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A REVIEW OF METHODS FOR REMOVAL OF LEAD FROM INDUSTRIAL WASTEWATERS

KRITI BOHRA[11], MISA[1A], SHAKSHI SHUKLA[1A] AND SHASHANK GARG*[1]

Department of Biotechnology, School of Bioengineering and Biosciences, Lovely Professional University, Phagwara 144 001, Punjab, India

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Abstract - Lead is toxic for human's health even in its minute form. It is necessary to remove lead from industrial wastewaters as the whole population depends on water for their survival and are facing many problems relating water pollution. Lead can cause serious health related issues starting from common problems like hallucinations and headache to severe concerns like infertility and miscarriages in women, and abnormal spermatogenesis in males. Lead not only effects humans but animals as well. There are certain standards for lead to be present in food and water which are set by government and if those standards are not followed then that food or water is dangerous for human consumption. In this review paper two different methods for treatment of lead are described. These methods are elaborated with their mechanism, working principle along with their advantages and disadvantages. The main prominence has been given on the utilization of eco-friendly and the most effective way for amendments required for the removal oflead contaminants from wastewater.

INTRODUCTION

Wastewater treatment has become one essential need of the hour after realizing the fact that we are generating more wastewater than it can be treated by natural systems by itself. With the exponential growth of human population and the parallel increment in the industrial setups the amount of wastewater that is generated is beyond the capacities of nature to handle it. In earlier time ponds, wetlands, aquifers etc. served as natural systems which degraded the organic matter produced by living beings and returns safe water to underground resources. But, due to industrialization a greater number of recalcitrant compounds is being released into natural environment. One group of such compounds comprise heavy metals like lead (Pb), Chromium (Cr), Mercury (Hg), Copper(Cu). These compounds are shown to be toxic to human life. They can affect intelligence quotients (IQs) in children. A lot of efforts are being made to retain these compounds from entering natural ground waters. This review aims at comprehending the major electrochemical and biological methods which are utilized in treating the wastewaters containing Pb.

METHODS

Electrochemical Method

In today's world need for clean water is growing day by day. Electrochemical method is one of the promising methods for water treatment and it includes various techniques for lead removal with different properties and working principle. It has been found that electrochemical process is a tedious process as it involves various chemical reactions (Harish *et al.*, 2018).

Electrocoagulation

Electro coagulation (EC) is one of the most novel process for removing heavy metals from water when current is applied (Hamada *et al.,* 2018). It is used in wastewater treatment since 1889 (Vik *et al.,* 1984). The oxidation starts on sacrificial anode and reduction at cathode, there are various type of electrodes but the most common one is aluminum

and iron electrode which is easily available and low cost (Chandra and Dohare, 2020). Experimental set up of EC is given in (Fig. 1).

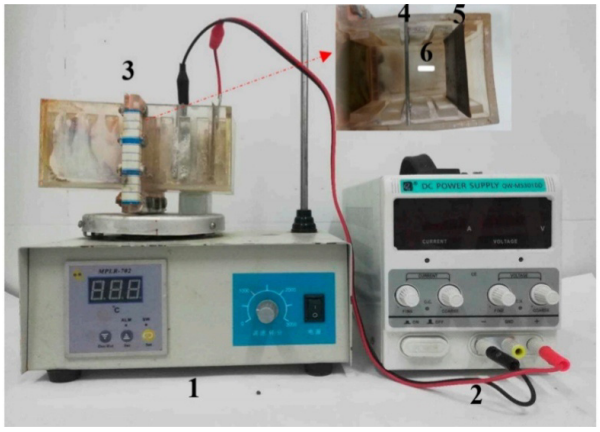

Fig. 1. Electrocoagulation (EC) experimental set-up: (1) Magnetic stirrer (2) DC power supply (3) electrolytic cell (4) anode plate (5) cathode plate (6) magnetic bar-stirrer
Source: (Jing *et al.*, 2020)

Pollutants like Heavy metal present in wastewater because of their surface electric charge or hydrogen bond, so when electricity is established, these charges began to neutralize, and the heavy metal ions are coagulated. The sludge or flocs will be produced as the metal will bond together forming mass (Mollah *et al.*, 2004). These flocs are easy to remove by filtration (Bazrafshan *et al.*, 2017).

The reaction involved in iron electrode which has 2 mechanisms (Mickova, 2015b).

Mechanism 1

Anode

$4Fe_{(s)} \rightarrow 4Fe^{2+}_{(aq)} + 8e^-$

$4Fe^{2+}_{(aq)} + 10H_2O_{(1)} + O_{2(g)} \rightarrow \quad 4Fe(OH)_{3(s)} + 8H^+_{(aq)}$

Cathode

$8H^+_{(aq)} + 8e^- \rightarrow 4H_{2(g)}$

Overall

$4Fe_{(s)} + 10H_2O_{(l)} + O_{2(g)} \rightarrow 4Fe(OH)_{3(s)} + 4H_{2(g)}$

Mechanism 2

Anode

$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$

Bulk Solution Reaction

$Fe^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Fe(OH)_{2(s)}$

Cathode

$2H_2O_{(l)} \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

Overall

$Fe_{(s)} + 2H_2O_{(l)} \rightarrow Fe(OH)_{2(s)} + H_{2(g)}$

In aluminum electrode

Anode

$Al(s) \rightarrow Al_3^+(aq) + 3e^-$

Cathode

$3H_2O(l) + 3e^- \rightarrow 3/2\ H_{2(g)+}\ 3OH^-$

EC is known as environment friendly technique (Azimi *et al.*, 2016) as it produces less sludge (Shakir and Hussein, 2009). Low investment required, it is easy to maintain and there is no need to add any chemical additives in it which makes this process clean as well (M *et al.*, 2018). The major disadvantage of this process is that electricity may not be available everywhere and sacrificial anode needs to be changed at regular interval.

Electroflotation

This process was first used in the year 1905 (Mickova, 2015a). It treats water by floating the pollutants on aqueous phase it has 3 steps. In (Fig. 2) you can see the experimental setup of electro flotation. In first step reactor having two electrodes with power supply attracts the pollutants and water electrolysis reaction takes place which releases oxygen and hydrogen.

$2H_2O_2 \rightarrow O_{2+}\ 2H_2$

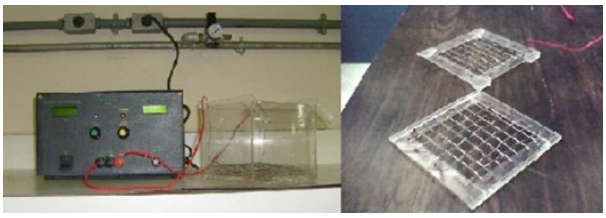

Fig. 2. Experimental Electro flotation unit and stainless-steel mesh electrode
Source: (Motaa *et al.*, 2015)

Heavy metals will either stay attracted or assimilate and hence flocs will be formed.In the second step the generated flocs will be separated and in third step using the filtration method pollutants will be removed.

The Execution of Electro flotation reactor is checked through power consumption and how much pollutant is removed during electrolysis the size of bubble formed is responsible for pollutant removal efficiency along with the type of electrodes, PH, and current density (Chen, 2004).

Electro flotation is used for groundwater

disinfection and in food processing industries. Major advantages of this process are its simple design operation, small units and it is environment friendly its disadvantage is when coalescence occurs which degrades the removal efficiency (Mickova, 2015a).

Electrofenton

Electrofenton (EF) is part of Advanced Oxidation Process. It is one of the most efficient and economical techniques for wastewater treatment (Marlina and Purwanto, 2019). It is the combination of electrolysis and Fenton reaction. In this process electrons are used which follows the principle of reduction at cathode having the reagents Fe^{2+} and H_2O_2 (Hussain *et al.,* 2021). The oxygen (O_2) reduction at cathode generates hydrogen peroxide (H_2O_2) in acidic solution (Equation 1) the H_2O_2 can be supplied externally and with formation or addition of H_2O_2 Fenton reaction (Equation 2) occurs and forms reactive species OH which is an important component to degrade the components.

$$O_2 + 2H^+ + 25R\ddot{U}'' \rightarrow H_2O_2 \text{ (Equation 1)}$$

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + OH^{\bullet} \text{ (Equation 2)}$$

Electrofenton is among the most popular processes for wastewater treatment it is economical, efficient and environmentally friendly (M and B.N, 2017). However, this process efficiency depends on PH, current density, and electrodes nature.

Biological Method

Bioremediation is an innovative and promising technology available for removal of heavy metals and recovery of the heavy metals in polluted water generated by different industries using microorganisms. Bioremediation can be done with microorganisms, fungi as well as plants. Bioremediation comprises of different biological techniques which involve the use of living organisms, i.e., Biosorption, Biotransformation, Biomineralization. When we use specifically plants, we called it as phytoremediation which uses plants for remediating contaminated waterunder which there are different techniques that are Biodegradation, Phytostabilization, Phytovolatization, Phytoextraction. It offers many benefits which include preservation of natural soil properties and possibility for environmentally sustainable and low-cost remediation. It is limited to the plant growth and its physiological properties which makes this method a time-consuming process. All these techniques are preferred over other techniques because of its cost effectiveness, and they cause no harm to the environment, despite their benefits these processes are slow and time consuming (Blaustein, 2021; Kalita and Joshi, 2017; Elekwachi *et al.,* 2014; Farraji *et al.,* 2016; Dixit *et al.,* 2015).

Biosorption

Biosorption is a process of adsorbing metals on its surface using naturally available biosorbates. It has the capacity to remove the metals at trace levels and helps in minimization of biological or chemical sludge. It does not require additional nutrient and is economical due to its reusability. Its major disadvantage is it takes long time for removal of metals (Edokpayi *et al.,* 2015; Arowojobe *et al.,* 2021).

Biomineralization

Biomineralization of metal ions is the natural synthesis of various minerals, such as sulphates, silicates, phosphates, oxides, and carbonates, with different mechanisms by the activity of living organisms. It also involves the precipitation of minerals associated with the release of heavy metals by microorganisms. It is a promising technique over other physio-chemical techniques as it can give effective results and does not cause harm to environment and causes no pollution, but it is found that when any particular area which is extremely contaminated by heavy metals then in this case this technique has short comings and its efficiency rate in more contaminated areas reduced to 50% (Akhgar, 2019).

Biostabilization

Biostabilization is a process where different plant species are utilized to immobilize unwanted waste materials including toxic heavy metals by accumulating it by roots and then, adsorbing it onto the root surface as shown in (Fig. 3). It helps in preventing the entry of contaminants into vegetative part and promotes plant growth. In this process most of the contaminants remain in water and requires a lot of amendments and monitoring processes (Bisht *et al.,* 2020; Romeh *et al*., 2015).

Bioextraction

Bioextraction is also known as phytoaccumulation and Phytoabsorption, it uses plants to absorb the metal contaminants from water or soil to clean up the pollutants by accumulating it in shoots, leaves

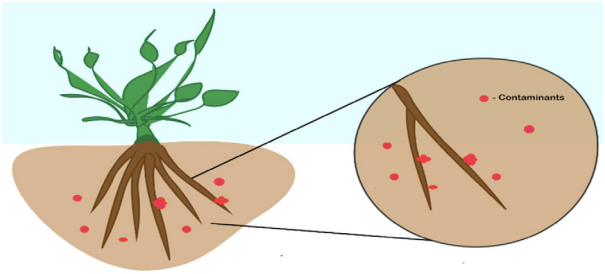

Fig. 3. Biostabilization mechanism: plants immobilized the contaminants (shown as red dot clusters) at contaminated sites, limited the movement of the contaminants and prevented its entry into the food chain.
Source: (Muthusaravanan *et al*., 2018)

and in other plant parts which is shown in (Fig. 4). The contaminants are removed permanently from water, and it is inexpensive. The plants used for phytoextraction grows very slowly (Buta *et al.*, 2014; Ali *et al*., 2013).

Biovolatilization

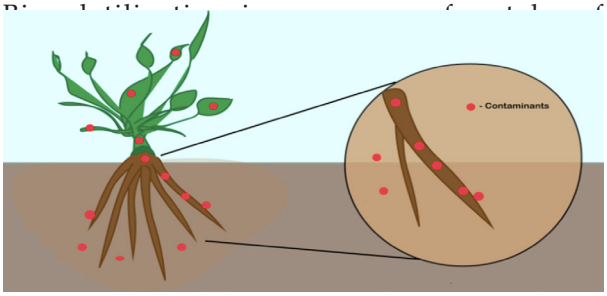

Fig. 4. Phytoaccumulation (also known as phytoextraction) mechanism: Plants absorb the contaminants (shown as red dots) from contaminated sites and accumulated in shoots, leaves and other plant parts.
Source: (Muthusaravanan *et al*., 2018)

contaminants from wastewater and soil, using plants and then converting it into volatile forms i.e., less toxic form to further release it into the atmosphere which is depicted in (Fig. 5). It can help in converting pollutants to non-toxic compounds which can help in natural degradation process effectively but releasing of contaminants may result in accumulation which can be stored in different fruits or vegetables. It is observed that most of the research of Phytovolatilization are related to its soil-based removal of effluents and there is not any recent study on utilization of this method for wastewater treatment (Blaustein, 2021; Verma and Jaiswal, 2016; Sachdeva and Sharma, 2019).

CONCLUSION

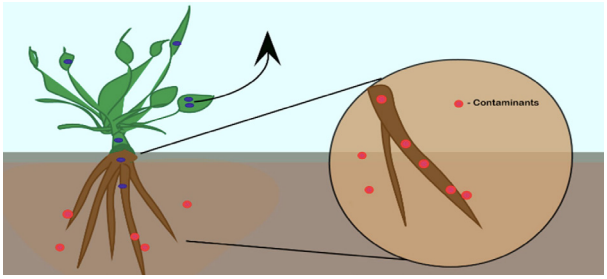

Fig. 5. Phytovolatilization mechanism: contaminants (shown as red dots) get absorbed by plants and degraded into less toxic compounds (shown as blue dots) and released into the atmosphere during transpiration process.
Source: (Muthusaravanan *et al.*, 2018)

Among the methods discussed in the paper, biological methods are found to be most eco-friendly and electrochemical methods are found to produce toxic sludge which requires additional steps for its handling and are although fast and cheap to operate but it does not detoxify the Pb ion and hence just accumulate the ions which shall be treated separately before is disposal. This increases the overall cost of the process. Biological methods like adsorption are more like physical adsorption process but it saves money as some waste material is being used an adsorbent. Other biological methods are although useful, but their natural rate is very slow which limits their usage while handling higher loads. Research and development can be done in a direction which utilize properties of different methods to get an augmented technology which can answer these gaps collectively.

REFERENCES

Ali, H., Khan, E. and Sajad, A, M. 2013. Phytoremediation of heavy metals—Concepts and applications. *Chemosphere.* 91(7) : 869-881.

Azimi, A., Azari, A., Rezakazemi, M. and Meisam, Ansarpour, 2017. Removal of Heavy Metals from Industrial Wastewaters: A Review. *Chem Bio Eng Review.* 4 (1) : 37-59.

Bazrafshan, E., Mohammadi, L., Moghaddam, A.A. and Mahvi, A.H. 2015. Heavy metals removal from aqueous environments by electrocoagulation process – a systematic review. *Journal of Environmental Healthscience & Engineering.* 13.

Bisht, R., Chanyal, S. and Srivastava, R. 2020. A systematic review on phytoremediation technology: removal of pollutants from waste water and soil. *Int J Res Eng Sci Manage.* 3 (1) : 54-59.

Blaustein, R. 2017. Phytoremediation of Lead: What Works,

What Doesn't. *Bioscience.* 67 (9) : 868.

Buta, E., Toroko, A., Cantor, A,C,M., Buta, M. and Majdik, C. 2014. Comparative Studies of the Phytoextraction Capacity of Five Aquatic Plants in Heavy Metal Contaminated Water. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* 42 (1) : 173-179.

Chandra, S.A. and Dohare, D. 2020. Study of Electrocoagulation Process for Removal of Heavy Metals from Industrial Wastewater A Review. *International Journal of Engineering Research & Technology (IJERT).* 09 (09).

Chen, G. 2004. Electrochemical technologies in wastewater treatment. *Separation and Purification Technology.* 38 (1): 11-41.

Dixit, R., Wasiullah, Malaviya, D., Pandiyan, K., Singh, U.B., Sahu, A., Renu Shukla, R., Singh, B.P., Rai, J.P., Sharma, P.K., Lade, H., and Paul, D. 2015. Bioremediation of Heavy Metals from Soil and Aquatic Environment: An Overview of Principles and Criteria of Fundamental Processes. *Environmental Sustainability and Applications.* 7 (2).

Edokpayi, J. N., Odiyo, J.O., Msagati, T. A. M. and Popoola, A.E.O. 2015. A Novel Approach for the Removal of Lead(II) Ion from Wastewater Using Mucilaginous Leaves of Diceriocaryum eriocarpum Plant. *Sustainability.* 7 (10) : 14026-14041.

Elekwachi, C.O., Andresen, J. and Hodgman, T.C. 2014. Global use of bioremediation technologies for decontamination of ecosystems. *Journal of Bioremediation & Biodegradation.* 5 (4).

Farraji, H., Zaman, N.Q ., Tajuddin, R.M. and Faraji, A. 2016. Advantages and disadvantages of phytoremediation A concise review. *Int J Env Tech Sci.* 2 : 69-75.

Jing, G., Ren, S., Gao, Y., Sun, W. and Gao, Z. 2020. Electrocoagulation: a promising method to treat and reuse mineral processing wastewater with high cod. *Water.* 12 (2) : 595.

Hamada, M., Ghalwa, A.N., Farhat, N.B., Mahllawi, K.A. and Jamee, N. 2018. Optimization of Electrocoagulation on Removal of Wastewater Pollutants. *International Journal of Waste Resources.* 8 (4).

Harish, N., Janardhan, P. and Sanjeev, S.A. 2018. Effective adsorption of lead and copper from aqueous solution by samaneasaman and banana stem. *Advances in Environmental Research.* 7 (3) : 225-237.

Hussain, M., Mahtab, M.S. and Farooqi, I.H. 2021. A comprehensive review of the Fenton-based approaches focusing on landfill leachate treatment. *Advances in Environmental Research.* 10 (1) : 59-86.

Jalilvand, N., Akhgar, A., Alikhani, H.A., Rahmani, H.A. and Rejali, F. 2019. Removal of Heavy Metals Zinc, Lead, and Cadmium by Biomineralization ofUrease-Producing Bacteria Isolated from Iranian Mine Calcareous Soils. *Journal of Soil Science and Plant Nutrition.* 20 : 206–219.

Kalita, D. and Joshi, S, R. 2017. Study on bioremediation of Lead by exopolysaccharide producing metallophilic bacterium isolated from extreme habitat. *Biotechnology Reports.* 16 : 48-57.

M, B., M, Krishna,BM., and Manoj, Kumar, B. 2018. A Review of Electrocoagulation Process for Wastewater Treatment. *International Journal of Chem Tech Research.* 11.

?? Electro Fenton process for wastewater treatmnt A review. *International Journal of Advance Research, Ideas and Innovations In Technology.* 3 (1).

Mickova, I. 2015a. Advanced Electrochemical Technologies in Wastewater Treatment. Part II: Electro-Flocculation and Electro Flotation. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS),* 14(2).

Mickova, I. 2015b. Advanced Electrochemical Technologies in Wastewater Treatment Part I: Electrocoagulation. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS).* 14 (2).

Mollah, M.Y.A., Morkovsky, P., Gomes, J.A.G., Kesmez, M., Parga, J. and Cocke, D.L. 2004. Fundamentals, present and future perspectives of electrocoagulation. *Journal of Hazardous Materials.* 114 (1-3) : 119-210.

Motaa, I., D,O,D., a, C, D,A, J., Casqueirab, R.D.G. and Junior, A.G.D.O. 2015. Study of electroflotation method for treatment ofwastewater from washing soil contaminated byheavy metals. *Journal of Material Reserch and Technology.* 4 (2) : 109-113.

Muthusaravanan, S., Sivarajasekar, N., Vivek, J.S., Paramasivan, T., Naushad, Mu., Prakashmaran, J., Gayathri, V. and Al-Duaij, O.K. 2018. Phytoremediation of heavy metals: Mechanisms, methods and enhancements. *Environmental Chemistry Letters.* 16 : 1339–1359.

Marlina, E. and Purwanto, 2019. Electro-Fenton for Industrial Wastewater Treatment: A Review. Paper presented at the *E3S Web of Conferences.*

Romeh, A. A., Khamis, A.M. and Metwally, S.M. 2015. Potential of Plantago major L. for Phytoremediation of Lead-Contaminated Soil and Water. *Water, Air and Soil Pollution.* 227 (9).

Sachdeva, S.A. and Sharma, A. 2012. Azolla: role in phytoremediation of heavy metals. *Int J Eng Sci.* 1 (2277) : 9698.

Shakir, I.K. and Husein, B.I. 2009. LEAD Removal from Industrial Wastewater by Electrocoagulationprocess. *Iraqi Journal of Chemical and Petroleum Engineering.* 10 (2).

Verma, J.P. and Jaiswal, D.K. 2016. Book Review: Advances in Biodegradation and Bioremediation of Industrial Waste. Frontiers in Microbiology.

Vik, E., A., Carlson, D, A., Eikun, A, S. and Gjessing, E,T. 1984. Electrocoagulation of potable water. *Water Research.* 18 (11) : 1355-1360.

Yemisi, A., Aiyesanmi, A.F. and Adebayo, M.A. 2021. Removal of Aqueous Lead and Cadmium using Persea americana Seed Coat: Single and Binary Studies. *Advance Journal of Chemistry - Section B,* 3 (1): 16-24.