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Removal of lead ions from industrial wastewater: A review of Removal methods

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Review article

ABSTRACT

Background and aims: The removing of (potential) toxic heavy metal ions from sewage, especially in industrial and mining waste effluents, has been widely studied in recent years. The aim of present study was to investigate the various methods for lead removal of lead ions from industrial wastewater.

Methods: This study was a review research. Data were collected through different databases in various articles. The various methods for lead removal from industrial wastewater were compared to each other.

Results: The present study showed the various methods for lead removal from industrial wastewater including chemical precipitation, electrochemical reduction, ion exchange, reverse osmosis, membrane separation, and adsorption. Technical applicability, plant simplicity and cost-effectiveness are the key factors that play major roles in the selection of the most suitable treatment system for inorganic effluents.

Conclusions: Adsorption is proposed as an economical and effective method for the retention of lead ions from aqueous industrial wastes because it is simple, effective and economic in removal of heavy metals from aqueous solution.

Keywords: Heavy metal removal, Lead, Industrial wastewater.

INTRODUCTION

The removing of (potential) toxic heavy metal ions from sewage, especially in industrial and mining waste effluents, has been widely studied in recent years. Heavy metals contaminations could exist in wastes of many industries, such as metal plating, mining operations, tanneries, chloralkali, radiator manufacturing, smelting and alloy industries as well as storage battery industries.[1-3]

Another significant source of heavy metals wastes may result from printed circuit board (PCB) manufactures .[4] Tin, lead, and nickel solder plates are the most common used resistant’s over plates. Moreover, other sources for the metal wastes may include the wood processing industry (arsenic containing wastes produced by chromatid copper-arsenate wood treatment), inorganic pigment manufacturing (which may produce pigments containing chromium compounds and cadmium sulfide), petroleum refining (which could generate conversion catalysts

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contaminated with nickel, vanadium, and chromium) and photographic operations (which might produce film with high concentrations of silver and ferrocyanide).[4-6] Because of the possibility of discharging large amounts of wastewater contaminated by metal, industries which bearing heavy metals, such as; Cd, Cr, Cu, Ni, As, Pb, and Zn, could be considered as the most hazardous ones among the chemical-intensive industries.[7,8] In addition, due to their high solubility in aquatic environments, heavy metals could be absorbed by living organisms. In fact, once they enter the food chain, a large concentration of heavy metals might be accumulated in the human body.[9] If the metals are ingested beyond the permitted concentration, they could result in serious health disorders. Therefore, it is obligatory to treat metal contaminated wastewater before discharging into the environment.[4,10]

Lead is a heavy, soft, malleable, bluish grey metal.[11] Lead is of particular interest, because of its toxicity and its widespread presence in the environment.[12] Lead is a well-known highly toxic metal considered as a priority pollutant.[13] It is an industrial pollutant, which enters the ecosystem through soil, air and water. Lead is a systemic poison causing anaemia, kidney malfunction, tissue damage of brain and even death in extreme poisoning situation.[11,14] It is very toxic in nature. Generally speaking, lead pollution, spreading over earth and ground water, comes from natural sources and industrial effluents.[4,15,16] Processing industries, such as acid battery manufacturing, metal plating and finishing, ammunition, tetraethyl lead manufacturing, ceramic and glass industries and environmental clean-up services treat and disposal of lead contaminated water are the major sources of lead pollution.[17,18] The presence of high levels of lead in the environment may cause long-term health risks to humans and ecosystems.[11,16] According to the World Health Organization (WHO), the maximum permissible limit (MPL) of lead in drinking water is 0.05 mg/L. The permissible limit (mg/L) for Pb (II) in wastewater, given by Environmental Protection Agency (EPA), is 0.05 mg/L.[17,19] In industrial wastewaters, lead-ion concentrations approach 200–500 mg/L; this concentration is very high in relation to water quality standards, and lead-ion concentration of wastewaters must be reduced to a level of 0.05–0.10 mg/L before discharging to water ways or sewage systems.[19-21] Hence proper treatment of industrial wastewaters which are releasing lead into the aquatic and land systems is very important.[22] To mitigate the lead ions pollution, many processes like adsorption, precipitation, coagulation, ion exchange, cementation, electro-dialysis, electro-winning, electro-coagulation and reverse osmosis have been developed.[4,7,23]

Some above mentioned methods are described briefly as follows: Precipitation is the most common method for removing lead ions up to parts per million (ppm) levels from water. Since the lead ions salts are insoluble in water, when the correct value is added, precipitation caused. This process is cost-effective and its efficiency is affected by low pH and the presence of other salts (ions). The process requires addition of other chemicals, which finally leads to the generation of a high water content sludge, the disposal of which is cost intensive. Precipitation with lime, bisulphite or ion exchange lacks the specificity and is ineffective in removal of the lead ions at low concentration.[23,24]

Ion exchange is another method used successfully in the industry for the removal of lead ions from effluents. Though it is relatively expensive when compared to the other methods, it has the ability to achieve ppb levels of clean up while handling a relatively large volume. An ion exchanger is a solid capable of exchanging either cations or anions from the surrounding materials.

Commonly used matrices for ion exchange are synthetic organic ion exchange resins. The disadvantage of this method is that it cannot handle concentrated metal solution as the matrix gets easily fouled by organics and other solids in the wastewater. Moreover ion exchange is nonselective and is highly sensitive to pH of the solution.[23,24]

Electro-winning is widely used in the mining and metallurgical industrial operations for heap leaching and acid mine drainaging. It is also used in metal transformation and electronics and electrical industries for removal and recovery of lead ions. Metals like Ag, Au, Cd, Co, Cr, Ni, Pb, Sn and Zn present in the effluents can be recovered by electro-deposition using insoluble anodes.[23]

Electro-coagulation is an electrochemical approach, which uses an electrical current to remove lead ions from solution. Electro-coagulation system is also effective in removing suspended solids, dissolved metals, tannins and dyes. The contaminants present in wastewater are maintained in solution by electrical charges. When these ions and other charged particles are neutralized with ions of opposite electrical charges provided by electro-coagulation system, they become destabilized and precipitated in a stable form.[23,25]

Cementation is a type of another precipitation method implying an electrochemical mechanism in which a metal having a higher oxidation potential passes into solution e.g. oxidation of metallic iron, Fe (0) to ferrous iron (II) to replace a metal having a lower oxidation potential. Copper is mostly separated by cementation along with noble metals such as Ag, Au and Pb as well as As, Cd, Ga, Pb, Sb and Sn can be recovered in this manner.[23]

Reverse osmosis and electro-dialysis involves the use of semi-permeable membranes for the recovery of lead ions from dilute wastewater. In electro-dialysis, selective membranes (alternation of cation and anion membranes) are fitted between the electrodes in electrolytic cells, and under continuous electrical current, the associated ion migrates, allowing the recovery of lead ions.[23,26]

The choice of treatment depends on effluent characteristics such as concentration of lead, pH, temperature, flow volume, biological oxygen demand, the economics involved and the social factor like the standard set by government agencies.[11] The precipitation process is usually not sufficient to reduce lead concentration to the level required by water quality standard.[12] Although these methods are expensive and they are also associated with several limitations such as generation of sludge, low percentage retention of metal ions, energy consumption and low selectivity which makes the process less suitable for small scale industries. Thus adsorption is proposed as an economical and effective method for the retention of lead ions from aqueous industrial wastes.[17,27] However, adsorption on to the surface of activated carbon is the most widely used method.[11]

CONCLUSION

The present study showed the various methods for lead removal from industrial wastewater including chemical precipitation, electrochemical reduction, ion exchange, reverse osmosis, membrane separation, and adsorption. Recently, numerous approaches have been studied for developing cheaper and more effective technologies, both to decrease the amount of produced wastewater and to improve the quality of the treated effluent. Adsorption has become one of the alternative treatments, in recent years; the search for low-cost adsorbents that have metal-binding capacities has been intensified. Although many techniques can be employed for treatment of wastewater with heavy metals, it is important to note that the selection of the most suitable treatment for metal contaminated wastewater depends on some basic parameters such as pH, initial metal concentration, the overall treatment performance compared to other technologies, environmental impacts as well as economic parameters such as the capital investment and operational costs. Finally, technical applicability, plant simplicity and cost-effectiveness are the key factors that play major roles in the selection of the most suitable treatment system for inorganic effluents. All the factors mentioned above should be taken into consideration in selecting the most effective and inexpensive treatment in order to protect the environment.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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