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Remediation of Heavy Metals from Well Water in Gold Mining Communities in Tarkwa-Nsuaem, Western Region of Ghana using Synthetic Silver Impregnated Zeolite X (AgZX)

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Abstract

This study evaluates the use of synthetic silver impregnated zeolite X (AgZX) for remediating heavy metals from well water in ten gold mining communities in Tarkwa-Nsuaem Municipal, in the western region of Ghana. Heavy metal contamination in groundwater is a serious environmental challenge. The adsorption capacities for Pb^{2+}, Cd^{2+} and As^{2+} ions were analyzed. The outcome indicated a momentous adsorption of heavy metals, demonstrating that synthetic AgZX as a prospective way out for water purification. The result depicted the maximum percentage adsorption capacities of 93.5%, 87.5%, and 67.5% for Pb^{2+}, Cd^{2+} and As^{2+} ions respectively, and that synthetic AgZX had a high adsorption capacity for these metals. The adsorption data well-fitted to the linear Langmuir isotherm, and the adsorption of Pb^{2+}, Cd, $^{2+}$ and As$^{2+,}$ ions levels by the AgZX, follows the pseudo-second-order kinetics model, which relies on the assumption that chemisorption may be the rate-limiting step. Indicating monolayer adsorption, with maximum monolayer coverage (Q$_{max}$) of the synthetic AgZX, the Langmuir constant (K$_L$), the Langmuir separation factor (R$_L$) and R^2 values to be 5.934x10^3 mg/g, 1.93 x10^{-2} 1/mg, (3.5 x10^{-2} – 7.71 x10^{--1}) and (0.9945-0.9973) respectively. Correlation coefficient (R^2 approximately 1) implies favorable adsorption. Free energy constant, K$_L$ less than 1, and the Langmuir separation factor (R$_L$ less than 1) indicates it is linear, chemisorptions, reversible and that the synthetic AgZX could be an excellent adsorbent for heavy metals remediation. The study demonstrated the potential of synthetic AgZX as a low-cost and sustainable adsorbent for the remediation of heavy metals from water.

Key Words: Synthetic Silver impregnated zeolite X (AgZX), Chemisorption, Mutagenic, Batch adsorption, Monolayer adsorption, Adsorption capacities, and Langmuir isotherm model

1. Introduction

Heavy metal pollution in water bodies poses major environmental and health risks to humans, particularly to pregnant mothers and children. Heavy metals are toxic at even low levels, and have health issues associated with them, and when accumulated pose serious human health issues (Akpor, O. B., & Muchie, M., 2011). Both natural and synthetic zeolites, with their exceptional composition and properties show potential adsorbents for remediating heavy metals from groundwater sources (Vilensky, et. al,. 2002). Zeolites are good adsorbent of neutral, anions and cations in water contaminates, have been extensively considered for its adsorption properties (Szostak, R., 1989). Its high surface area, chemical stability, and availability make it an attractive substance for heavy metal remediation (Breck, 1974; Li et al., 2020). Zeolites have antimicrobial properties and can be applied removing bacteria, viruses, and other microorganisms in water treatment, air purification by removing airborne pathogens (Madina Suleimenova et al., 2023), and in medical fields as antimicrobial coatings and wound dressings(Breck,1974). Previous studies have shown zeolites effectiveness in remediating heavy metals like copper, mercury, and lead from polluted water (Moussavia, et. al., 2011; Mousavi, et. al., 2013). Studies have shown that the adsorption capabilities of zeolites, particularly modified zeolites, involve heavy metal ions bind to their surface through electrostatic forces, van der Walls forces or chemical bonding **(**Motsi, et. al., 2009). The main reason for the high adsorption capacities of zeolites is due to their vast interior surface area of numerous hundred square meters per gram and microspores with diameters ranging from 0.3 to 1.0 nm is attributed to its ability to precipitate out of solution as insoluble compounds with heavy metals (Islem et al.,2011)**.** This study aims to impregnate synthetic zeolite X with silver ions to ascertain its effectiveness in removing lead, cadmium, and arsenic from well water samples. Potable water is crucial for all forms lives within the gold mining communities in Tarkwa-Nsuaem Municipal, well water is often polluted with hazardous metals like lead, cadmium, and arsenic, which can cause serious health issues including brain, kidney damage, and cancer (Salem, et al., 2000; Sardar, et al., 2013). Since these metals are non-biodegradable in organisms, it's vital to find effective ways to remediate them. Adsorption, especially using silver impregnated zeolite X an environmentally friendly, easily developed and cost-effective will be an effective, best, and alterative adsorbent in removing heavy metals contaminates in water and protecting individuals' health.

Quality Control

All the glassware were thoroughly washed in a solution of laboratory detergents (TEEPOL), well rinsed in distilled water, and dried at 130 ^{o}C to avoid contamination. Laboratory quality control measures were also followed during the analysis of each set of samples collected.

2. Methodology

Sample Collection

Well water samples were collected from ten gold mining communities in Tarkwa-Nsuaem Municipal, western region of Ghana. The well water sampling was influenced by age of well and distance of well to mining sites in Tarkwa-Nsuaem metropolitan. Triplicates of hand-dug wells in each of the ten communities were sampled, totaling thirty. The bucket was then lowered into the well, allowed to get filled with water, then pulled up, and poured back into the well again for four more times to ensure that the content of the well was thoroughly mixed before samples were collected (Bieranye et al., 2016). The hand-dug wells were samples with a high-density plastic bucket with a long rope attached to the opened end. The samples were collected into 5 L high-density polyethylene (HDPE) bottles, which were immersed in aqua regia for 24 hr, cleansed, and rinsed three times with distilled water. The bottles were then dried on a ceramic bench. The samples were then acidified with concentrated nitric acid, labeled, sealed, and transported to the laboratory in an ice chest.

Reagents

Analar 36 % hydrochloric acid (HCl), Analar 70 % nitric acid (HNO_3), and Silver nitrate ($AgNO_3$).

Materials

Synthetic Zeolite X (ZX) obtained from United Kingdom

Preparation of 3: 1v/v Aqua Regia (11.50 M HCl : 15.5 M HNO_3)

The aqua regia procedure put forth by Nieuwenhuize et al. (1991) for trace element digestion was followed (Sastre, et. al., 2002). Exactly, 150 mL of 36 % Analar hydrochloric acid (11.50 M HCl) was added to 50 mL 70 % Analar nitric acid (15.5 M HNO_3).

Digestion of Well water Samples for Arsenic, Lead and Cadmium

Well water was digested in a 250 mL conical flask with 50 mL of aqua regia (3:1 HCl: HNO_3) at 106 °C to prevent metal losses. The digestion was complete when the solution reduced to about 2 mL and brown nitrogen dioxide gas ceased. The digested solution was cooled, diluted with distilled water, and analysed for arsenic, lead and cadmium using an atomic absorption spectrometer.

Synthesis of Silver Impregnated zeolite X

Synthetic zeolite X was prepared using ion exchange method (Breck, 1974). One gram of silver nitrate was weighed, dissolved with distilled water and quantitatively transferred into 100 ml volumetric flask and topped it up to the mark with distilled water to form 0.1 M $AgNO_3$ solution. Ten grams of the synthetic Zeolite X was mixed with the silver nitrate solution, covered and allowed to stand for 48 hr to load the impregnation of silver ions unto the synthetic zeolite X pores. The mixture filtered and residue washed severally with cuprous amount of distilled water to removed excess silver nitrate, and dried in an oven at 490 ^{o}C to remove moisture. The silver impregnated synthetic zeolite X was characterized by FTIR analysis.

Table 1: General FTIR Assignments in Synthesized Silver Impregnated Zeolite X

Peak	X(cm^{-1})	Y(%T)	Peak	X(cm^{-1})	Y(%T)
1	3696.81	96.63	**2**	3620.93	96.32
3	1164.28	94.49	**4**	1113.42	45.94
5	1028.91	62.53	**6**	1604.29	58.96
7	936.43	69.73	**8**	911.44	68.56
9	832.75	90.57	**10**	767.07	85.74

11	753.36	83.55	**12**	693.85	83.32
13	532.04	50.1	**14**	464.16	39.71
15	429.83	48.4	**16**	410.52	50.52

Table 1 indicates peaks 3, 4, 5, and 6 within the range 1000 - 1100 cm^{-1} represents Si-O stretching vibrations. The Peaks 7 and 8 within the range 900 to 950 cm^{-1}, were due to Al-OH bending vibrations. However, the presence of peaks 9 to 16 in table 1 could be attributed to the intensity bands observed in zeolite with exchangeable silver ions (Mozgawa, et. al,. 2011). **Discussion**

3. Data Analysis

The adsorption data were analyzed using, the mean level and standard deviations, the paired sample T-Test, and the Langmuir isotherm model to determine the maximum adsorption capacity of silver impregnated zeolite.

Table 2: Mean Levels and Standard Deviations of Lead, Cadmium, and Arsenic in Untreated Well water Samples (mg/ L)

Sample Code	Pb (mean ± SD)	Cd (mean ± SD)	As (mean ± SD)
WW 1	10.81 ± 0.37	0.38 ± 0.06	2.29± 0.71
WW 2	12.73 ± 0.89	0.65± 0.06	2.30 ± 0.16
WW 3	13.55 ± 0.89	0.45± 0.05	2.00 ± 0.06
WW 4	15.73± 0. 64	0.46 ± 0.05	2.71± 0.33
WW 5	16.44 ± 0.09	0.39 ± 0.02	2.87 ± 0.29
WW 6	1.12 ± 1.22	0.30 ± 0.09	2.88± 0.04
WW 7	3.53 ± 5.12	0.34 ± 0.20	2.61± 0.83
WW 8	1.50± 0.98	0.19 ± 0.00	2.59 ± 0.07
WW 9	9.05 ± 12.50	0.33 ± 0.02	2.45 ± 0.48
WW 10	0.37± 1.06	0.35 ± 0.06	0.29± 0.28

Table 2 shows that the mean levels and standard deviations (SD) of lead (Pb), cadmium (Cd), and arsenic (As) in untreated well water vary across various localities. Well water 5 had the highest lead (Pb) contents (16.44 ± 0.09 mg/L), suggesting serious pollution. Well water 10 had the lowest levels (0.37± 1.06 mg/L). Cadmium (Cd) values were greatest in well water 2 (0.65± 0.06 mg/L) and lowest in well water 8, 0.19 ± 0.00 mg/L. Arsenic (As) levels were very stable, ranging from 2.00 ± 0.06 mg/L (well water 3) to 2.88± 0.04 mg/L (well water 6).

Table 3: Paired Sample T-Test on Well water Samples for the Lead, Cadmium and Arsenic after Treatment with AgZX

	Pd		**Cd**		**As**	
	Test Statistic	**P-value**	**Test Statistic**	**P-value**	**Test Statistic**	**P-value**
WW 1	41.34	0.015	9.28	0.068	4.57	0.137
WW 2	20.25	0.031	11.13	0.057	20.92	0.030

WW 3	21.51	0.030	12.09	0.053	4.76	0.132
WW 4	34.55	0.018	11.85	0.054	8.17	0.078
WW 5	25.84	0.025	25.14	0.025	13.86	0.046
				0.126	10.11	0.063
WW 6	1.31	0.416	4.97			
WW 7	0.98	0.508	2.26	0.265	4.44	0.141
WW 8	2.17	0.275	103.54	0.006	55.91	0.011
WW 9	1.02	0.492	23.20	0.027	7.29	0.087
WW 10	0.49	0.710	8.47	0.075	11.75	0.054

Significance level = 5

Table 4: General Paired Sample T-Test on Heavy Metals in Well water Samples

Metal	Test Statistic	P-Value
Pb	7.71	0.000
Cd	18.13	0.000
As	35.64	0.000

Percentage Removal Efficiency

Percentage removal efficiency (%) = $[(C_i-C_e)/C_i] \times 100$--------------------(1)

where C_i and C_e represent the initial and equilibrium levels of heavy metal ions in mg/L, respectively.

Table 5: Percentage Removal Efficiencies for the Lead, Cadmium and Arsenic

Sample code	Pb(%)	Cd(%)	As(%)
WW 1	86.4	75.7	48.1
WW 2	91.2	87.5	50.6
WW 3	87.0	84.4	43.5
WW 4	93.5	77.3	61.2
WW 5	90.8	76.4	67.8
WW 6	44.2	75.8	61.4
WW 7	72.4	67.9	55.1
WW 8	49.5	53.2	63.6
WW 9	89.3	66.6	56.2
WW 10	18.9	70.4	61.1

From Table 5, it can be seen that the highest percentage removal of lead was about ninety-four percent (93.5%) whiles the least was about nineteen percent (18.9%) for well 4 and 10 respectively. Likewise, well 2 showed the highest cadmium removal (87.5%) whiles well 8 showed the least cadmium removal (53.2%). Equally, the highest arsenic (As) removal was in well 5 (67.8%) and the lowest was well 3 (43.5%). The table supports earlier findings that silver impregnated zeolite removes lead and cadmium more effectively than arsenic, with variations likely due to adsorption kinetics, water chemistry, and heavy metal-binding interactions. The results showed that synthetic silver impregnated zeolite X exhibited high adsorption capacities for heavy metal ions. The adsorption mechanisms involved ion exchange, complexation, and surface adsorption (Erdem, et al. 2004), and the structure, and surface area of synthetic silver impregnated zeolite X influenced the adsorption capacity (Motsi, et al. 2009). The study showed that treating the well water samples with AgZX significantly reduced lead and cadmium levels in some well water, while arsenic removal was less consistent. Variations in results across samples were likely due to treatment conditions or environmental factors. Overall, statistical analysis confirmed AgZX effectiveness in reducing heavy metal pollution in well water.

Batch Adsorption Experiments

Batch adsorption experiments were conducted to assess the AgZX capacity to adsorb lead, cadmium, and arsenic at room temperature, simulating environmentally relevant conditions, with a constant volume of well water. The adsorption capacity of silver impregnated zeolite X was calculated using the following equation:

$Q = (C_i - Ce) \times V / m$--------------------(2)

Where q is the adsorption capacity, C_i is the initial metal level, Ce is the equilibrium metal level, V is the volume of the solution, and m is the mass of silver impregnated zeolite X. Adsorption capacity measures how much metal was removed per unit of adsorbent.

Table: 6 Adsorption Capacity (Q) for the Lead, Cadmium and Arsenic in mg/g

Sample code	Pb	Cd	As
WW 1	21.628	0.767	4.576
WW 2	25.476	1.422	4.602
WW 3	27.098	0.894	3.998
WW 4	31.450	0.912	5.414
WW 5	32.880	0.779	5.746
WW 6	2.250	0.593	5.758
WW 7	7.080	0.678	5.216
WW 8	3.006	0.383	5.172
WW 9	18.100	0.661	4.896

WW 10	0.734	0.703	4.590

From Table 6, lead (Pb) adsorption was highest in well 5 (32.88 mg/g), followed by well 4 (31.45 mg/g), showing strong interactive binding forces between the heavy metals ions on the surface of the AgZX, and hence high adsorption. Well 10 had the lowest (0.734 mg/g), suggesting poor Pb adsorption. Meanwhile, cadmium (Cd) adsorption was highest in well 2 (1.4218 mg/g), showing efficient removal, while well 8 had the lowest (0.3832 mg/g). In the same way, arsenic (As) adsorption showed relatively consistent values, with well 5 (5.746 mg/g) and well 6 (5.758 mg/g) performing best. These results indicate that while AgZX effectively adsorbed heavy metals, its performance varied depending on metal type and well water conditions. Further optimization may be required to improve adsorption in well water with lower efficiency.

Determination of Optimum Contact Time

The well water2 (WW2) sample, which recorded the highest levels of Pb(14.5983 mg/l), Cd(0.7783 mg/l), and As(0.1582 mg/l) was used for the determination of the optimum contact time. To determine the optimum contact time, contact time was varied from (10, 20, 30, 40, 50, and 60) minutes, whilst additional physicochemical parameters were kept constant. Hundred milliliters of each well water 2 sample was measured into 250 ml volumetric flasks labeled (10, 20, 30, 40, 50, and 60) minutes. One gram of AgZX adsorbent was added to the contents of the flasks. The flasks were sealed tightly with cotton wool plugs wrapped with aluminum foil to produce an air-tight reactor. The flasks and its contents were then fitted onto a flask shaker, and rotate at 250 rpm for 10, 20, 30, 40, 50, and 60 respectively. The flasks were removed and then allowed to stand for 30 mins, the resulting mixtures for each were filtered and each filtrates analyzed for residual lead, cadmium, and arsenic.

Table 7: Contact Time Optimization Process for Percentage Removal of Pb, Cd, and As using AgZX

Time/min	Pb		Cd		As	
	Ce/	Qe	Ce	Qe	Ce	Qe
10	11.4074	3.1909	BDL	0.7783	0.1142	0.0440
20	8.6232	5.9751	BDL	0.7783	0.0869	0.0713
30	6.9605	7.6378	BDL	0.7783	0.0451	0.1131
40	4.1445	10.4538	BDL	0.7783	0.0104	0.1478
50	1.4131	13.1852	BDL	0.7783	0.0052	0.1530
60	1.4132	13.1851	BDL	0.7783	BDL	0.1582

The results shows, that the initial level of lead decreased to 11.4074 mg/l on the first ten minutes of treatment. A decreased to 8.6232 mg/l occurred on the 20th minutes, and on 30th minutes the initial level decreased to 6.9605 mg/l. on the 40th, 50th and 60th minutes the initial levels of lead decreased to 4.1445 mg/l, 1.1431 mg/l, and 1.4132 mg/l respectively. The 50th minutes appeared to be the optimum time with 90.32 % Pb removed the well water sample. The first 10th minutes observed the removal of all the initial level of Cadmium(0.7783mg/l) in the well water sample, corresponding to a 100% removal, indicating availability of adsorption sites on the surface of the adsorbent AgZX (Karmen, et al., 2012). However, the percentage Arsenic removal, increased constantly from 27.81 % for the first 10 minutes to 100 % at the 60th minutes, could be attributed to unavailability of adsorption sites on the surface of the adsorbent AgZX, due to surface saturation (Ho, et al., 2002; Igwe, et al., 2011). The percentages of Pb, Cd, and As removed (Table 8) was estimated using equation 2 in which Ci and Ce in mg/l, are the levels of Pb, Cd, and As before and after treatment respectively. The percentage of Pb removed increased from 28.86 % on the 10th minutes to a maximum value of 90.32 % on the 50th minutes. After the 50th minutes, further increased in contact time resulted in a marginal decrease in the levels removed. The marginal decreased observed after the 50th minutes could be attributed to unavailability of adsorption sites on the surface of the adsorbent AgZX, due to surface saturation (Ho, et al., 2002; Igwe, et al., 2011).

Equilibrium study

Adsorption isotherms are mathematical models that relate the amount of the adsorbate adsorbed onto the adsorbent and the residual amount of the adsorbate in the aqueous phase when the adsorption process has attained equilibrium. The adsorption data were analyzed using the linear form of Langmuir isotherm model equation employed to determine the maximum adsorption capacity of the silver impregnated zeolite X. The Langmuir isotherm is represented by the linear form:

$Q_e = (1/Q_{max}K_L) + (Ce/Q_{max})$--------------------(3)

where Qe (mg/g) and Ce (mg/l) are equilibrium solid and liquid phase levels of adsorbate, respectively, and Q_{max} (mg/g), the maximum amount of metal ions adsorbed per unit mass of adsorbent. An essential dimensionless parameter (R_L), a characteristic of the Langmuir isotherm is expressed as:

$R_L = 1/(1+K_L C_e)$--------------------(4).

The dimensionless parameter (R_L) is the separation factor and it determines whether the adsorption process is favorable or unfavorable.

Where, Q_e is heavy metal level on the AgZX at equilibrium (mg /g); Q_{max} (mg/g) and K_L(1/mg) are Langmuir constant related to be maximum adsorption capacity corresponding to complete coverage of available adsorption sites and a measure of adsorption energy (equilibrium adsorption constant), respectively. These constants are determined from the slope and the intercept from a linear plot of (Ce/Q_e) against **Ce**, so that

$Q_{max} = 1 / \text{slope}$ and $K_L = \text{slope/intercept}$--------------------**(5)**

Table 8: Linear Langmuir Isotherm Constants for Adsorption of Pb, Cd, and As on Synthetic Silver Impregnated Zeolite X at room temperature (25 °C).

Heavy metal	Q_{max}	K_L	R^2	R_L
Pb	59.3356	0.0193	0.9973	0.0353
Cd	59.3356	0.0193	0.9945	0.4073
As	59.3356	0.0193	0.9945	0.7717

The study found that AgZX, is an effective, and sustainable adsorbent for removing heavy metals specifically lead, cadmium, and arsenic from well water. Its high adsorption capacity and alignment with the Langmuir isotherm model indicate strong metal affinity and monolayer adsorption. In table 8, Langmuir isotherm was used to analyze adsorption data on AgZX, with values of Q_{max} and K_L being 59.3356 mg/g and 0.0193 L/mg for all three metals. The separation factor R_L values ranged from 0.0353 to 0.7717, indicating the adsorption of lead, cadmium, and arsenic onto the AgZX. The applicability of isotherm models was evaluated by judging the correlation coefficient, R_2 values. The isotherm with R_2 close to unity (R_2=1) was selected as the best fit, explaining the adsorption process. The adsorption isotherm data was then fitted to these models to find the most suitable model for the study. The Langmuir isotherm model effectively describes the adsorption of lead, cadmium, and arsenic, with lead showing the best fit. The AgZX is an environmentally friendly, viable, and sustainable adsorbent, for heavy metal remediation from well water. Further research is needed to optimize the process and assess the AgZX effectiveness against other metals.

Kinetic Adsorption Study

To examine the domineering method of adsorption processes such as mass transfer and chemical reaction, the Lagergren pseudo–first–order and Lagergren pseudo-second-order equations were applied to model the kinetics of lead, cadmium, and arsenic, in well water samples onto AgZX.

The Lagergren pseudo-first-order and the second order equations (Hong, et al., 2009; Igwe, et al., 2011), are given as;

The Lagergren pseudo-first-order equation: $In(Qe - Qt) = InQe - k_1t$ ………………….(6),

The Lagergren pseudo-second-order equation: $t/Qt = 1/K_2Qe^2 + t/Qe$ ………………..(7),

Where k_2 is the adsorption rate constant (g/mg min). k_2 and Q_e are found from the intercept and slope of t/Q_t vs t, plot so that $Qe=1/slope$ and $K_2 = slope/intercept$ ……………………(8),

where Q_e and Q_t are amount of metal ions (mg /g), adsorbed onto the zeolite at any time at equilibrium and time t (min), respectively, and k_1 is the adsorption rate constant ($mins^{-1}$) of pseudo-first-order kinetics. A plots of In(Qe - Qt) against t gives the slope = k_1 values and their corresponding intercept = InQe values for lead, cadmium, and, arsenic, respectively. The values obtained from the Lagergren pseudo-second-order reactions at different Pb^{2+}, Cd^{2+}, and $As^{2+,}$ ions levels on the AgZX. Tables 9, 10, and 11, illustrate the plots values of pseudo-first-order and pseudo-secondt-order equations along with the corresponding kinetics correlation coefficients, R^2 values for lead(0.9973),, cadmium(0.9945), and arsenic(0.9945), using AgZX adsorbent. It was observed that adsorption values obtained from different Pb^{2+}, Cd^{2+}, and $As^{2+,}$ ions concentrations on the AgZX, as shown in tables (9, 10, and 11), on Lagergren pseudo-second-order equations yielded very good straight lines (correlation coefficients, $R^2 > 0.98$) as compared to the plots of pseudo-first-order.

Table 9: Lagergen Pseudo First-order and Second-order Constants for Lead Adsorbed onto AgZX

Time(t)/min	Qe	Qt	In(Qe-Qt)	t/Qt	First-order	Second-order
10	14.5983	3.1909	2.4343	3.1339	slope(K1) = 0.0247	slope(1/Qe) = 0.0685
20	14.5983	5.9751	2.1545	3.3472	Intercept(ln(qe)) = 2.6809	intercept (1/k2) = -0.0221
30	14.5983	7.6378	1.9403	3.9278		
40	14.5983	10.4538	1.4218	3.8264		
50	14.5983	13.1852	0.3458	3.7921		
60	14.5983	13.1850	0.3458	4.5506		

Table 10: Lagergen Pseudo First-order and Second-order Constants for Arsenic Adsorbed onto AgZX

Time(t)/min	Qe	Qt	ln(Qe-Qt)	t/Qt	First-order	Second-order
10	0.1582	0.0440	-1.9519	227.2727	Slope (K1) =0.0418	slope(1/Qe)=6.3211
20	0.1582	0.0713	-2.4430	280.5049	Intercept(ln(Qe))= -1.8439	intercept(1/k2) =-0.0636
30	0.1582	0.1131	-3.0989	265.2520		
40	0.1582	0.1478	-4.5659	270.6360		
50	0.1582	0.1530	-5.2591	326.7974		
60	0.1582	0.1532	-5.2983	391.6449		

Table 11: Lagergen Pseudo First-order and Second-order Constants for Cadmium Adsorbed unto AgZX

Time/min(t)	Qe	Qt	In(Qe-Qt)	t/Qt	First-order	Second-order
10	0.7783	0.7781	-8.5172	12.8518	slope(K1) = 0.2756 intercept(ln(qe)) = -0.2506	slope(1/qe) = 39.6792 intercept(1/k2) = 32.6568
20	0.7783	0.7781	-8.5172	25.7036		
30	0.7783	0.7781	-8.5172	38.5555		
40	0.7783	0.7781	-8.5172	51.4073		
50	0.7783	0.7781	-8.5172	64.2591		
60	0.7783	0.7781	-8.5172	77.1109		

The degree of goodness of the plots of these equations can be judged from the value of the coefficient of determination of the plots, which can also be regarded as the criterion in the determination of the adequacy of a kinetic model (Demirbas, et al., 2004 ; Igwe, et al., 2011). Therefore, it can be concluded that the pseudo-first-order kinetics model does not show excellent agreement with the experimental data, and both facts suggest that the adsorption of Pb^{2+}, Cd, $^{2+}$ and As$^{2+,}$ ions levels by the AgZX, follows the pseudo-second-order kinetics model, which relies on the assumption that chemisorption may be the rate-limiting step (Ho, et al., 2002; Igwe, et al., 2011).

4. Conclusion

Silver impregnated zeolite X, reveal a possible for remediating heavy metals from well water. In conclusion, this study has demonstrated the effectiveness of the AgZX as an adsorbent for the remediation of heavy metals from well water in all the 10 communities. The results of this study suggest that the AgZX can be used as a sustainable adsorbent for the remediation of heavy metals from polluted water. Correlation coefficient ($R_2 \approx 1$) implies favorable adsorption, Free energy constant, $K_L < 1$ and the Langmuir separation factor ($R_L < 1$) indicates it is linear, chemical adsorption and reversible. The results show the reproducible nature of the heavy metal ions removal process using AgZX as adsorbent. Therefore, it is recommended that the AgZX be used as an adsorbent for the remediation of heavy metals from water. Further research is required to optimize synthesis conditions, advance adsorption capacity, and investigate scalability for realistic applications. Silver impregnated zeolite X provides a cost-effective and sustainable explanation for water purification in communities affected by heavy metal pollution.

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