Removal of Lead from Water by Sorption on Kaolinite Clay

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ABSTRACT

This work demonstrates a description, experimental results and a design of a water treatment apparatus. The apparatus was manufactured to remove the lead metal from contaminated water by continuous pumping principle. This method depends on adsorption of lead ions by Iraqi clay metals surface as kaolinite. In this work counted amounts of clay metal were saved in several cloth bags to guarantee a wide use of clay and consequently a larger surface area. The bags were put inside a vertical container with quantities of glass small pipe pieces to increase the volume and the surface area. This container was placed completely inside another container. The contaminated water passed throw a pipe to the internal container which contains the clay metal from down direction to upper direction of the container, to fill it and flood to the outer container which has an exit pass of the pure water. The lead contaminated water was taken (10 ppm) from a storage tank through a pump with flow meter to inter the purifying container . For testing purposes the outlet purified water was analyzed by atomic absorption device. The experiments indicated that 5 grams of the clay can remove 100 mg of lead from 10 liter of water by a flow rate of 0.05 liter/min.

Keywords: kaolinite clay, lead, adsorption, contaminated water, apparatus design.

Introduction

In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by heavy metals. Also, human exposure has risen dramatically as a result of an exponential increase of their use in several industrial, agricultural, domestic and technological applications. Reported sources of heavy metals in the environment include geogenic, industrial, agricultural, pharmaceutical, domestic effluents, and atmospheric sources[1].

Food may be polluted by lead because of soul pollution and from using insect pesticides which contain lead. Exposure to lead metal causes kidneys failure, severe nervous system collapse and more effect on heart and blood vessels. The lead concentration in the blood increases for people who work in crowded traffic places when the gasoline containing lead is still used. New studies showed that cables, wires and plastic industry are considered as the largest users of lead compounds.Many techniques were used to remove lead from liquid media membrane and adsorption on sugar cane [2]. For these reasons, it's important to remove lead from water and other environmental sources. Miretzky[3] used dead large plant leaves to remove heavy metal ions as cadmium, nickel, copper, zinc and lead from water, lead has the most removable efficiency from solutions. Barbooti [4] and others could obtain the highest efficiency to remove heavy metals more than 99 % by precipitating magnetic ion by treating drained water with bivalent iron sulfate (ii) for two hours in 50 oC and pH=10 with a percent of 15 of bivalent iron/total metal.

Barbooti [5] could remove lead and chrome ions from water by efficiency more than 94 % by adsorption onto Iraqi kaolinite and by doing experiment design of data analyzing to reach the perfect experimental condition. He assumed that lead adsorption did not affected by pH of the solution, and the neutral solution gives a good adsorption.

Most of the heavy metals are hazardous and they have adverse effects on human health. They may cause the serious health problems like upsets on kidneys and brain cells thereby disturbing their regular function [6]. Further, they can accumulate in the body and results in additional disturbance to health. Lead (Pb) is one of the hazardous elements which are present in industrial effluents. Consumption of trace amount lead concentration may result in permanent adverse health effects of brain development.

Removal of heavy metals from industrial waste water is a worldwide challenge. Inorganic pollutants are difficult to treat as they are non-biodegradable, hence they remain in nature. Such pollutant when enters the food cycle, affect human, plant, animal lives and aquatic systems. Therefore, their removal becomes critical from the environmental point of view. Experimental parameters affecting the adsorption process like pH value, initial metal concentration, dose of adsorbent (clay), agitation time, and speed were analyzed to get optimum conditions for maximum removal of lead. Experimental data were fitted well to the Langmuir adsorption isotherm with maximum adsorption capacity of 26.3 mg/gram at correlation coefficient of 0.955. It was found that Langmuir adsorption model is fit well with experimental data. Successful application of bentonite clay from Bhawnagar area for removal of lead from aqueous solution greatly supports its field application.

Industrialization in all sectors is at peak throughout the world. Industries are using different type of chemicals as a part of their manufacturing process. Effluents released from these industries contain chemical pollutants. Some of them are mentioned here as lead, cadmium, zinc, arsenic, chromium, copper, etc. Another source responsible for water and soil contamination is effluents discharged from dying industries [7] like textile, leather, printing, painting, plastic, fertilizer and pesticide, mining and smelting ferrous ores, energy and fuel production and food [8]. Textile finishing industries are the main contributors to environmental pollution by way of releasing waste water containing the heavy metals and dyes [9].

Pollution is particularly worse in less developed countries as a consequence of the high cost of the treatment technologies and the lack of proper regulations. In underdeveloped countries, the residues derived from industrial activities, which can contain heavy metals and others hazardous elements, are often released directly into the environment without a proper treatment. Once in the environment, they are dispersed through air, soils and surface water. Heavy metals are especially harmful due to their features of high toxicity, persistence, and accumulation

The presence of heavy metals in the natural environment including air, water, soil and plants is becoming an increasing health and environmental concern owing to the wide range of anthropogenic sources of heavy metals polluting the environment with growing industrialization and extensive use of chemicals [1], [10], [11]. Wastewater effluent streams from many industries display wide range of heavy metals in varying concentrations [12]. Heavy metals can directly enter the human body through the food chain causing serious health danger if present in excess concentration beyond permissible limits [13].

Heavy metals pollutions from wastewater discharges present an increasing concern for health, eco-system and the environment due to their persistence and bio accumulation via the food chain. Heavy metals in excess concentration cause problems of toxicity and growth inhibition to living things. While the cation exchange capacity of clay with respect to heavy metal removal is well documented, a two-step clay-coagulation combined process is studied in this research in which an excess clay addition in powder form to wastewater is followed by coagulation with aluminum sulphate to further remove heavy metal by synergy with the clay adsorption and to settle the clay adsorbent through flocculation and settlement. High percentage removal of heavy metals ranging from 96-99% has been observed. The saturated adsorption is adequately modeled by Freundlich as well as Langmuir isotherm models for the excess clay range studied. The clay-coagulation combined treatment technology can also be adapted to heavy metal removal in water treatment applications in which coagulation is often used for the removal of the colloidal portion of suspended solids [14].

Compared with several other adsorbents available for heavy metal removal, adsorbents of natural clay material offer better adsorption capacity while being low cost and easily available [10]. Adsorbents such as activated carbon are reportedly 20 times more expensive than clay [15], [16].

Clay minerals are aluminosillicates groups with sizes falling in the colloid fraction of soils with particle sizes smaller than 0.002 mm [17]. They are classified into:montmorillonite, smectite, kaolinite, illite, and chlorite. Montmorillonite, kaolinite, and illite are commonly used adsorbents owing to their greater surface area and structural rigidity [10], [19]. Clay soils are known for their high cation exchange capacity that makes them preferred adsorbent materials. The net negative charge present on the clay structure is because of substitution of silicon ion (Si4+) by aluminum ion (Al3+) that gives rise to Bronsted acidity formed on the surface by dissociation of water molecules. This acidity enhances the adsorption capacity. Lewis acidity in turn arises because of exposed trivalent Al3+ ions following structural rupture of the Si-O-Al bonds by dehydroxylation of some Bronsted acid sites.

Clay adsorbents have demonstrated excellent removal of heavy metals or metalloids including As, Cd, Cr, Co, Cu, Fe, Pb,Mn, Ni and Zn from water. Montmorillonite have high adsorption capacity compared with kaolinite and illite [2]. Lead was removed almost 100% and chromium 86% according to [5] indicating lead is removed better than chromium. High percentage removal of heavy metal is aided by excess clay addition as much 12.5 g/L of wastewater using montmorillonite clay [5]. Arsenic removal has been studied with membranes formed from montmorillonite, kaolinite, and illite operated through pumping [20].The removal by rejection as high as 90% of arsenic in the feed stream has been reported.

Industrial activities result in discharge of heavy metals contaminated water which is liable to cause serious environmental degradation and impaired human and animals health problems [21], [22], [23]. As consequence, several physical-chemical technologies such as ion exchange, chemical precipitation, membrane filtration, adsorption, solvent extraction, electrochemical have been developed for the removal of heavy metals from contaminated water prior to discharge into the ecosystem. However, each technology has its limitations with some relatively expensive [15], [23]. Among the existing technologies, adsorption becomes an attractive alternative technique in treatment heavy metals wastewater contaminated due to its documented cost effectiveness. Recently, different adsorbents such as activated carbon, sand, waste tea leaves, eggshell, zeolites, olive stones, clay, wood sawdust, chitosan, fly ash, coal and peat moss. Babel and Kurniawan [15] were used to remove heavy metals from aqueous solution. Due to their excellent properties such as high surface area, ion exchange capability, present of negative surface charge and their universal abundant in nature, natural clays minerals are considered as cost-effective alternative to the widely used expensive activated carbon for the removal of heavy metal ions from wastewater.

A variety of specialized treatment processes for the removal of heavy metals prior to their discharge into the environment have been developed [24]. Among them, the simple adsorption of lead metals on kaolinite adsorbents. In conventional treatment, adsorption is the technique of choice for the removal of dissolved heavy metals. Adsorption of heavy metals lowers the concentrations of all metals. The solubility of precipitated metal compounds is the key to this method's success; if a metal can form an insoluble compound, then the compound can be removed via clarification and filtration. Of the few adsorption methods, activated carbon, kaolinite, and bentonite are the main methods currently used.

This work depends on using Iraqi clay mineral of known composition, as kaolinite to remove lead from water and make a procedure of experimental method.

METHODS

The used material were lead powder of purity 98 % from Merek company and Iraqi kaolinite clay from the general company of geological survey and mining related to ministry of industry and minerals. Figure 1 shows the X-ray diffraction analysis of the metals. The analyzing results indicate a high content of kaolinite with other elements as shown in table 1. The results obtained from the general company of geological survey and mining related to ministry of industry and minerals.

Apparatus description

Figure 2 shows the experimental setting of the apparatus used.

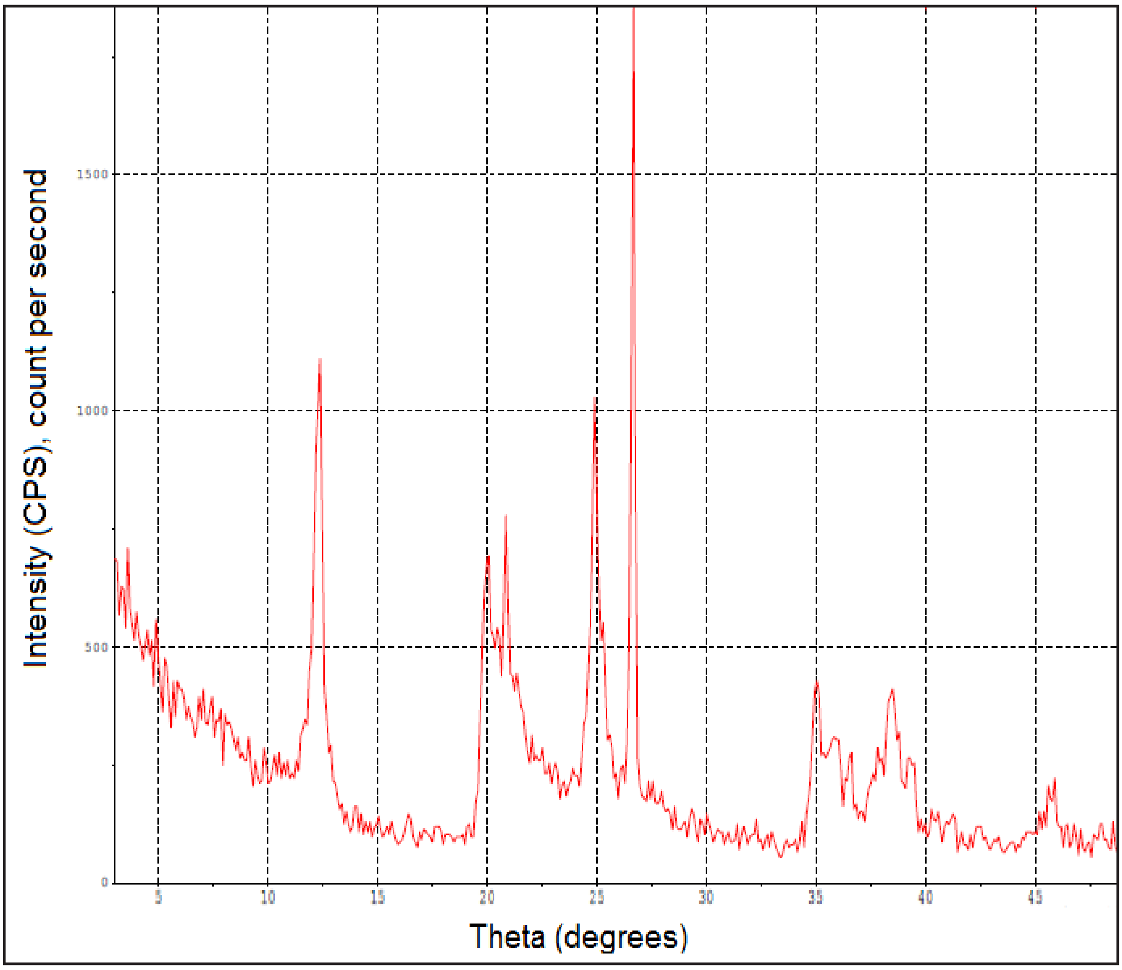

Figure 1: X-ray diffraction pattern of Iraqi kaolinite metal clay according to the general company of geological survey and mining related to ministry of industry and minerals.

Table 1: chemical composition of the used kaolinite clay according to the general company of geological survey and mining related to ministry of industry and minerals.

SiO2 %	Fe2O3 %	Al2O3 %	CaO %	L O I %	Na2O %	CL %	Description
51.55	2.63	30.9	0.26	11.28	0.34	0.21	Attached

١- Run pump
٢- Wooden base
٣- Contaminated water
٤- Pump
٥- water flow meter
٦- pipeline
٧- adsorption tower
٨- desalinated water

Figure2: the experimental setting

The lead powder was used to prepare lead solution after dissolving it by concentrated nitric acid and dilution by distilled water to have 20 liters solution of 10 ppm concentration.The lead contaminated water to be purified is placed in plastic container of 20 liters capacity with the opening in the bottom and joined with a pump to control the flow velocity throw a flow meter connected to the inlet of the purifying container. The adsorption can was put as vertical and the contaminated water was pump form down to top to insure complete filling of water. The water passed inside the can through cloth bags filled with clay which were surrounded by many small glass tubes pieces to fill the container. The velocity of the flow was controlled to permit the inlet water drop to remain about 60-90 minutes with contact by adsorption materials (cloth bags filled of clay minerals) to insure good exchange of ions. The design of purifying insures the exit of pure water after the inner container filling then the water overflows the outer container to discharge for test purposes. The quantities of materials used: 50 liters of lead solution of 10 ppm concentration, 5 cloth bags were filled by 1-gram clay for each.

EXPERIMENTAL RESULTS AND DISCUSSION

Many experiments were done to calculate the lead adsorption capacity of the clay. Each gram of the clay adsorb 21 mg of lead for a synthetic contaminated solution of 10 ppm which mean that each gram of clay adsorb 2.1 liters of solution. Five clay bags were put inside the purifying container. Firstly distilled water flowed across the clay particles to soak and to improve the process of adsorption. Many small plastic sealed containers of 50 ml were prepared to take samples to determine the breakthrough point which indicate the first sample having lead. Many samples of exit water (40 ml) were collected and numbered. Then these samples were taken for analyzing by atomic adsorption techniques. As shown in figure3.

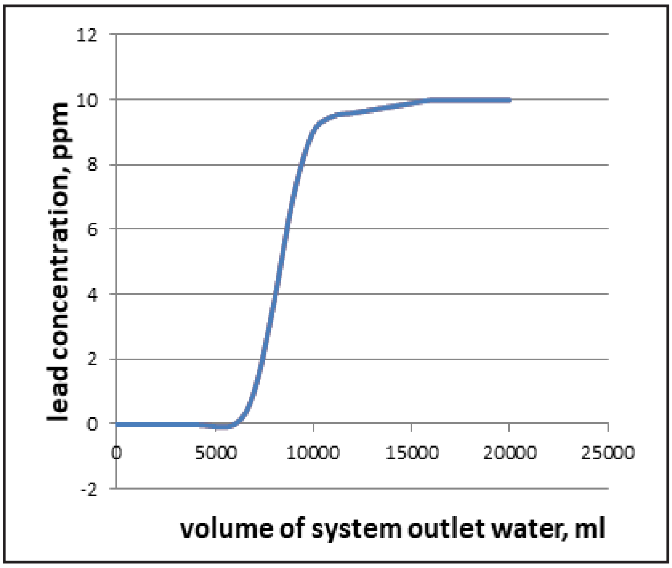

Figure 3:exit lead concentration against volume of outlet water at 0.05 L/m.

CONCLUSIONS

Figure 3 represents calculated lead concentration for the samples form number 1 to 125 where the lead disappears. Then gradually the lead appears in the samples until the number 250 the exit lead concentration was equal the initial lead concentration in the solution which means the pass of 250 *40= 10000 ml of solution which purified completely from lead.

(10000 ml solution * 10 (µg/ml))/5 g clay = 20000µgPb/g clay = 20 mg Pb/g clay

This result of adsorption capacity of clay gives the same beginning estimation.

The volume of the treatment container can handle more clay bags and the bag can have 4 to 5 grams of clay which means that 150 liters of lead contaminated water can be treated. Replacing the new clay bags by the old ones happen in 2 to 3 minutes, so the system will not stop to change the bags because the velocity of flow is slow.

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