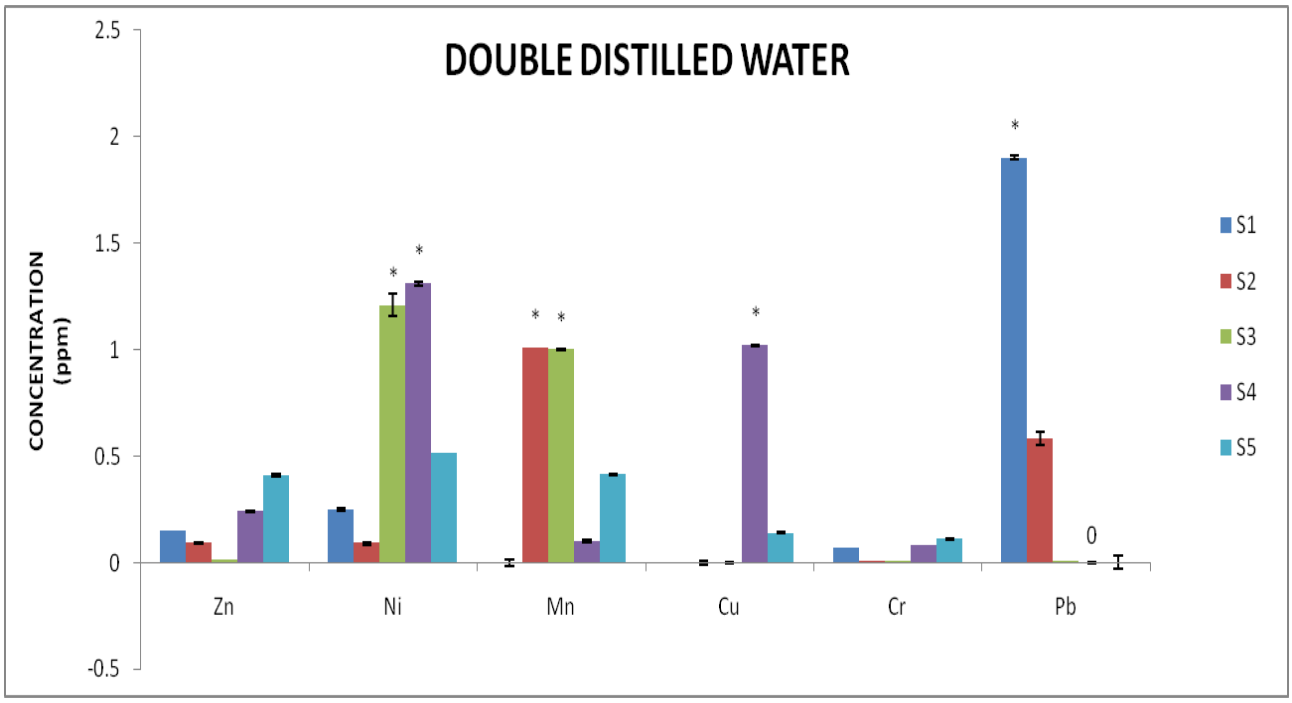

Figure 1 : The concentration of metals (ppm) in double distilled water at 60±2°C for 2 hrs. The result were reported as a mean ±SD from three set of experiments.*p<0.05

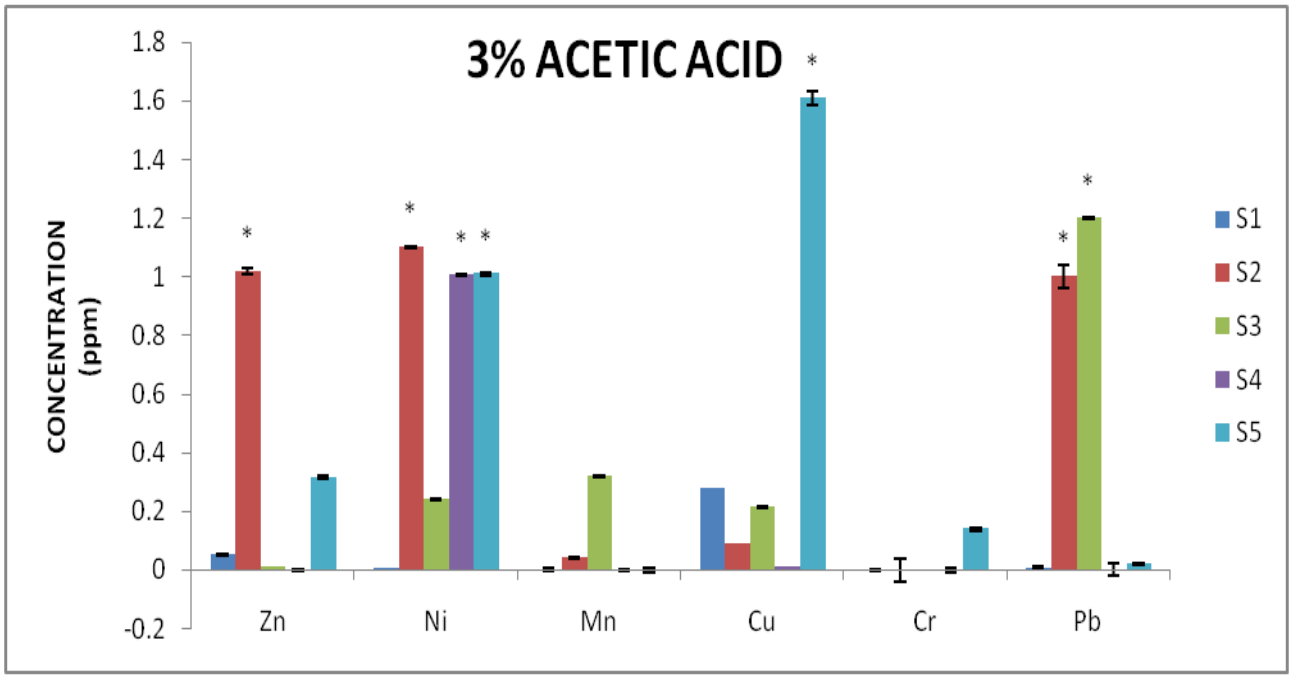

Figure 2 : The concentration of metals (ppm) in 3% acetic acid at 60±2°C for 2 hrs. The result were reported as a mean ±SD from three set of experiments.*p<0.05

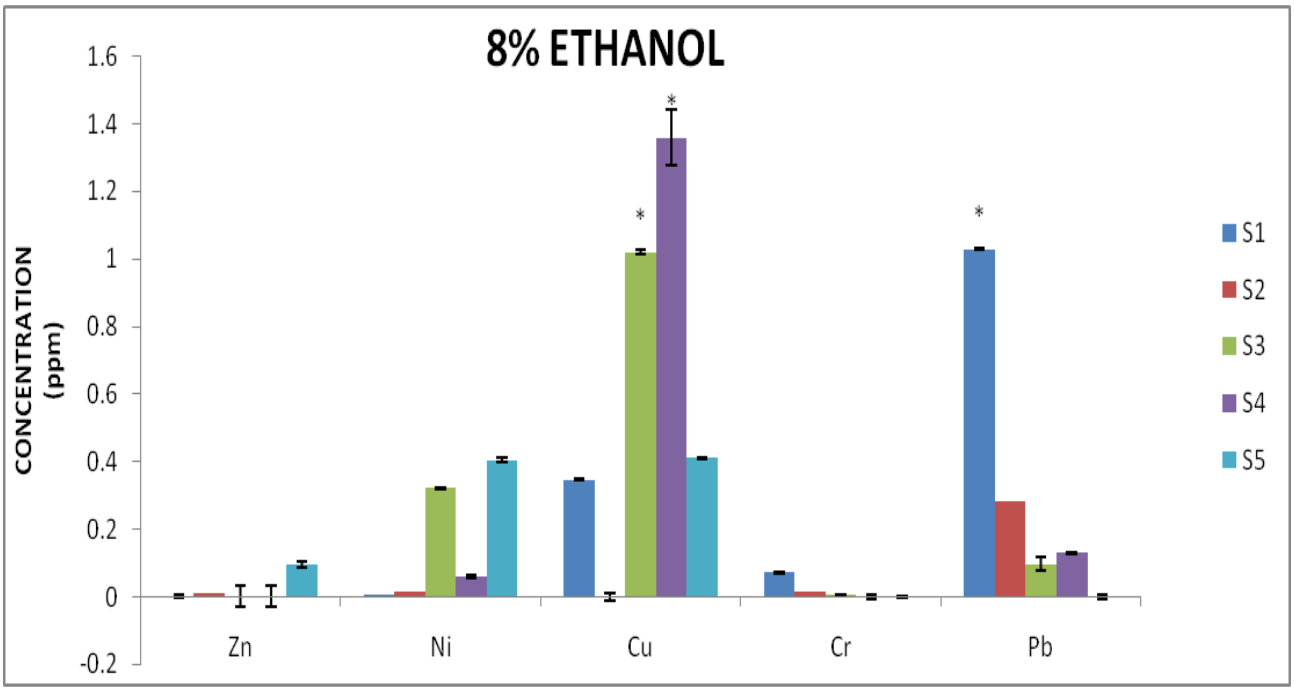

Figure 3 : The concentration of metals (ppm) in 8% ethanol at 60±2°C for 2 hrs. The result were reported as a mean ±SD from three set of experiments.*p<0.05

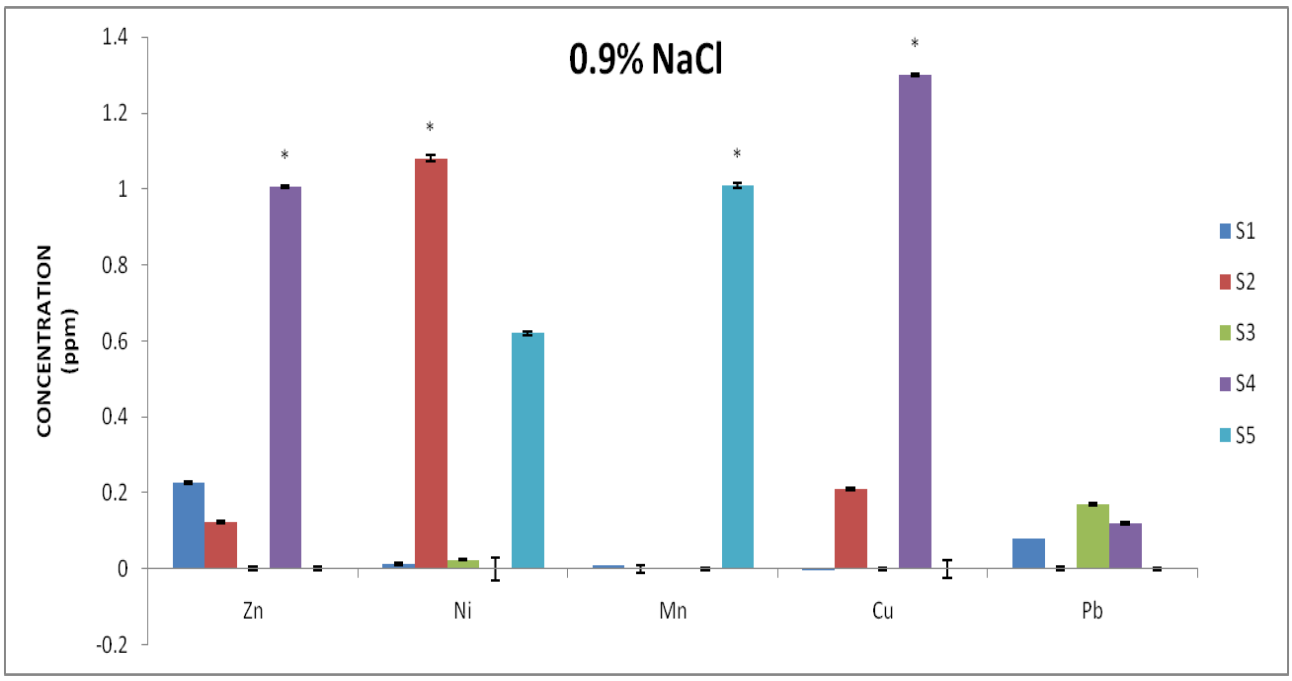

Figure 4 : The concentration of metals (ppm) in 0.9% NaCl at 60±2°C for 2 hrs.
The result were reported as a mean ±SD from three set of experiments.*p<0.05

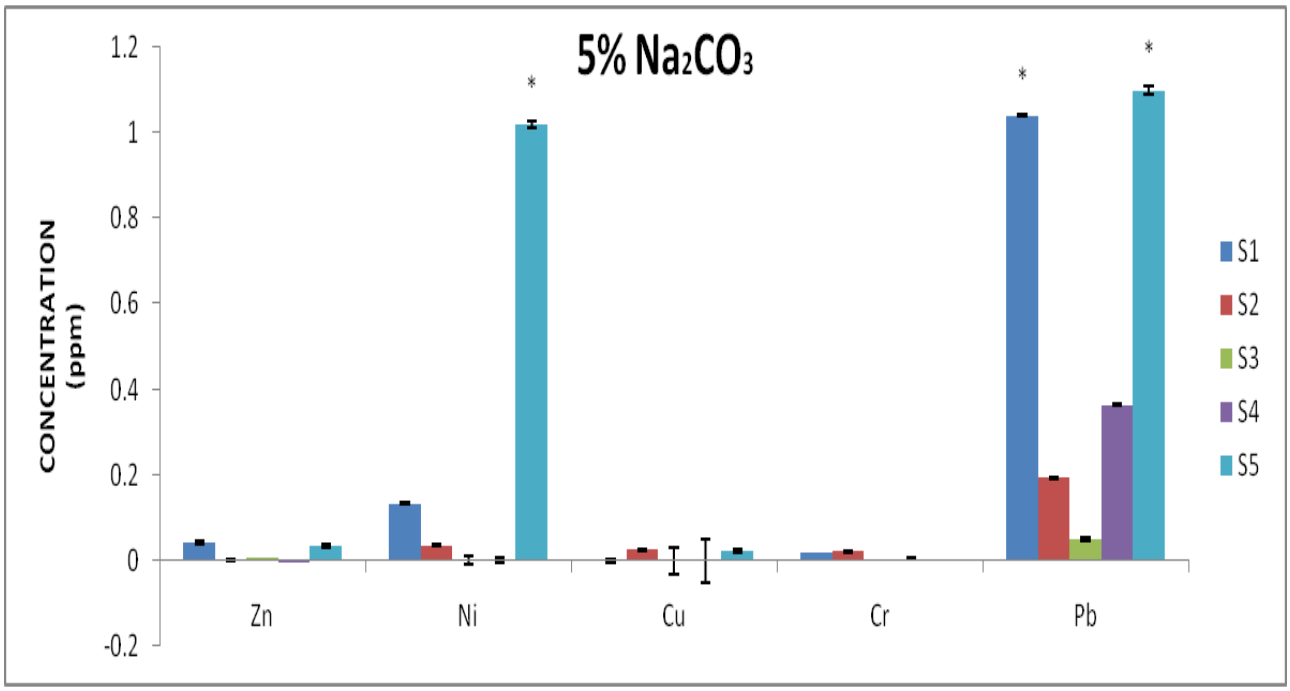

Figure 5 : The concentration of metals (ppm) in 5% Na2CO3 at 60±2°C for 2 hrs.
The result were reported as a mean ±SD from three set of experiments.*p<0.05

IV. Conclusion

This report documented the exposure of human to toxic heavy metals through plastic food containers. The food containers purchased from various districts of U.P,(India), contain toxic heavy metals such as Pb, Cu, Ni, Zn, Mn, Cr and Cd. Out of which the concentration of Pb, Cu, Ni, Zn and Mn were above allowed limit that may creates a major health problems for consumer. Therefore, it is need to safeguard the health of consumer through awareness of society about harmful effects of plastic food containers, especially local made containers having no specification of additives.

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A Comparative Study of Adsorption Kinetics and Mechanisms of Zinc (II) Ion Sorption using Carbonized and modified Sorghum (*Sorghum Bicolor*) Hull of two Pore Sizes (150µm and 250µm)

By Imaga C. C. & Abia A. A
University of Port Harcourt, Nigeria

Abstract- Aim of this study was to investigate the use of modified and carbonized SorghumHull of two different pore sizes (150*µ*m and 250*µ*m meshes)inthe removal of Zinc (II) ion from aqueous solution. The effect of contact time (20,40, 60, 80 and 100) minuteswere investigated and reported. The maximum adsorption for 150*µ*m and 250*µ*m were at 40^{th} and 60^{th} minutes respectively (55.152mg/l and 55.196mg/l). Both pore sizes showed peak adsorption of Zn^{2+}at various contact time as shown in table 1. Kinetic modelings of the results of Zn^{2+} of both pore sizes were also investigated. These results showed that Pseudo second order kinetic model best describes the process and the Mechanism of adsorption show that 150*µ*m and 250*µ*m were particle diffusion controlled.

Keywords: biosorbents, detoxification, heavy metals, adsorption kinetics, sorption mechanisms, pore size, thiolation, biosorption.

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Keywords: biosorbents, detoxification, heavy metals, adsorption kinetics, sorption mechanisms, pore size, thiolation, biosorption.

I. Introduction

Adsorption, an established industrial separation technique used in bulk separation technique uses both bulk/batch separation and purification suited for the solution of such problems. To accomplish these needs, new direction point to the development of adsorbents of a combined and hybrid nature such as organic and inorganic material made carbon and combined adsorbents, regulation of lingo-cellulosic materials sorption properties by modification for environmental application (Imaga C.C and Abia A.A, 2015). Recent environmental concerns as well as heightened defence against chemical terrorism call for both new protection technologies and for the improvement of existing ones including adsorption.

Biosorption consists of a group of applications which involve the detoxification of hazardous substances instead of transferring them from one medium to another by means of microbes and plants. This process is characterised as less disruptive and can be often carried out on site eliminating the costly need to transport the toxic materials to treatment sites (Imaga and Abia, 2014), biosorbents are prepared from naturally abundant and/or waste biomass. Due to high uptake capacity and very cost-effective source of the raw material, biosorption is a progression towards a perspective method. Various biomaterials have been examined for their biosorptive properties and different types of biomass have shown levels of high enough to warrant further research. Biosorbent of plant origin are mainly agricultural by-products such as Sugar beet pulp (Zolgharnein *et al.,* 2011), Maize wrapper (Babarinde*et al*., 2008), Maize cob (Opeolu*et al*., 2009), modified Saw dust of Spruce (Urik*et al.,* 2009).

Heavy metal refers to any chemical element with a specific gravity that is at least five times the specific gravity of water and is toxic or poisonous at higher amounts(Imaga C.C and Abia A.A, 2015).

Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

a) ZINC

Zinc is one of the commonest elements in the earth's crust. It's found in air, soil, and water, and is present in all foods. Pure Zinc is a bluish-white shiny metal. Zinc has many commercial uses as coating to prevent rust, in dry cell batteries, and mixed with other metals to make alloys like brass and bronze. Zinc is released into the environment by natural processes, but most comes from activities of people like mining, steel production, coal burning, and burning of waste. It attaches to soil, sediments, and dust particles in the air. Harmful health effects generally begin at levels from 10-15 times the RDA (in the 100 to 250 mg/day range). Eating large amounts of Zinc, even for a short time, can cause stomach cramps, nausea, and vomiting. Taken

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longer, it can cause anemia, pancreas damage, and lower levels of high-density lipoprotein cholesterol (HDL - the good form of cholesterol). Environmental toxicity of Zinc in water is dependent upon the concentration of other minerals and the pH of the solution, which affect the ligands that associate with Zinc (Heijerick *et al*., 2002a; Paquin *et al*., 2002; Santore 2002). Zinc is often present in soils and grasses as a result of atmospheric deposition. Soil pH limits the mobilization of Zinc in soil. Thus, Zinc from tire debris will be less available and become immobile with soil interactions (Smolders and Degryse 2002). Zinc tends to sorb more readily at a high pH (pH >7) than at a low pH (EPA 1979d). Zinc is capable of forming complexes with a variety of organic and inorganic groups (ligands).

Sorption kinetics describes the solute uptake rate and evidently this rate controls the residence time of adsorbate at the solid-liquid interface. Studies on the kinetics of metal sorption by various adsorbents are of importance for designing an adsorption system. The rate at which sorption takes place is of utmost importance when designing batch sorption systems. Consequently it is important to establish the time dependence of such systems for various processes (Imaga C. *et al*., 2014). The results from such studies provide information on the minimum time required for considerable adsorption to take place and information on diffusion control mechanism between metal ions as they move towards the adsorbent surface.

In this study, a lingo-cellulosic material (Sorghum Hull) was used as biosorbent in the removal of heavy metal Zinc (II) ion from aqueous solution in a batch sorption system. The effects of contact time,mechanisms and sorption kinetics of the carbonised and Mercapto-acetic acid modification and Particle size were investigated.

II. Materials and Methods

The Sorghum Hulls (*Sorghum bicolor*) were sourced from a brewery (Consolidated Breweries plc, Imo State, Nigeria). The material Sorghum Hull was later abbreviated as 'SH'. All reagents used were analytical grades purchased and used without further purification.

a) Methods

i. *Adsorbent Preparation*

The Sorghum Hulls were washed and air dried in preparation for the adsorption analysis. The air dried Sorghum Hulls were crushed with a manual blender to smaller particles and sieve analysis was performed using the mechanical sieve screen to obtain final sample sizes of 150μm and 250μm (Imaga C.C and Abia A.A, 2015).

ii. *Activation of Sorghum Hulls*

The screened fine Sorghum Hulls powder was further soaked in excess of 3.0M HNO_3 solution for 24 hours. It was then filtered through a Whatman No.41 Filter paper and rinsed with deionised water.

The rinsed Sorghum Hulls were later air dried for 24 hours. The treatment of the biomass with 3.0M HNO_3 solution aids the removal of any debris or soluble biomolecules that might interact with metal ions during sorption. This process is called chemical activation of the Sorghum Hulls (Imaga C.C and Abia A. A, 2015).

iii. *Carbonisation of the Sorghum Hulls*

The process was carried out using a Muffle furnace(Carbolite Sheffield, England, LMF4) which allowed limited supply of air. The carbonization took place at 250°C for one hour after which the charred products were allowed to cool to room temperature according to (Imaga C.C and Abia A.A, 2015).

iv. *Chemical Modification of Sorghum Hulls with Mercapto-Acetic Acid (Maa)*

The air-dried activated and carbonated Sorghum Hulls were acid treated by dissolving it in excess 1.0M Mercapto acetic acid ($HSCH_2COOH$) solution, stirred for 30 minutes and left to stand for 24 hours at 28°C and was called Carbonised and Modified Sorghum Hull abbreviated as CMSH 150μm and 250μm.(Imaga C.C and Abia A.A, 2015)

After 24 hours, the mixtures in the beakers designated as CMSH 150μm and 250μm were filtered off using Whatman No. 41 filter paper and were air dried. The two working adsorbents CMSH 150μm and 250μmwere stored in air tight plastic containers and labelledrespectively. (Imaga C.C and Abia A.A, 2015)

v. *Preparation of Adsorbate Solutions for Sorption Studies*

A stock solution of 1000ppm of the metal Zinc was prepared from Zinc Chloride ($ZnCl_2$); assay 98% (Halewood Chemicals Limited). Thereafter, serial dilution was carried out on the stock solution to obtain working solution of 60 ppm of the Zinc (II) ion. The concentration of the standard was confirmed using an Atomic Adsorption Spectrophotometer .The pH of the solution was kept at 7.0.

vi. *Sorption Studies at Different Contact Time*

Kinetics of sorption studies were carried out according to the method described by Imaga C.*etal*., 2014. Kinetics of sorption for $Zn^{2+}$was carried out for each adsorbent (CMSH 150μm and 250μm) at pH of 7.0 and temperature of 28°C(301K).30cm^3 of standard solution of the metal, initial concentration of 60mg/l was transferred into various 250cm^3 Erlenmeyer flask and labelled. Then 0.2g of each adsorbent CMSH 150μm and 250μm was transferred into the different flasks and agitated in a shaker for different contact times (20, 40, 60, 80 and100 minutes). After each agitation time, the content of the flask was then filtered using Whatman No.41 filter paper. The residual concentration of metal ions in 20cm^3 of the filtrate of each metal solution was determined using Atomic Adsorption Spectrophoto-

meter (AAS) (GBC SCIENTIFIC AVANTA PM AAS A.C.N 005472686 manufactured by GBC Scientific equipment Pty Ltd. Dandenong Victoria Australia.). The adsorbed concentration was then calculated by difference. Glass wares and plastic wares were washed with deionized water and rinsed to eliminate errors (Imaga C. *et al.*, 2014).

III. Results and Discussion

a) Effect of Contact Time on Amount of Metal Ion Adsorbed

The amount of metal adsorbed by an adsorbent at a particular time is one of the factors governing the efficiency of adsorption. The amount of Zn^{2+} adsorbed by the adsorbents CMSH 150µm and 250µm as a function of time is presented in table 1. The variation in the amount of the metal ion adsorbed by the adsorbents is shown in figure1.

Table 1 : Effect Of Contact Time On Amount Of Zinc (II) Ion Adsorbed For CMSH 150µm And 250µm

Contact Time(Mins)	Amount Of Metal Ion Concentration Adsorbed	
	Zn^{2+} 150µm	Zn^{2+} 250µm
20	55.045	55.115
40	55.152	55.059
60	55.117	55.196
80	54.993	55.072
100	55.017	55.158

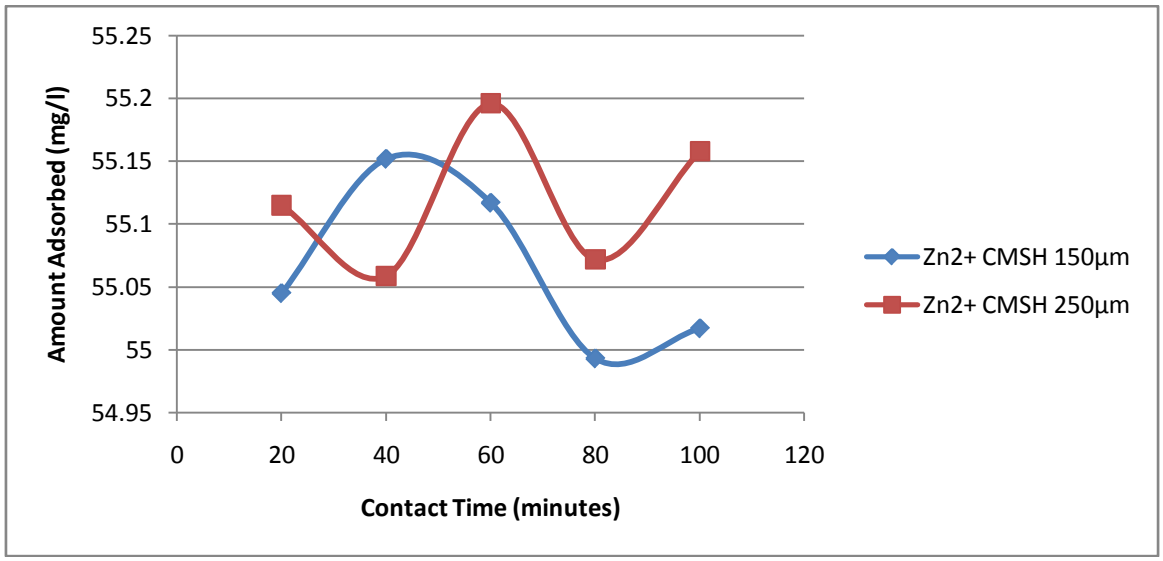

Figure 1 : Graph of Amount Adsorbed versus Contact Time for Zn^{2+} (CMSH 150µm and 250µm)

The maximum sorption time for 150µm and 250µm were at 40th and 60th minutes (55.152mg/l and 55.196mg/l), respectively. The Zn^{2+}sorption is higher in 250µm than in 150µm except in the 40th minute. The rate of sorption in 150µm occurred faster (20th, 60th, 80th and 100th minutes) [55.045, 55.117, 54.993, 55.017]mg/l than in 250µm(20th, 60th, 80thand 100thminutes) [55.115, 55.196, 55.072, 55.158] mg/l, respectively except in the 40th minute where the adsorption of Zn^{2+} was higher in 150µm than in 250µm.This could be attributed to the pore size of the adsorbent, in that smaller pore sizes gives faster rate of adsorption while larger pore sizes gives slower rate of adsorption. This also could be largely due to their variations in surface areas. However, the sorption of Zn^{2+} by both 150µm and 250µm were very high.

b) Kinetic Modeling

Quantification of the changes in sorption of metals with time requires the use of appropriate kinetic model. The kinetic models-Elovich model, Pseudo first and Second order models were employed to investigate

the kinetics of sorption of the divalent Zn^{2+} by the adsorbents.

i. *Pseudo-First Order Model*

The pseudo-first order adsorption kinetic rate equation is expressed as:

$$\ln(q_e - q_t) = \ln q_e - K_1 t \quad (1)$$

Where,

q_e is the equilibrium biosorption capacity in mg/g

q_t is the sorption capacity at any time, t in mg/g

K_1 is the pseudo-first order rate constant in $gmg^{-1}.min^{-1}$

The plot of the pseudo- first order of $Zn^{2+}$is not shown as the data could not be generated because pseudo-first order did not give any measure of fit to the kinetic data.

ii. *Pseudo-Second Order Model*

The pseudo-second order adsorption kinetic rate equation is expressed as:

$$\frac{dqt}{dt} = K_2(q_e - q_t)^2 \quad (2)$$

Where

K_2 (g/mg/min) is the rate constant of pseudo-second order adsorption.

q_e and q_t (mg/g) respectively, are the sorption capacity at equilibrium and at time t.

For the boundary conditions t=0 to t=t and q_t=q_t, the integrated form of the above equation becomes:

$$\frac{1}{q_e - q_t} = \frac{1}{q_e} + kt \quad (3)$$

This is the integrated rate law for a pseudo-second order reaction. The rate equation can be rearranged to obtain;

$$q_t = \frac{t}{\frac{1}{k_2 q_e^2} + t/q_e} \quad (4)$$

This has a linear form;

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + 1/q_e\, t \quad (5)$$

Where $h_o$can be regarded as the initial rate as (t/qt)→ 0 hence h_o(mg/g/min)

$$h_o = K_2 q_e^2$$

The equation becomes

$$\frac{t}{q_t} = \frac{1}{h_o} + 1/q_e(t)$$

A plot of t/qt versus t gives a linear relationship from which $q_e$and K_2 can be determined from the slope and intercept of the plot, respectively (C. Theivarasu *et.al.*, 2010).

The pseudo-second order rate equation was tested for the sorption of Zn^{2+}on CMSH 150µm and 250µm, respectively. Table 2, presents data for the pseudo-second order constants. The variation oft/qt with time from the pseudo- second order equation fits the adsorption of the $Zn^{2+}$by the adsorbents are shown in figures 2 and 3.

Table 2 : Pseudo Second Order Constants For CMSH 150*µm* And 250*µm*

Constants	Zinc (Ii) Ion	
	CMSH 150*µm*	CMSH 250*µm*
R^2	1.0000	1.0000
$K_2(gmg^{-1}min^{-1})$	1.457	4.430
$h_o(mgg^{-1}min^{-1})$	99.010	303.030
$q_e(mgg^{-1})$	8.244	8.271

The results obtained show a very highly significant linear relationship of the sorbed Zinc (II) ion by the various adsorbents CMSH 150*µm* and CMSH 250*µm*, respectively. The correlation coefficient (R^2) values are high (1.0000 each) showing that pseudo second order model gave the best fit and a good description of the sorption of Zinc (II) ionby the two adsorbents.

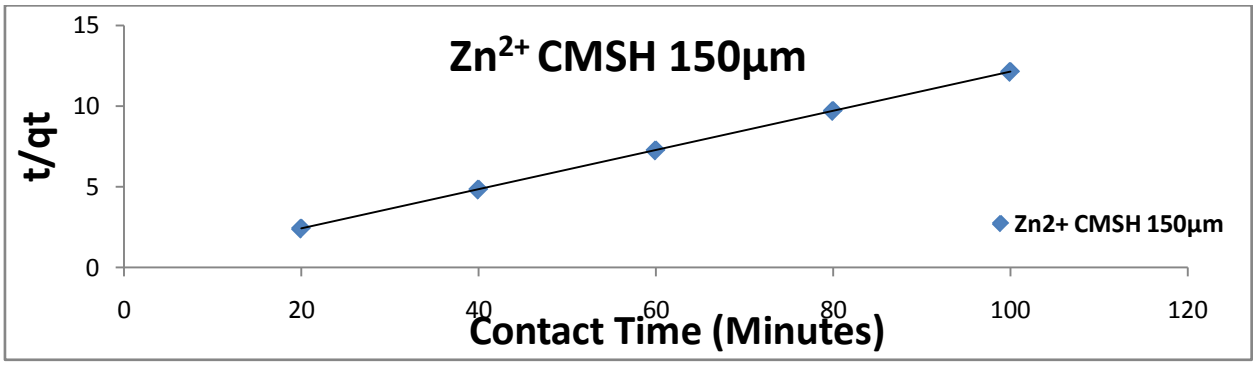

Figure 2 : Pseudo Second Order Isotherm Model of Zn^{2+} CMSH 150μm

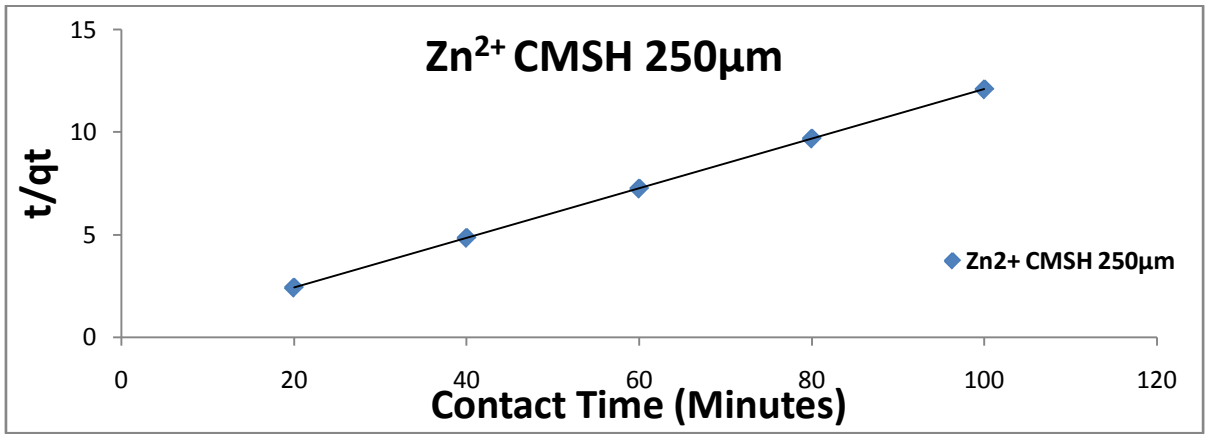

Figure 3 : Pseudo Second Order Isotherm Model of Zn^{2+} CMSH 250μm

iii. *Elovich Isotherm Model*

Elovich model equation was also used successfully to describe second order kinetic assuming that the actual solid surfaces are energetically heterogeneous, but the equation does not propose any definite mechanism for adsorbate–adsorbent. It has extensively been accepted that the chemisorption process can be described by this semi-empirical equation given below. The linear form of this equation is given by (S. M. Yakout and E. Elsherif, 2010):

$$q_t = \frac{1}{\beta} ln(\alpha\beta) + \frac{1}{\beta} lnt \qquad (8)$$

Where α is the initial adsorption rate (mg/g min), and the parameter β is related to the extent of surface coverage and activation energy for chemisorption (g/mg).The Elovich coefficients could be computed from the plots qt versus ln t. The initial adsorption rate, α, and desorption constant, β, were calculated from the intercept and slope of the straight-line plots of qt against lnt. Table 3 lists the kinetic constants obtained from the Elovich equation. It will be seen that applicability of the simple Elovich equation for the present kinetic data indicates that the Elovich equation was unable to describe properly the kinetics of the metal ion on the adsorbents of the two pore sizes. The value of αand β varied as a function of the solution temperature. Also, the experimental data did not give a good correlation for these results.

Table 3 : Calculated Values Of Elovich Isotherm Model Constants Of Adsorbents 150μm And 250μm

Constants	Zn^{2+} 150 μm	Zn^{2+} 250 μm
R^2	0.1142	0.0722
B(gmg^{-1})	185.185	277.778
α($mgg^{-1}min^{-1}$)	5.691e+663	1.875e+993

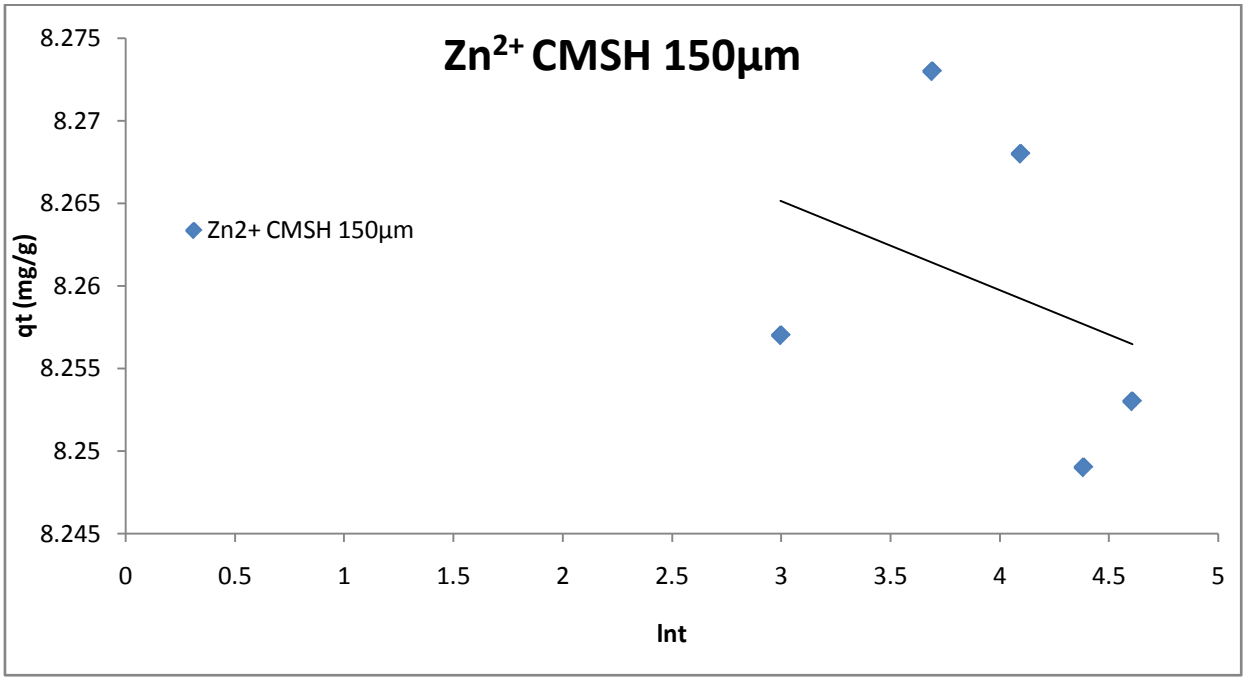

Figure 4 : Elovich Isotherm Model of Zn^{2+} CMSH 150*µm*

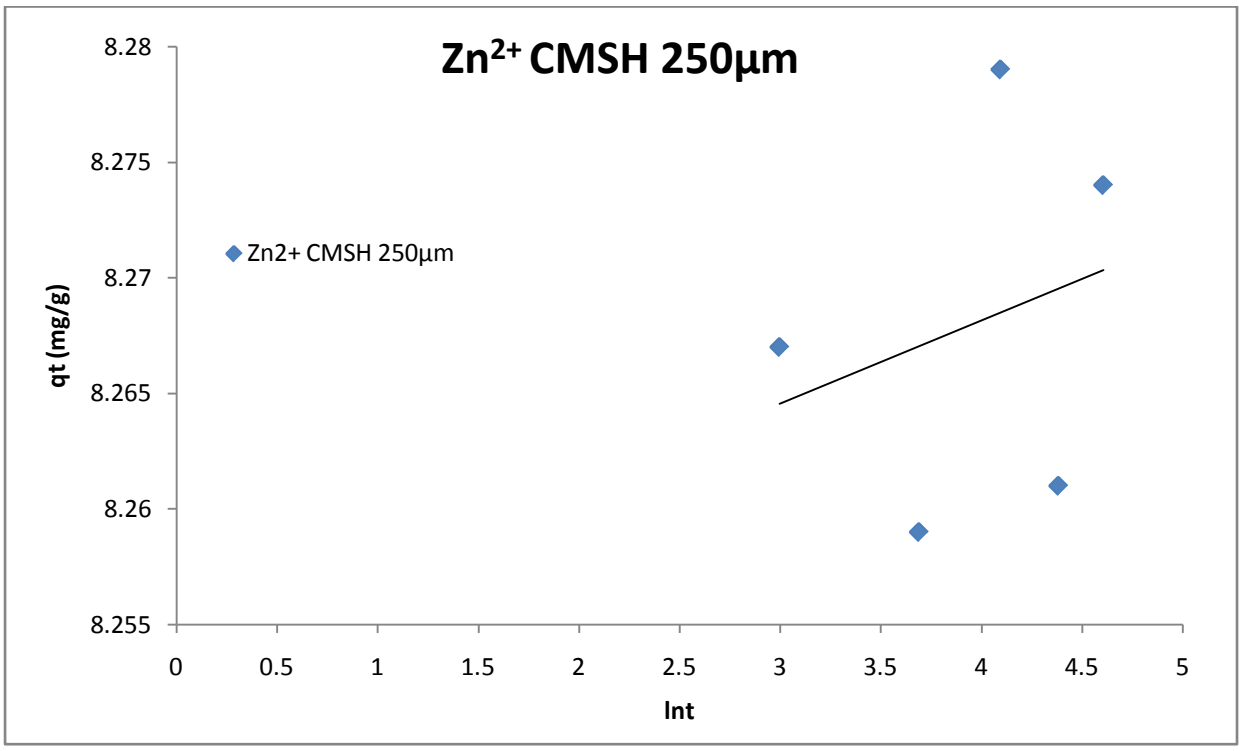

Figure 5 : Elovich Isotherm Model of Zn^{2+} CMSH 250*µm*

c) Adsorption Mechanisms

i. *Liquid Film Diffusivity Model*

The kinetics of sorption of Zinc (II) ion onto two different adsorbents of different pore sizes may be controlled by several independent processes such as bulk diffusion, external mass transfer, film diffusion, chemical reaction, and intra particle diffusion.Imaga C.C and Abia A.A, 2015; Itodo *et al.*, (2010) used the linear driving force concept and developed a simple relationship:

$$\ln (1- \alpha_e) = -K_p t + D_F \quad (9)$$

Here $\alpha_e = q_t/q_e$ is the fractional attainment of equilibrium and K_p is the rate constant.

A plot of ln (1-α_e) versus time (t) yields the K_P the rate constant (min^{-1}) as the slope of the graph and a dimensionless constant D_F as intercept. If a plot of ln (1- α_e) against t is a straight line, then adsorption is controlled by particle diffusion. The diffusion of Zinc (II) ions to the adsorbent surface is independent of the initial concentration of the Zinc (II) ions.If it is not a straight line, then it indicates that the sorption process is film- diffusion controlled. The fractional attainment at equilibrium is the ratio of the amounts of sorbate removed from solution after a certain time to that removed when sorption equilibrium is attained. It would definitely be expected that factors such as the number of reactive sites on the substrate and the bulkiness of thesubstrate would affect the rate of sorption. However, a great deal of information is gotten from the fractional attainment of equilibrium. The rate of attainment of equilibrium may be either film diffusion controlled or particle-diffusion controlled, even though these two different mechanisms cannot be sharply demarcated (Itodo *et. al.*, 2010).

Table 4 : Liquid Film Diffusivity Constants For CMSH 150µm And 250µm

Constants	Zn^{2+} 150 µm	Zn^{2+} 250 µm
R^2	0.9098	0.9616
Kp(min^{-1})	$40x10^{-5}$	$50x10^{-5}$
D_F	-0.1107	-0.1167

The R^2 values of Zn^{2+}150µmand Zn^{2+} 250µmsuggests that the diffusivity model does entirely support the sorption of Zn^{2+}using the two adsorbents and its two pore sizes. The diffusion rate constant K_p and the linear driving force D_F (diffusion parameter) obtained from the slope and intercepts of the plots are presented in table 4.A look at figures 6 and 7 shows that Zn^{2+}150µm and Zn^{2+}250µm areparticle diffusion controlled since the plotted graphsare linear. Since sorption of Zn^{2+} 150µm and Zn^{2+} 250µmare particle diffusion controlled (plot is linear), it could be affected by the following processes: (1) diffusion from the surface to the internal sites (surface diffusion or pore diffusion); (2) uptake which can involve several mechanisms: physicochemical sorption, ion exchange, precipitation or complexation (Igwe *et al.*, 2005); (3) diffusion of the solute from the solution to the film surrounding the particle;(4) diffusion from the film to the particle surface (external diffusion); The mechanism of sorption depicted to be particle diffusion controlled means that intraparticle mass transfer resistance is rate limiting(Igwe *et al.*, 2006). This means that in the presence of a mixture of the metal ions, the metal ions compete for the adsorption sites on the adsorbent.This competition affects the diffusion properties of the metal ions, hence decreases the adsorption capacity of the metal ions. The R^2values confirm this. Thus, the metal ion that successfully reaches the adsorption site faster depends on the above factors and also on the ionic radii of the metal ions. Competition among the metalions for adsorption sites clearly affected the adsorption capacity (Igwe *et al.*, 2005; Imaga C.C and Abia A.A, 2015).

Consequently, in an adsorption process, the metal ions from the bulk solution should move through the thin liquid film surrounding the adsorbent. The thin film may produce a diffusion barrier for the metal ion to penetrate before they arrive at the binding sites on the adsorbent.This suggests that the metal ion must overcome this film barrier to be adsorbed at the sites on the adsorbent.This mechanism is consistent with the fact that the rate of diffusion of the metal ion also affects adsorption rate. This conclusion was also arrived at by Abia and Asuquo (2005) in their study onPb^{2+}, Ni^{2+}, Cd^{2+} and $Cr^{3+}$with oil palm fibre.

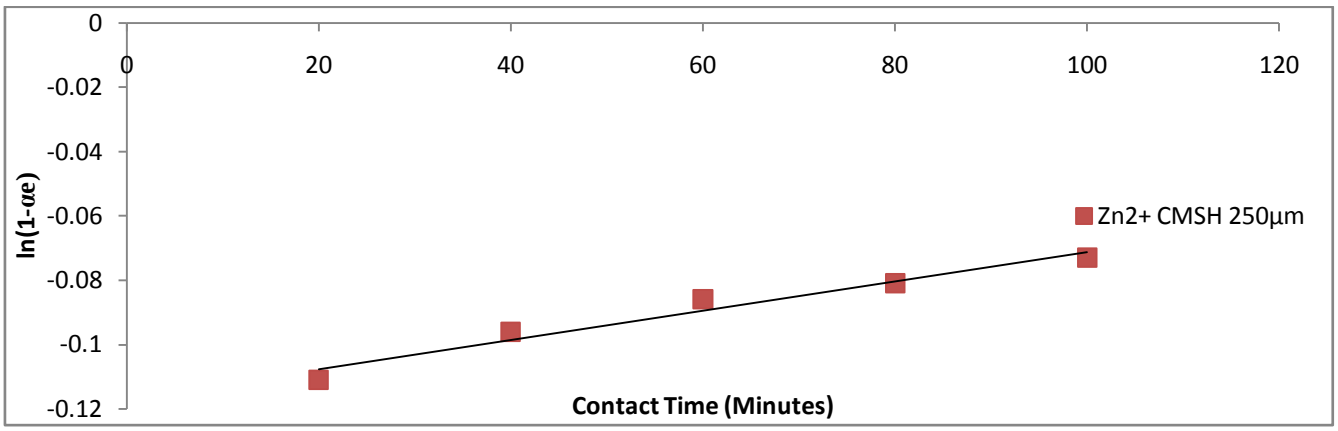

Figure 6 : Liquid Film Diffusivity Model For CMSH 250µm

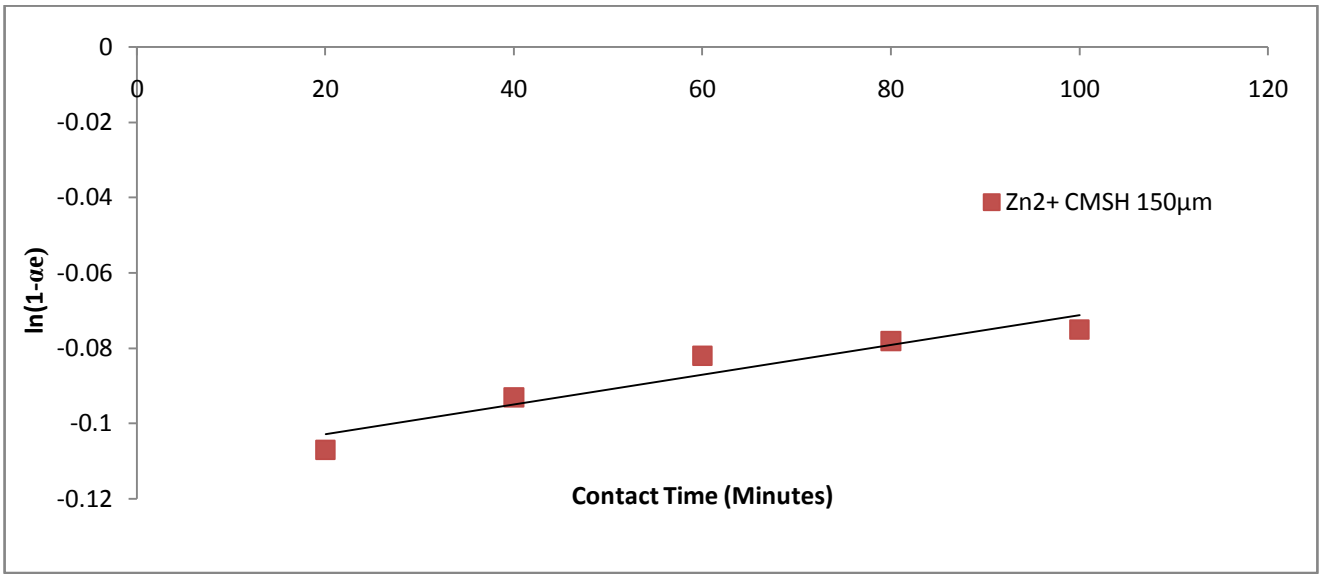

Figure 7 : Liquid Film Diffusivity Model For CMSH 150µm

ii. *Mass Transfer Model*

The mass transfer kinetic model is generally expressed as (Abia *et al*., 2006)

$$C_o - C_t = Dexp(K_o t) \quad (10)$$

Where,

C_O is the initial metal ion concentration (mg/l)

C_t is the metal ion concentration at time t in mg/l

T is the shaking time in minutes

D is the fitting diameter

K_O is a constant which is the mass transfer adsorption coefficient

A linearized form of the equation is written thus:

$$\ln(C_o - C_t) = \ln D + K_o t \quad (11)$$

If the sorption of the metal ion is depicted by the mass transfer model, then the plot of ln (C_o-C_t) versus time should give a linear relationship from where lnD and K_o can be determined from the intercept and slope of the plot, respectively.

Table 5 : Mass Transfer Constants For Cmsh 150µm And 250µm

CONSTANTS	Zn^{2+} 150 µm	Zn^{2+} 250 µm
R^2	0.2655	0.0789
D	4.871	4.911
K_O	0.0002	-0.0001

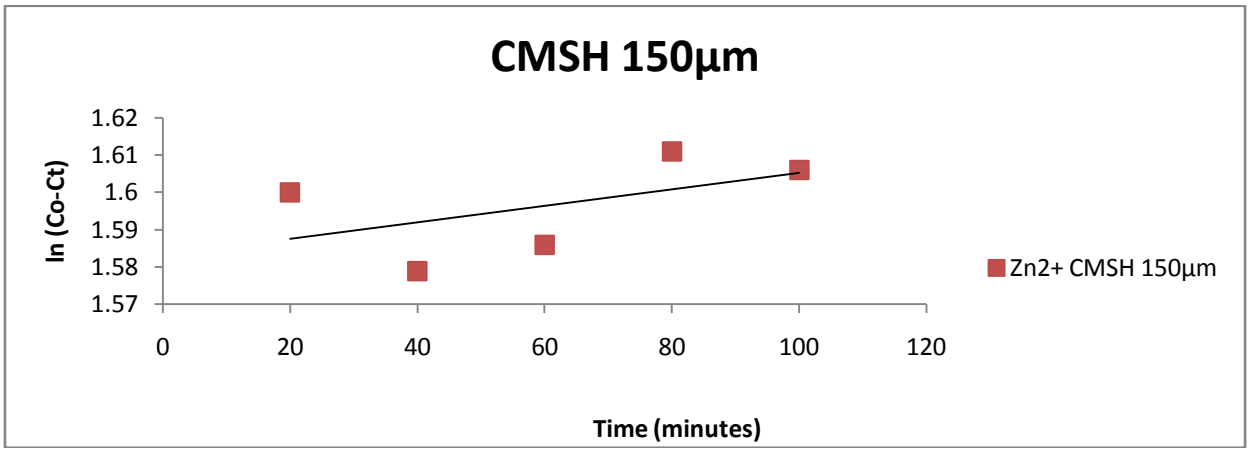

Figure 8 : Mass Transfer Model of Metal Ions of Sample Pore Size CMSH 150µm

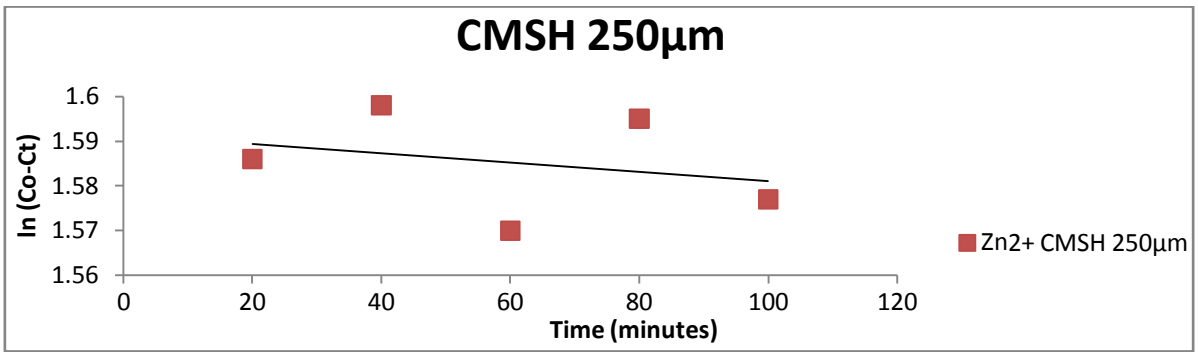

Figure 9 : Mass Transfer Model of Metal Ions of Sample Pore Size CMSH 250µm

From the results, the low R^2 values suggest that the mass transfer diffusivity model does not support the adsorption of the metal ions using the various adsorbents and their two pore sizes. Mass transfer is the movement of chemical species in a fluid mixture caused by some forms of driving force. There are two main mechanisms of mass transfer: diffusion and mass transport by convection (Aikpokpodion Paul E. *et al.*, 2013; Imaga C.C and Abia A. A, 2015). These mechanisms (diffusion and mass transport by convection) were not supported suggesting that mass transfer model does not favour the sorption of Zn^{2+}. The diffusion rate constant K_o and D (fitting parameter) obtained from the slope and intercepts of the plots are presented in table 5. A look at figures 8 and 9 shows that the plots are non- linear suggesting that the sorption process is not diffusion and mass transport by convection controlled. The confirmation is shown on their low R^2 values. Imaga C.C and Abia A.A, 2015stated that the rate of diffusion of ions between soil solution and soil surfaces is generally low due to molecular collisions that give rise to extremely strong hindrance to the movement of molecules.

iii. *Intra Particle Diffusivity Model*

Intra particle diffusivity equation for description of sorption kinetics was explored using the intra-particle diffusivity model given below (Imaga C.C and Abia A.A, 2015):

$$q_t = k_{id} t^{1/2} + C \qquad (12)$$

Where,

k_{id} is the rate of sorption controlled by intra particle diffusivity ($mgg^{-1}min^{-1(1/2)}$)

C depicts the boundary layer thickness.

This model predicts that the plot of q_t versus $t^{1/2}$ should be linear with k_{id} and C as slope and intercept respectively if intra particle diffusivity is involved in the sorption process. Intra particle diffusivity is the rate controlling step if the line passes through the origin.

Table 6 : Intra Particle Film Diffusivity Constants For CMSH 150µm And 250µm

Constants	Zn^{2+} 150 µm	Zn^{2+} 250 µm
R^2	0.1858	0.0685
$K_{id}(mgg^{-1}min^{-1(1/2)})$	-1.33×10^{-2}	6.9×10^{-3}
C	55.165	55.068

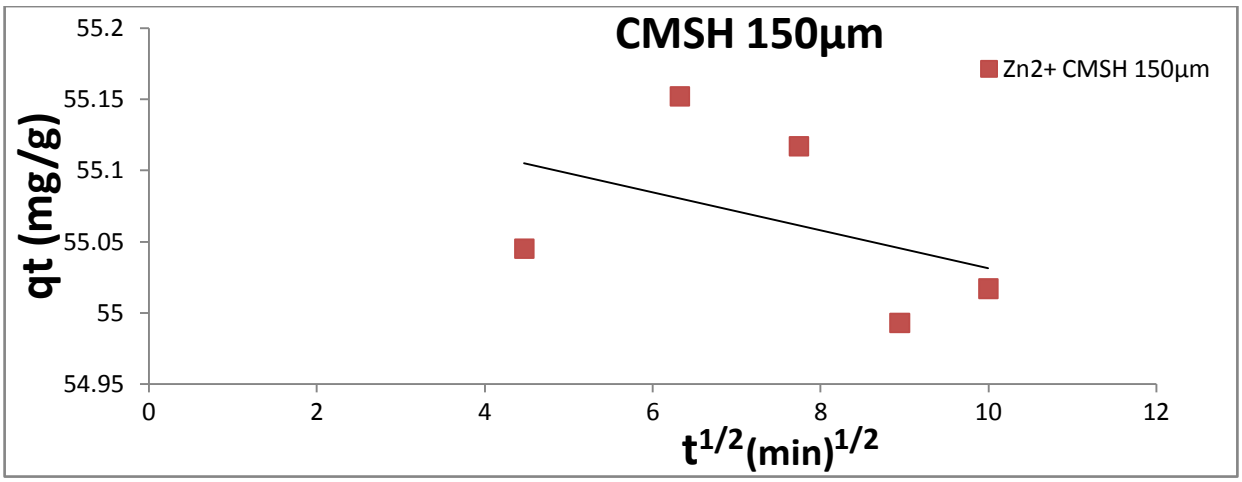

Figure 10 : Intra Particle Diffusivity Model For CMSH 150µm

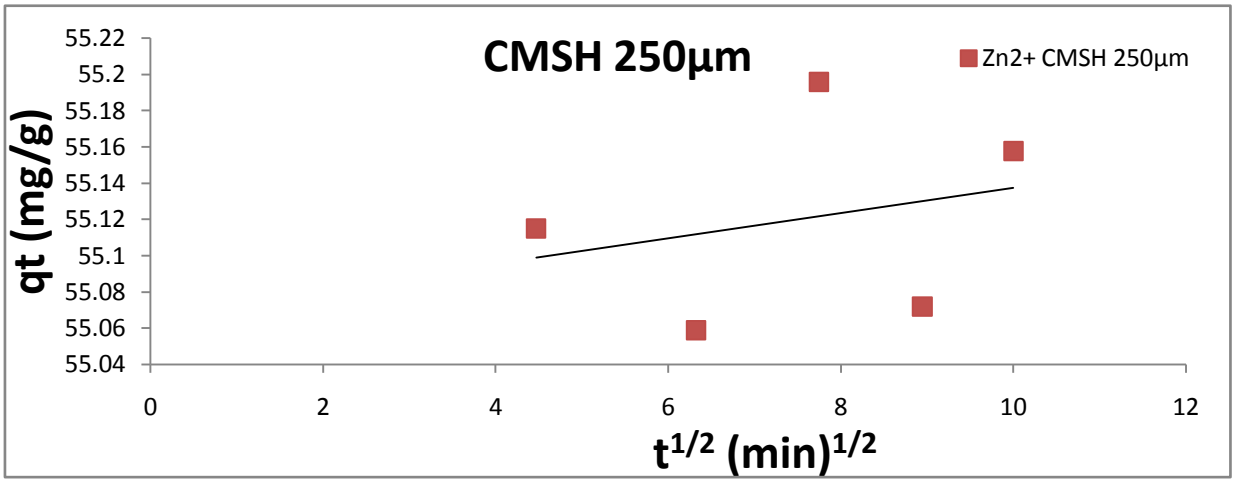

Figure 11 : Intraparticle Diffusivity Model For CMSH 250*µm*

According to (Itodo A.U *et al.*, 2010; Imaga C.C and Abia A.A, 2015), of the intraparticle diffusivity plot, the sorption mechanism assumes intra particle diffusivity model if the following conditions are met:

1. High R^2 values to ascertain applicability
2. Straight line which passes through the origin for the plot area q_t versus $t^{1/2}$
3. Intercept C< 0.

A validity test which deviates from 2 and 3 above shows that the mode of transport is affected by more than one process (Hameed, 2009; Imaga C.C and Abia A.A, 2015).The intercept C values are very high (well above zero values).

Higher values of k_{id} illustrate an enhancement rate of adsorption, whereas, larger k_{id} values illustrate better adsorption which is related to improved bonding between adsorbate and adsorbent particles(Itodo A.U *et al.*, 2010). From the assertion above, the values of k_{id} are relatively very low showing that there is no enhancement rate of adsorption which illustrates no adsorption and no better bonding between adsorbate and adsorbent particles.

From the results obtained in table 6, it shows that none of these conditions (1, 2 and 3) listed above were met suggesting that the intraparticle diffusivity model adsorption mechanism does not in any way favour the adsorption of $Zn^{2+}$with the adsorbent of the two different pore sizes.

iv. *Intra Particle Diffusion Model*

The intraparticle diffusion model, according to (Imaga C.C and Abia A.A, 2015; Akpokpodion Paul E. *et al., 2013*; A.A. Abia *et al.,* 2007)is expressed as:

$$R = K_{id}(t)a \qquad (13)$$

Linearising the equation, becomes

$$\log R = \log K_{id} + a \log t \qquad (14)$$

Where,

R is the percent of metal ion adsorbed

t is the contact time in minutes

a is the slope on a logarithmic plot which depicts the adsorption mechanism

K_{id} is the intra particle diffusion rate constant which is taken as a rate factor, that is, percent of the sorbate adsorbed per unit time ($mgg^{-1}min^{-1(1/2)}$)

If the sorption can be represented by the model, a plot of log R versus log t should yield a linear relationship with a slope **a** and an intercept **log K_{id}.**

According to (Akpokpodion Paul E. *et al., 2013*),this model is based on the assumption that, diffusion into the interior pores of the soil particles from the soil solution controls the adsorption of Mg^{2+} onto the studied soils.

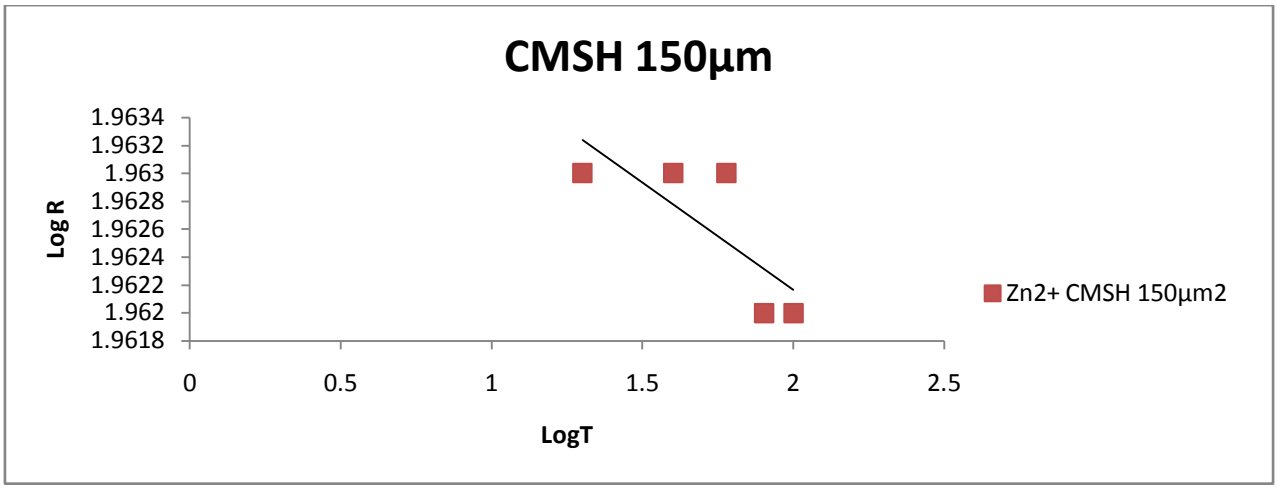

Figure 13 : Intra Particle Diffusion Model For CMSH 150*µm*

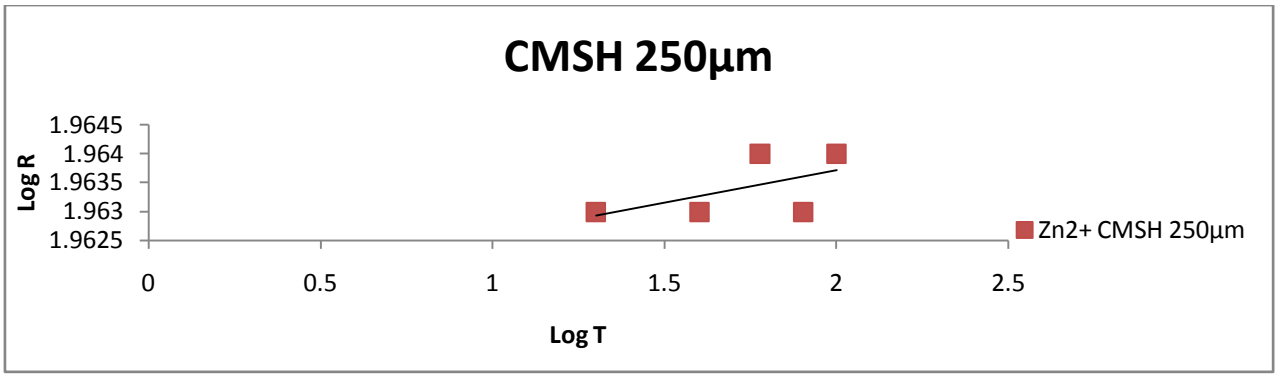

Figure 14 : Intra Particle Diffusion Model For CMSH 250*µm*

From the results obtained in table 7, it follows that R^2, k_{id} and **a** values are low suggesting that the intraparticle diffusion model adsorption mechanism does not in any way favour the adsorption of $Zn^{2+}$with the adsorbent of the two pore sizes. This means that the values of k_{id} being relatively very low shows that there is no enhancement rate of adsorption illustrating no sorption and no better bonding between sorbate and sorbent particles. Higher values of k_{id} illustrate an enhancement rate of adsorption, whereas, larger k_{id} values illustrate better adsorption which is related to improved bonding between sorbate and sorbent particles (Imaga C.C and Abia A.A, 2015; Itodo A.U *et al.*, 2010).

Table 7 : Intra Particle Film Diffusion Constants For CMSH 150*µm* And 250*µm*

Constants	Zn^{2+} 150 *µm*	Zn^{2+} 250 *µm*
R^2	0.6026	0.0632
A	-1.5×10^{-3}	-1.24×10^{-2}
$K_{id}(Mgg^{-1}min^{-1(1/2)})$	0.2934	0.2986

IV. Pore Size Analysis

One of the most important adsorbent parameters is the pore size and pore size distribution. Adsorbent surface area is the factor directly affecting the analyte retention. Pore size is defined as the ability of the analyte molecules to penetrate inside the particle and interact with its inner surface. This is especially important because the ratio of the outer particle surface to its inner one is about 1:1000. The surface molecular interaction mainly occurs on the inner particle surface. Micro-pores are easily accessible to the analytes since there is littleor no steric hindrance effect. Meso-pores are partially accessible but molecular diffusion into the pore spaces are restricted by steric hindrance effect which significantly slows mass transfer and decreases the adsorption efficiency (Imaga C.C and Abia A.A).

From the results, the two pore sizes are effective to use and can equally serve as a good low

cost adsorbent for the sorption of Zn^{2+} from aqueous solution.

V. Conclusion

The conclusions based on experimental study were:

(i) Adsorbent preparation by carbonization and chemical modification of biosorbent using Mercapto acetic acid showed good affinity for Zn^{2+}.

(ii) The result obtained can be used for design purposes.

(iii) These results can be used as a basis for the study of desorption and recovery of $Zn^{2+}$from solution.

(iv) Pore size analysis showed that 150μm mesh had faster adsorption rate than 250μm mesh, although both recorded high adsorption values.

(v) For liquid film diffusivity model, Zn^{2+} 150μmandZn^{2+}250μm favoured particle diffusion controlled adsorption.

(vi) Mass transfer, Intra particle diffusivity, Intra particle diffusion and Elovich models did not favour the sorption of Zn^{2+} using the adsorbent of the two different pore sizes.

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

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17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

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Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

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· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

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The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
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- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

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- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

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This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

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- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

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The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
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- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
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- Submit to generally acknowledged facts and main beliefs in present tense.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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