Assessment of Kaolin Canister Filters for Heavy Metal Removal from Contaminated Bore-Hole Water in Gold Mining Communities in Tarkwa-Nsuaem in the Western Region of Ghana

James Atta Dadson[1*]; David Kofi Essumang[2]; Emmanuel Asare Ayim[3]; Anthony Adjorlolo-Gasokpoh[4]

[1]Department of Medical Laboratory Sciences, Faculty of Health and Allied Sciences, Takoradi Technical University, Ghana
[2]Department of Chemistry, School of Physical Sciences College of Agriculture and Natural Sciences, University of Cape Coast, Cape Coast, Ghana
[3]Department of Mathematics and Statistics, Faculty of Applied Sciences, Takoradi Technical University, Ghana
[4]Department of Industrial and Laboratory Sciences, Faculty of Health and Allied Sciences, Takoradi Technical University, Ghana

Corresponding Author: James Atta Dadson[1*]

Publication Date: 2025/06/17

Abstract: The study ascertains the efficiency of kaolin canister filters for removing heavy metals from contaminated bore-hole water in ten gold mining communities the in Tarkwa-Nsuaem Municipal, in the western region of Ghana. Contamination of groundwater is a grave environmental setback. This research looked at how effective kaolin canister filter worked as an adsorbent to remove heavy metals from water. The findings showed the maximum adsorption capacities of 93.5, 87.5, and 67.5% for lead, cadmium and arsenic respectively, and that kaolin canister filter had a high adsorption capacity for these metals. The adsorption data well-fitted to the linear Langmuir isotherm model indicating monolayer adsorption, with maximum monolayer coverage (q_{max}) of the kaolin canister filter, the Langmuir constant (K_L), the Langmuir separation factor (R_L) and R^2 values to be 5933.56 mg/g, 0.0193 1/mg, ($35.3E^{-03}$ – $771.0E^{-03}$) and (0.9945-0.9973) respectively. 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, physical adsorption, reversible and that the kaolin canister filters could be an excellent adsorbent for heavy metals removal (Jang, et al., 2010). The study demonstrated the potential of kaolin canister filter as a low-cost and sustainable adsorbent for the removal of heavy metals from water.

Keywords: *Kaolin Canister Filter, Klin, Heavy Metal, Mutagenic, Batch Adsorption, Monolayer Adsorption, Adsorption Capacities, Physical Adsorption, and Langmuir Isotherm Model.*

How to Cite: James Atta Dadson; David Kofi Essumang; Emmanuel Asare Ayim; Anthony Adjorlolo-Gasokpoh (2025). Assessment of Kaolin Canister Filters for Heavy Metal Removal from Contaminated Bore-Hole Water in Gold Mining Communities in Tarkwa-Nsuaem in the Western Region of Ghana. *International Journal of Innovative Science and Research Technology*, 10(5), 4644-4650. https://doi.org/10.38124/ijisrt/25may2108

I. INTRODUCTION

Clay minerals, particularly kaolin has been extensively considered for its adsorption properties. Kaolin, an abundant clay mineral is noted for its large surface area, and chemical stability makes it a suitable adsorbent for heavy metal removal (Jang, et al., 2010). Earlier researchers have shown kaolin, an efficient in removing heavy metals from contaminated water (Amrhar, et. al., 2015). Heavy metals are non-biodegradable, toxic at even low levels, and are associated with serious human health issues particularly in children and pregnant women (Kabata-Pendias, 2011; Bieranye, et.al, 2016). Clays are excellent adsorbent of neutral, anions and cations in water contaminates in water (Amrhar, et. al., 2015), can be used to contribute to improving the existing treatment methods. Clays store and cycle water

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may2108

from rainfall, filter toxic substances through sorption processes that result in surface and groundwater quality (Cai, et, al. 2014; Islem et al., 2011). Studies have shown that the adsorption capabilities of clays, particularly kaolin involve heavy metal ions bind to the surface clay through electrostatic forces, van der Walls forces or chemical bonding (Sposito, 2008). In addition, heavy metal ions exchange ions such as Al or Si on the kaolin surface, forms complexes with hydroxyl(-OH) or silanol(Si-OH) functional groups (Jiang, et al., 2010). The main reason for the high adsorption capacity of kaolin is its large surface areas ranging up to 800m^2/g, and the presence of numerous surface pores helps to precipitate heavy metal ions out of solution as insoluble compounds (Islem et al.,2011; Sposito,2008). Clean water is crucial for all forms organisms particularly, humans. In the gold mining communities in Tarkwa-Nsuaem Municipal, bore-hole water is used for domestic purposes and often contaminated with dangerous metals, which can cause serious health issues including brain, kidney damage, and cancer (Salem, et al., 2000; Sardar, et al., 2013). Since these metals do not metabolite, but build up in the body, it is important to find effective ways to remove them. Kaolin canister filter a safe, cheap, and abundant natural material has shown promise in treating contaminated water and protecting individuals' health **(**Jang, et al. 2010). The study explored the use of kaolin canister filter to remove heavy metals from borehole water in ten the gold mining communities in Tarkwa-Nsuaem Municipality. The water is often contaminated with toxic metals like lead, cadmium, and arsenic, posing serious health risks to children and pregnant women. Therefore, developing safe and effective methods for cleaning contaminated water is therefore crucial.

➢ *Quality Control*

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

II. METHODOLOGY

➢ *Sample Collection*

Bore-hole water samples were collected from ten gold mining communities in Tarkwa-Nsuaem Municipal, in western region of Ghana. 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 double deionized. The bottles were then dried on a ceramic bench. Thirty bore-hole samples were collected, with each sample collected in triplicate. The water was pumped out of the system to ensure depth. The samples were then acidified with concentrated nitric acid, labelled, sealed, and transported to the laboratory in an ice chest.

➢ *Development of Kaolin Canister Filter*

The raw kaolin was obtained from Bokazo, in the Nzema east district in the western region of Ghana. The kaolin was pounded into a fine powder using ceramic pestle and mortar. The powdered kaolin was soaked and washed repeatedly with double deionized water until all the leachable impurities had been removed, filtered, and then oven-dried at 110 °C for 12 hr to remove moisture. The dried powdered kaolin was sieved using a plastic sieve of pore size 10nm. Kaolin canister filter was made by weighing 53.5 g of kaolin and mixed with 5.2 g of rice husk and 8.7 g of starch. Mixture was placed on a plastic board and was mixed manually. To ensure a thorough mix, the mixing process was done for a long time, at least for not less done 30 min. The water of about 20% (15.0 cm^3) by weight of the mixture was slowly added continuously to obtain a homogenous colloidal slurry of increased plasticity (Cai et al., 2014). The homogenous colloidal slurry was wedged by folding over upon itself repeatedly until a smooth knead was formed, and compacted into a canister shape. The wet canister was air-dried for about 3 days at room temperature, and then sun-dried for an additional 2 hr before firing in the brick klin, to a temperature of 450 ºC for 2 hr. The hot kaolin canister filter was allowed to cool to room temperature. The durability of the kaolin canister filter was affirmed by its sonorous sound produced. The flow rate for the canister was determined, and if any crack detected was discarded.

➢ *Reagents / Chemicals*

Analar 36 % hydrochloric acid, and Analar concentrated nitric acid.

➢ *Materials*

Kaolin from Bokazo; starch from Beposo-Nkran and rice husk from Ohiamadwen in Daboase district, all in the western region of Ghana.

➢ *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 (11.5 M HCl) was added to 50 mL (69.0 to 70.5) % Analar nitric acid (15.5 M HNO_3).

➢ *Physico-chemical Parameters of Bore-Hole, Water Samples*

The results obtained for the analysis of the physico-chemical parameters of the bore-hole water samples such as the temperature, pH and the conductivity of all samples are presented (Table 1).

Table 1 Mean Physico-Chemical Parameters Bore-Hole Water Before and a Treatments

Sample Code	Age /yr	RI/(m)	pH before	pH after	Temp. before/ºC	Temp. after/ºC	conductivity /(µs/cm)
BH1	12	2.46	7.01	6.90	28.60	28.88	0 .081
BH2	5	1.60	6.68	6.91	29.90	28.85	0.040
BH3	6	3.71	6.84	6.82	30.00	28.82	0.043
BH4	3	4.79	6.94	6.92	30.20	28.89	0.039

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may2108

BH5	7	4.80	7.28	6.99	30.20	28.84	0.040
BH6	9	4.80	6.86	6.80	30.30	28.91	0.038
BH7	7	4.80	7.07	7.20	30.20	28.77	0.038
BH8	30	2.40	6.99	7.10	30.10	28.89	0.040
BH9	12	3.20	6.83	6.80	30.20	28.66	0.041
BH10	88	2.40	6.92	6.98	30.10	28.83	0.038

Source: Field and laboratory work (2025)
Keys: Radius of Influence (RI), Bore-hole (BH)

The pH of bore-hole water samples ranged from 6.68 to 7.28, with an average of 6.98. The pH limits set by the World Health Organization (WHO) fall within the 6.5 to 8.5 range for drinking and domestic purposes. Temperature also affected the solubility of gases and the rate of chemical reactions in water. The electrical conductivity (EC) values of borehole water samples from various communities ranged from 28.72 to 30.25 ^{o}C. The conductivity values of the water were 0.068 µs/cm, 0.039 µs/cm, 0.038 µs/cm, 0.041 µs/cm, 0.040 µs/cm, 0.042 µs/cm, 0.040 µs/cm, 0.038 µs/cm, and 0.041 µs/cm, respectively. The low conductivities recorded in all borehole waters ranged from 0.038 to 0.068 µs/cm, indicating very few ions present in the samples, compared to the WHO acceptable limit of 700 µs/cm at 25 ^{o}C. This suggests that the bore-hole water samples in communities are suitable for drinking and domestic consumption.

➢ *Digestion of Bore-hole Water Samples for Arsenic, Lead and Cadmium*

Borehole 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 doubly deionized water, and analysed for arsenic, lead and cadmium using an atomic absorption spectrometer.

➢ *Filtration of Bore-hole Water Samples through the Kaolin Canister Filter*

Hundred milliliters for each bore-hole water samples were measured filtered through the kaolin canister filter and analyzed using atomic adsorption spectroscopy for the equilibrium levels of lead, cadmium, and arsenic present, and each metal ions adsorbed were determine.

➢ *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 kaolin canister filter.

III. DISCUSSION

Table 2 Mean Levels and Standard Deviations of Lead, Cadmium, and Arsenic in Untreated Bore-hole Water Samples (mg/ L)

Sample code	Pb (mean ± SD) xE^{-02}	Cd (mean ± SD) xE^{-02}	As (mean ± SD) xE^{-02}
BH1	1081.4 ± 37.0	38.4 ± 5.9	228.7 ± 70.8
BH2	1273.8 ± 88.9	64.9 ± 5.8	230.1 ± 15.6
BH3	1354. 9 ± 89.1	44.7 ± 5.2	199.9 ± 59.4
BH4	1572.5 ± 64.3	45.6 ± 5.4	270.7 ± 33.1
BH5	1644.1 ± 90.0	39.0 ± 2.2	287.4 ± 29.3
BH6	112.4 ± 121.7	29.7 ± 8.5	287.9 ± 40.3
BH7	353.0 ± 512.0	33.9 ± 21.2	260.8 ± 83.1
BH8	150.3 ± 98.0	19.2 ± 0.3	258.6 ± 6.5
BH9	905.0 ± 1250.0	33.1 ± 2.0	244.7 ± 47.5
BH10	36.8 ± 106.1	35.2 ± 5.9	229.4 ± 27.6

Table 2 shows that the mean levels and standard deviations (SD) of lead (Pb), cadmium (Cd), and arsenic (As) in untreated bore-hole water vary across various localities. Bore-hole 5 had the highest lead (Pb) contents (1644.1 ± 90.0 mg/L), suggesting serious pollution. Bore-hole 10 had the lowest levels (36.8 ± 106.1 mg/L). Cadmium (Cd) values were greatest in bore-hole 2 (64.9 ± 5.8 mg/L) and lowest in bore-hole 8, 19.2 ± 0.3 mg/L. Arsenic (As) levels were very stable, ranging from 199.9 ± 59.4 mg/L (bore-hole 3) to 287.9 ± 40.3 mg/L (bore-hole 6). The study showed that filtering the bore-hole water samples through kaolin canister filter significantly reduced lead and cadmium levels in some bore-holes, while arsenic removal was less consistent. Variations in results across samples were likely due to treatment conditions or environmental factors. Overall, statistical analysis confirmed kaolin canister filter's effectiveness in reducing heavy metal pollution in groundwater.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may2108

Table 3 Paired Sample T-Test on Bore-hole Water Samples for the Lead, Cadmium and Arsenic after Treatment with Kaolin Canister Filter

Heavy Metal	**Pd**		**Cd**		**As**	
Sample code	**Test Statistic**	**P-value**	**Test Statistic**	**P-value**	**Test Statistic**	P-value
BH1	41.34	0.015	9.28	0.068	4.57	0.137
BH2	20.25	0.031	11.13	0.057	20.92	0.030
BH3	21.51	0.030	12.09	0.053	4.76	0.132
BH4	34.55	0.018	11.85	0.054	8.17	0.078
BH5	25.84	0.025	25.14	0.025	13.86	0.046
BH6	1.31	0.416	4.97	0.126	10.11	0.063
BH7	0.98	0.508	2.26	0.265	4.44	0.141
BH8	2.17	0.275	103.54	0.006	55.91	0.011
BH9	1.02	0.492	23.20	0.027	7.29	0.087
BH10	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 Bore-Hole Water Samples

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

- *The Percentage Removal Efficiency*

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

Where,

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

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 bore-hole 4 and 10 respectively. Likewise, bore-hole 2 showed the highest cadmium removal (87.5%) whiles bore-hole 8 showed the least cadmium removal (53.2%). Equally, the highest arsenic (As) removal was in bore-hole 5 (67.8%) and the lowest was bore-hole 3 (43.5%). The table supports earlier findings that kaolin canister filter removes lead and cadmium more effectively than arsenic, with variations likely due to adsorption kinetics, water chemistry, and metal-binding interactions.

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

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

Fourier Transform Infrared Spectroscopy (FTIR) of the kaolin was done to provide information on its chemical composition and ascertain the molecular structure. In Tables 6 and 7, peaks 1 and 2 indicate the hydroxyl stretching region within the range 3600 to 3700 cm^{-1} due to -OH and Si-OH stretching vibrations and interactions between heavy metal ions and silanol groups. Si-O stretching region within 1000 to 1200 cm^{-1} observed at peaks 3, 4, 5, and 6 were due to Si-O stretching vibrations and indicate interactions between heavy metal ions and silanol groups.

Table 6 General FTIR Assignments in Kaolin before Filtration

Peak	**X(cm^{-1}) (cm^{-1})**	**Y(%T) (%T)**	**Peak**	**X(cm^{-1}) (cm^{-1})**	**Y(%T) (%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

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may2108

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 13 in table 7 could be attributed to the formation of complexes or precipitation between heavy metal ions and the kaolin, and Si-O-Al bending vibrations occurred in the region 400 to 500 cm^{-1}(Mozgawa, et. al., 2011).

Table 7 General FTIR Assignments in Kaolin after Filtration

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

➢ *Batch Adsorption Experiments*

Batch adsorption experiments were conducted to assess the kaolin canister filter's capacity to adsorb lead, cadmium, and arsenic at room temperature, simulating environmentally relevant conditions, with a constant volume of borehole water. The adsorption capacity of kaolin canister filter was calculated using the following equation:

$$q = (C_0 - Ce) \times V / m \quad \ldots(2)$$

Where q is the adsorption capacity, C_0 is the initial metal level, Ce is the equilibrium metal level, V is the volume of the solution, and m is the mass of kaolin canister filter. Adsorption capacity measures how much metal was removed per unit of adsorbent. From Table 8, lead (Pb) adsorption was highest in bore-hole 5 (32.88 mg/g), followed by bore-hole 4 (31.45 mg/g), showing strong interactive binding forces between the heavy metals ions on the surface of the kaolin canister filter and hence high adsorption. Bore-hole 10 had the lowest (0.734 mg/g), suggesting poor Pb adsorption. Meanwhile, cadmium (Cd) adsorption was highest in bore-hole 2 (1.4218 mg/g), showing efficient removal, while bore-hole 8 had the lowest (0.3832 mg/g). In the same way, arsenic (As) adsorption showed relatively consistent values, with bore-hole 5 (5.746 mg/g) and bore-hole 6 (5.758 mg/g) performing best.

Table 8 Adsorption Capacity (q) for the Lead, Cadmium and Arsenic in mg/g

Sample code	Pb	Cd	As
BH 1	21.628	0.767	4.576
BH 2	25.476	1.422	4.602
BH 3	27.098	0.894	3.998
BH 4	31.450	0.912	5.414
BH 5	32.880	0.779	5.746
BH 6	2.250	0.593	5.758
BH 7	7.080	0.678	5.216
BH 8	3.006	0.383	5.172
BH 9	18.100	0.661	4.896
BH 10	0.734	0.703	4.590

These findings indicate that while kaolin canister filter effectively adsorbed heavy metals, its performance varied depending on metal type and borehole conditions. Further optimization may be required to improve adsorption in bore-holes with lower efficiency.

➢ *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 to determine the maximum adsorption capacity of the kaolin canister filter. The Langmuir isotherm is represented by the linear form:

$$q_e = (1/q_{max}K_L) + (Ce/q_{max}) \quad \ldots(3)$$

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:

$$R_L = 1/ (1+K_LC_e) \quad \ldots(4)$$

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 kaolin canister filter at equilibrium (mg /g); q_{max} (mg/g) and K_L(1/mg) are Langmuir constant related to be maximum adsorption

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may2108

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

$$q_{max} = 1 / \text{slope} \quad \text{and} \quad K_L = \text{slope/intercept}……………….. (5)$$

Table 9 Linear Langmuir Isotherm Constants for Adsorption of Pb, Cd, and As on Kaolin Canister Filter at room temperature (30 ºC).

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 kaolin canister filter is an effective, low-cost, and sustainable adsorbent for removing heavy metals specifically lead, cadmium, and arsenic from bore-hole water. Its high adsorption capacity and alignment with the Langmuir isotherm model indicate strong metal affinity and monolayer adsorption. In table 9and fig.9a & 9b, Langmuir isotherm was used to analyze adsorption data on kaolin canister filter, with values of qmax 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 kaolin canister filter. 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.

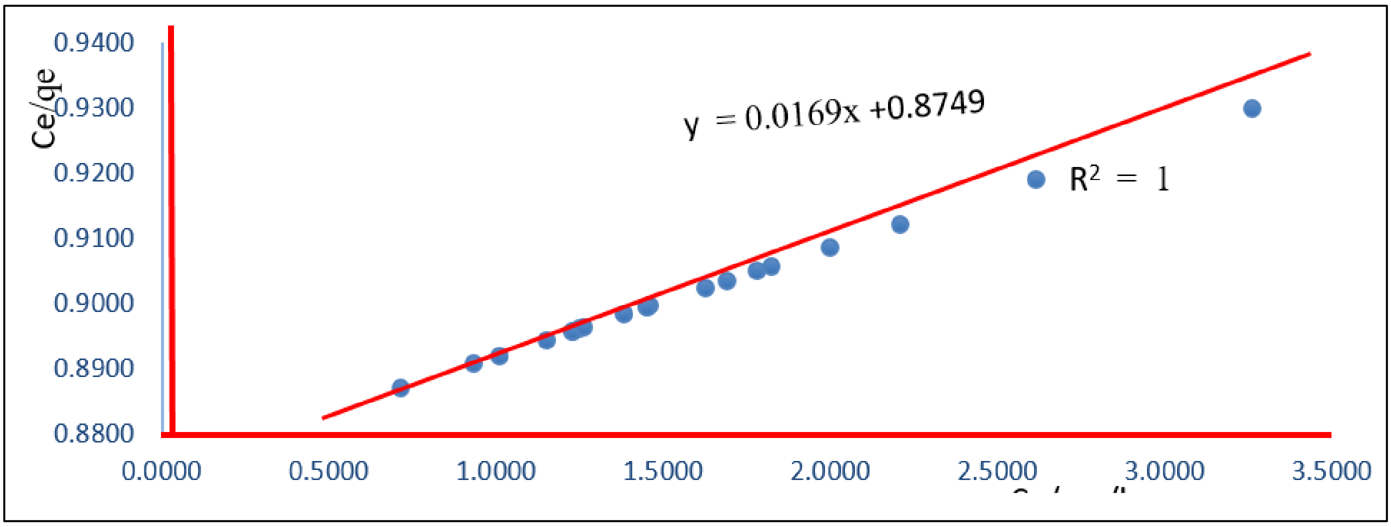

Fig 1a Langmuir Adsorption Isotherm for Lead (II) ions

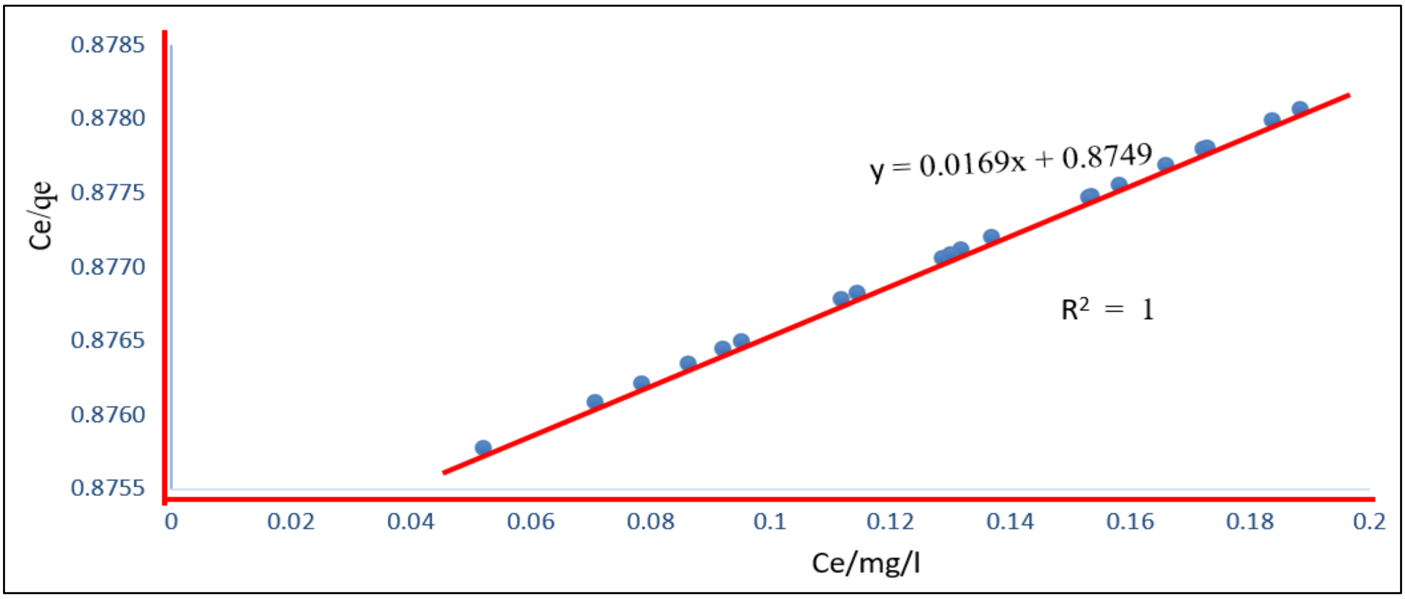

Fig 1b Langmuir Adsorption Isotherm for Arsenic and Cadmium Ions

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25may2108

The Langmuir isotherm model effectively describes the adsorption of lead, cadmium, and arsenic, with lead showing the best fit. The kaolin canister filter is a viable, low-cost and sustainable adsorbent for heavy metal remediation from bore hole water, indicating monolayer adsorption. Using the kaolin canister filter source is also environmentally friendly. Further research is needed to optimize the process and assess the kaolin canister filter's effectiveness against other metals (Sposito, 2008).

IV. CONCLUSION

In conclusion, this study has demonstrated the effectiveness of the kaolin canister filter as an adsorbent for the remediation of heavy metals from bore-hole water in all the 10 communities. The results suggest that the kaolin canister filter can be used as a low-cost and sustainable adsorbent for the removal of heavy metals from bore-hole 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, physical adsorption and reversible. The results show the reproducible nature of the heavy metal ions removal process using kaolin canister filter as adsorbent (Jang, et al., 2010). Therefore, it is recommended that the kaolin canister filter be used as an adsorbent for the removal of heavy metals from polluted water.

REFERENCES

[1]. Amrhar, O., Nassali, H., & Elyoubi, M. S. (2015). Adsorption of a cationic dye, Methylene Blue, onto Moroccan Illicitic Clay. Journal of Mater. Environmental Science 6(11), 3054-3065.

[2]. Bieranye, M. S., Fosu, S. A., Sebiawu, G. E., Jackson, N., & Karikari, T. (2016). Assessment of the quality of groundwater for drinking purposes in the Upper West and Northern regions of Ghana. Springer Plus, 5(1), 1-15.

[3]. Cai, J., Shen, B., Li, Z., Chen, J., & He, C. (2014). Removal of elemental mercury by clays impregnated with KI and KBr. Chem.Eng.J., 241(1), 19-27.

[4]. Islem, C., Mounir, M., & Fakher, J. (2011). Use Of Clay To Remove Heavy Metals From Jebel Chakir Landfill Leachate Journal of Applied Sciences in Environmental Sanitation 6(2), 143-148.

[5]. Jiang, M. Q, et al. (2010). Adsorption of Pb(II), Cd (II), Ni (II), and Cu(II),onto natural kaolinite clay. desalination, 252(1-3), Pp.-39.

[6]. Kabata-Pendias, A. (2011). Trace elements in soils and plants CRC Press, Boca Raton.FL, 1(1), 5-33.

[7]. Salem, H. M., Eweida, A., & Azza, F. (2000). Heavy metals in drinking water and their environmental impact on human health, Center for Environmental Hazards Mitigation. 542- 556.

[8]. Sardar, K., Ali, S., Hameed, S., Afzal, S., Fatima, S., Shakoor, M. B., et al. (2013). Heavy metals contamination and what are the impacts on living organisms. Greener Journal of Environmental Management and Public Safety, 4(1), 172-179.

[9]. Sastre, J., Sahuquillo, A., Vidal, M., & Rauret, G. (2002). Determination of Cd, Cu, Pb, and Zn in environmental samples: microwave-assisted total digestion versus aqua regia and nitric acid extraction Anal. Chim. Acta, 462(1), 59-72.

[10]. Sposito, G., (2008). The chemistry of soils.(2nd ed.). Oxford University Press.

[11]. WHO. (2008). Guidelines for Drinking Water Quality, Incorporating the first and Second Addenda, WHO, Geneva. (2008):SBN 978 92 4 154761 1, 1(3).