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ASSESSING THE EFFICIENCY OF CEMENT KILN DUST FOR HEAVY METALS REMOVAL FROM SIMULATED POLLUTED WATER

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Abstract: Heavy metal contamination in the environment is unavoidable issue. Heavy metals directly influence human being lives since they concentrate in the food cycle, even in low amounts. Some heavy metals pollute the water resources, in dangerous limits for human life. The current study suggested the cement kiln dust (CKD) as a low-cost and effective adsorbent to remove heavy metals ions from solutions. Therefore, the study investigated the copper, lead and cadmium removal from aqueous solution by cement kiln dust (CKD) as industrial by-product. The laboratory experiment included two factors. The first factor consists of three different diameter particles i.e., 50,100, and 150 μm. While the second factor included three concentrations of each of copper, cadmium, and lead ions namely 50,100, and 200 mg. L^{-1}. The cement kiln dust was identified by X-ray diffraction analysis (XRD) to determine its chemical characteristics. Also, pH and EC were measured for the cement kiln dust solution. Before the study starting, the initial concentration of the copper, cadmium, and lead were measured in the CKD power. The study was conducted at temperature of 25 C^o. The removal efficiency was calculated at two different time of shaking, namely 1 and 2 hours. The obtained results indicated that CKD can be used as a low cost and effective sorbent for copper, cadmium, and lead ions from polluted water. Moreover, the results show that the high pH and high surface area for the cement kiln dust have the main effect of making the CKD efficient adsorbent material.

Keywords: Sustainability, Waste material, Lead ions, Cement kiln dust, Adsorption.

1. Introduction

Over the past years, the rapid development of industrialization and expansion of the agricultural areas has significantly increased the production of different kinds of pollutants. Heavy metals pollution is an unavoidable issue that has devastating impacts on humanity life. Due to the critical role of water to living organisms and it's a crucial role as driving force behind economic growth. Nowadays, water pollution is considered as one of the most intrinsic global concerns facing both developed and developing countries, affecting extensively environmental health that directly linked to people life all over the world [1]. Currently, the researchers in the field of water conservation are principally focused on the quantity of water. However, the water quality that conveyed to the consumers during the water deficiency could threaten the human life if the safety measures were not taken into account [2]. Continuous population growth, put the freshwater resources under pressure as a result of the increased demand for food [3]. Since the agriculture sector is the largest consumer of water which consume up to 70%. Therefore, remediation of polluted water will provide the agricultural with alternative source of water to be used instead of freshwater to achieve the sustainability in this resource. From many source, a large number of heavy metals such as Fe, Pb, Cd, Cr, Ni, Zn, Hg, Mn, and Cu have entered the environment [4]. This has led to serious degradation of the ecological environment owing to heavy metals direct influence people's lives since they concentrate in the food chain, even in small quantity [5].

Recent studies pointed that the heavy metals lead to number of disorders, including prostate cancer, pancreatic cancer, and lung cancer [5]. Several techniques employed for removing heavy metal from the aquatic ecosystems have been evolved during recent decades [6]. Generally, Adsorption, is a simple method with good efficiency compared to other methods [7]. Various adsorbents types, for physical and chemical adsorption of heavy metal have been investigated, namely clay, inorganic polymers, zeolites and activated carbon [4]. Cement kiln dust (CKD) is by-product of cement production.

The Environmental Protection Agency (EPA) has classified cement kiln dust as a "special waste" and has granted it a temporary exemption from federal hazardous waste regulations outlined in Subtitle C of the Resource Conservation and Recovery Act (RCRA) [8]. Nowadays, recycling of industrial by-product has been widely used in alleviation of the environmental issues in sustainable and economic strategies by solving an environmental problem [9]. Due to the gap in the previous literature about adsorption efficiency based on the diameters particles of cement kiln dust. Therefore, this study was conducted to investigate the adsorption efficiency of three different diameters particles of Cement kiln dust.

2. Materials and Methods

The cement kiln dust was collected from Lafarge cement plant, Sulaymaniyah, north of Iraq, with particle size distribution illustrated in Table 1. Based on its composition, the cement kiln dust is classified as a heterogeneous one,[10]. Chemical composition of this material is summarized in Table 2. A two factorial laboratory experiment for the removal of lead, cadmium and copper from simulated polluted water were conducted using the by-product cement kiln dust (CKD) as an adsorbent. To simulate the Cu, Cd, and pb contamination in the water, 1000 mg. L^{-1} of each of $PbCL_2$, $CdCl_2$, and $CuSO_4$ $5H_2O$ was prepared as standard solution. The first factor included three concentrations prepared from each standard solution, namely 50, 100, and 200 mg. L^{-1}. While the second factor consist of the diameter of cement kiln dust particles, namely. 50, 100, and 125 μm.

The cement kiln dust characteristics was tested using XRD test which showed that the CKD have a crystalline phase as illustrated in Table 1. This test was carried out in the laboratories of Ministry of Sciences and Technology/ Nano Materials Research Department laboratory, Iraq. The pH and Electrical conductivity (EC) for the cement kiln dust under study were determined from the 1:1 soil-water suspensions by using a pH (WTW,inoLab 720, Germany) and EC meter (Benchtop EC/TDS/Salinity Meter With ATC- HI2300) respectively.

Removal efficiency of pollutants: The obtained data was examined to determine the performance of the system. The efficiency of treatment was determined according to the removal percentage of each parameter using the following formula:

Removal efficiency = $\frac{p_i - p_f}{p_i} * 100$

where Pi and Pf are the initial and final pollutant concentration [11].

Table 1. Some chemical characteristics of the considered cement kiln dust.

Parameters	Values	Units
pH	11.92	
EC	15	$dS.m^{-1}$
Cadmium (Cd)	< 0.00020	$mg.\ L^{-1}$
Lead (pb)	0.038	$mg.\ L^{-1}$
Copper (Cu)	0.00412	$mg.\ L^{-1}$
Al_2O_3	4.19	%
SiO_2	18.9	%
CaO	58.67	%
K2O	2.37	%
Na_2O	1.1	%
CL	0.39	%
Fe_2O_3	3.25	%
MgO	1.87	%
SO_3	4.32	%

3. Results and Discussion

Efficiency of cement kiln dust in removing copper from polluted water: The cement kiln dust efficiency in removing the copper element from the simulate polluted water is presented in Table2. According to current study results, the removing efficiency had inversely proportional to the particle diameter and positively with shaking time. In this context, the smallest cement kiln dust (50 μm) particles show the best removal amount up to 49.99 mg. L^{-1} which is equivalent to 99.98 % of removal compare to the initial concentration (50 mg. L^{-1}) under effect of 2 hours of shaking, followed by 49.98 mg. L^{-1} for the same particle diameter and 1 hour of shaking. The removal efficiency of cement kiln dust can be attributed to the high surface area of its fine particles. In addition to, the high pH of cement kiln dust aqueous solution which is closed to 12 Table 1. Plays a crucial role in increasing Cu removal polluted water. The current study findings accord with [12] who reported that the pH has significant role in heavy metals removal and suggested that the removal efficiency increased with pH increases.

Table 2. Removal amount and percentage of copper removal efficiency

Initial concentration	**Diameter**	**Shaking time**	**Final concentration**	**Removal amount**	**Percentage of removal**
(mg. L^{-1})	(μm)	(hour)	(mg. L^{-1})	(mg. L^{-1})	(%)
50	50	1	0.02	49.98	99.96
		2	0.01	49.99	99.98
	100	1	0.05	49.95	99.90
		2	0.03	49.97	99.94
	150	1	0.08	49.92	99.84
		2	0.06	49.94	99.88
100	50	1	1.15	98.85	98.85
		2	0.90	99.10	99.10
	100	1	1.40	98.60	98.60
		2	1.35	98.65	98.65
	150	1	1.90	98.10	98.10
		2	1.85	98.15	98.15
200	50	1	3.50	196.50	98.25

		2	3.46	196.54	98.27
	100	1	4.93	195.07	97.53
		2	4.88	195.12	97.56
	150	1	5.48	194.52	97.26
		2	5.45	194.55	97.27

The cement kiln dust removal efficiency slightly differs under effect of increasing the copper concentration. This finding refers to high efficiency of cement kiln dust in removing copper from contaminated water under relatively high concertation. For instance, the 50 μm diameter particles keep achieving the highest removal amount by giving 99.10 and 196.54 mg. L^{-1} under effect of concentration 100 and 200 mg. L^{-1} which is equivalent to 99.10 and 98.27 % respectively, even though the diameter of 100 and 150 μm did not significantly differ from the diameter 50 μm in removing the copper from the contaminated water. The high removal efficiency of different cement kiln dust diameter particles could attribute to high pH solutions, calcium carbonate and calcium oxide contents, high surface area, oxides content, and reducing metal solubility owed to enhanced sorption and/or precipitation [13].

Efficiency of cement kiln dust in removing cadmium from polluted water: The cement kiln dust efficiency in removing the cadmium element from the polluted water is presented in Table 3. Same trend of copper removing was observed in cadmium removing in terms of particles diameter and time shaking. However, the cadmium removal amount and percentage of removal were less compare to copper removal efficiency. In this regards, the small size particles of cement kiln dust (50 μm) show the best removing amount reached 49.85 mg. L^{-1} compare to the initial concentration which is 50 mg. L^{-1} under effect of 2 hours of shaking. In general, over all treatments the 2 hours shaking time superior to 1 hour shaking time. The reduction of cadmium removal amount compared to copper probably due to the solution temperature as mentioned by previous studies, where the cadmium removal increased with solution temperature increasing [14]. Thus, under current study the solution temperature was $25C^o$ hence the cadmium removal was slightly reduced compared to copper because cadmium adsorption more dependent on solution temperature [14].

In addition to, under high pH condition the competitiveness of Cd(II) for binding site increases which could contribute to slightly adsorption reduction [14]. Same pattern was observed at 100 and 150 μm diameter particles, where the highest removal amount was 49.73 and 49.25 mg. L^{-1} for 100 and 150 μm diameter particles respectively under effect of 2 hours shaking and 50 μm diameter particle. Increasing the concentration from 50 mg. L^{-1} to 100 and 200 mg. L^{-1} slightly effects on cadmium removal under effect of 100 and 150μm diameter particles. For the concentration 100 mg. l^{-1} and 100 μm diameter particle the highest removal amount reached 97.82 for two hour shaking while the highest removal amount for 100 mg. L^{-1} and 150 μm diameter particle reached 96 mg. L^{-1}. In general, the cadmium removal amount decreased with increasing cadmium concentration. The reduction could result from cement kiln dust saturation as a result to concentration increasing. In spite of this, according to current study results the cement kiln dust still efficient in removing heavy metals from polluted.

Table 3. Removal amount and percentage of cadmium removal efficiency

Initial concentration	**Diameter**	**Shaking time**	**final concentration**	**Removal amount**	**Percentage of removal**
(mg. L^{-1})	(μm)	(hour)	(mg. L^{-1})	(mg. L^{-1})	(%)
50	50	1	0.23	49.77	99.54
		2	0.15	49.85	99.70
	100	1	0.35	49.65	99.30
		2	0.27	49.73	99.46

	150	1	0.88	49.12	98.24
		2	0.75	49.25	98.50
100	50	1	2.26	97.74	97.74
		2	2.18	97.82	97.82
	100	1	3.60	96.20	96.40
		2	3.80	96.40	96.20
	150	1	4.10	95.90	95.90
		2	4.00	96.00	96.00
200	50	1	5.70	194.30	97.15
		2	5.10	194.90	97.45
	100	1	7.90	192.10	96.05
		2	7.50	192.50	96.25
	150	1	8.60	191.40	95.70
		2	8.45	191.55	95.77

Efficiency of cement kiln dust in removing lead from polluted water: The lead removing efficiency by cement kiln dust from the simulate polluted water is presented in Table 4. The observed results show that the removing efficiency effected by the particles diameter, where the removing amount increased with decreasing the particles diameter under effect of 2 hours shaking time. In this context, the highest recorded removing amount was 48.50 mg. L^{-1} with removing percentage of removal up to 97 % under effect of 2 hours of shaking time and 50 μm diameter particles. For lead removing amount by CKD, the obtained results show it depends on shaking time and solution temperature that might reflect the retention mechanisms [12] Same pattern was observed at 100 and 150 μm diameter particles, where the highest removal amount was 47.70 and 46.16 mg. L^{-1} for 100 and 150 μm diameter particles respectively under effect of 2 hors shaking and 50 μm diameter particle. Increasing the concentration from 50 mg. l^{-1} to 100 and 200 mg. L^{-1} notably effects on lead removal under effect of 100 and 150 μm diameter particles compared to copper and cadmium. Regarding the concentration of 100 mg. L^{-1} and 100 μm diameter particle, the highest removal amount reached 93.78 for two hour shaking while the highest removal amount for 100 mg. L^{-1} and 150 μm diameter particle reached 91.6 mg. L^{-1}. In general, the lead removal amount was less compared to copper and cadmium overall treatments. Notwithstanding, according to current study results the cement kiln dust still efficient in removing copper, lead and cadmium from polluted water. The high efficiency of CKD can attribute to increasing pH solutions, high content of oxides, silica, aluminum and iron oxides, high surface area, and reducing metal solubility owed to enhanced sorption and/or precipitation [15].

Table 4. Removal amount and percentage of lead removal efficiency.

Initial concentration	**Diameter**	**Shaking time**	**final concentration**	**Removal amount**	**Percentage of removal**
(mg. L^{-1})	(μm)	(hour)	(mg. L^{-1})	(mg. L^{-1})	(%)
50	50	1	1.80	48.20	96.40
		2	1.50	48.50	97.00
	100	1	2.50	47.50	95.00
		2	2.30	47.70	95.40
	150	1	3.90	46.10	92.20
		2	3.84	46.16	92.32
100	50	1	4.80	95.20	95.20
		2	4.60	95.40	95.40

	100	1	7.30	92.70	92.70
		2	6.22	93.78	93.78
	150	1	8.66	91.34	91.34
		2	8.40	91.60	91.60
200	50	1	11.82	188.18	94.09
		2	10.90	189.10	94.55
	100	1	14.46	185.54	92.77
		2	12.50	187.50	93.75
	150	1	17.97	182.03	91.01
		2	16.90	183.10	91.55

4.Conclusion

Overall treatments of study the results pointed out that the potential of CKD for removing copper, lead and cadmium from Simulated Polluted Water. The obtained results show that the 2 hours shaking superior to 1 hour overall treatments under study in removing the heavy metals under study. Also, the evidence show that the cement kiln dust pH, plays a significant role in increasing the efficiency of the cement kiln dust in removing copper, lead and cadmium from simulated polluted water. Moreover, the high surface area of the cement kiln dust exhibits considerable role in increasing its efficiency to remove the considered elements. The removal efficiency of the cement kiln dust in removing the considered heavy metals takes the order of copper > cadmium>lead. In general, the current study results show the possibility exploiting the cement kiln dust as sustainable adsorbent material.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

S. S. Mansoor, M. N. Al-Falahi; methodology, writing—original draft preparation, J. Sh. Al-Esawi; writing—review and editing, R. Baeelashaki; paraphrasing. All authors have read and agreed to the published version of the manuscript.

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The study was conducted in accordance with the protocol authorized by the University of Anbar, Ethics Committee, Iraq in cooperation with The Islamic Republic of Iran, From a commercial farm, fertile eggs from Ross (308) strain broiler breeder hens were obtained.

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The authors declare no conflict of interest.

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5. References

[1] S. M. Bassem, "Water pollution and aquatic biodiversity," *Biodiversity International Journal Review*, vol. 4, no. 1, 2020.

[2] M. Salehi, "Global water shortage and potable water safety; Today's concern and tomorrow's crisis," *Environ Int*, vol. 158, 2022, doi: 10.1016/j.envint.2021.106936.

[3] E. W. Sanderson, J. Walston, and J. G. Robinson, "From Bottleneck to Breakthrough: Urbanization and the Future of Biodiversity Conservation," *BioScience*, vol. 68, no. 6. 2018. doi: 10.1093/biosci/biy039.

[4] K. Lubis, E. Frida, K. Sebayang, P. Sinuhaji, S. Humaidi, and A. Fudholi, "The development of a novel FM nanoadsorbent for heavy metal remediation in polluted water," *S Afr J Chem Eng*, vol. 39, 2022, doi: 10.1016/j.sajce.2021.11.006.

[5] L. Joseph *et al.*, "Removal of contaminants of emerging concern by metal-organic framework nanoadsorbents: A review," *Chemical Engineering Journal*, vol. 369. 2019. doi: 10.1016/j.cej.2019.03.173.

[6] E. N. Zare, A. Motahari, and M. Sillanpää, "Nanoadsorbents based on conducting polymer nanocomposites with main focus on polyaniline and its derivatives for removal of heavy metal ions/dyes: A review," *Environmental Research*, vol. 162. 2018. doi: 10.1016/j.envres.2017.12.025.

[7] V. Kumar, D. Katyal, and S. S. Nayak, "Removal of heavy metals and radionuclides from water using nanomaterials: current scenario and future prospects," *Environmental Science and Pollution Research*, vol. 27, no. 33. 2020. doi: 10.1007/s11356-020-10348-4.

[8] S. S. Mansoor, K. B. Najim, and A. T. Mohammad, "Investigating the use of cement kiln dust (CKD) in producing alkali activated concrete," in *Proceedings - International Conference on Developments in eSystems Engineering, DeSE*, 2019. doi: 10.1109/DeSE.2019.00027.

[9] M. Seo, S. Y. Lee, C. Lee, and S. S. Cho, "Recycling of cement kiln dust as a raw material for cement," *Environments - MDPI*, vol. 6, no. 10, 2019, doi: 10.3390/environments6100113.

[10] S. Abd El-Aleem, M. A. Abd-El-Aziz, M. Heikal, and H. El Didamony, "Effect of cement kiln dust substitution on chemical and physical properties and compressive strength of portland and slag cements," *Arab J Sci Eng*, vol. 30, no. 2 B, 2005.

[11] A. Fardel, P. E. Peyneau, B. Béchet, A. Lakel, and F. Rodriguez, "Analysis of swale factors implicated in pollutant removal efficiency using a swale database," *Environmental Science and Pollution Research*, vol. 26, no. 2, 2019, doi: 10.1007/s11356-018-3522-9.

[12] "Investigation of Copper Removal from Aqueous Solution by Cement Kiln Dust as Industrial By-Product," *Alexandria Science Exchange Journal: An International Quarterly Journal of Science Agricultural Environments*, vol. 38, no. January-March, 2017, doi: 10.21608/asejaiqjsae.2017.2455.

[13] M. El Zayat, S. Elagroudy, and S. El Haggar, "Equilibrium analysis for heavy metal cation removal using cement kiln dust," *Water Science and Technology*, vol. 70, no. 6, 2014, doi: 10.2166/wst.2014.325.

[14] Z. Fan *et al.*, "Removal behavior and mechanisms of Cd(II) by a novel MnS loaded functional biochar: Influence of oxygenation," *J Clean Prod*, vol. 256, 2020, doi: 10.1016/j.jclepro.2020.120672.

[15] A. Pigaga, R. Juškenas, D. Virbalyte, M. G. Klimantavičiute, and V. Pakštas, "The use of cement kiln dust for the removal of heavy metal ions from aqueous solutions," *Transactions of the Institute of Metal Finishing*, vol. 83, no. 4, 2005, doi: 10.1179/002029605X61685.