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A Review on Various Techniques for the Removal of Heavy Metals from Wastewater

Various Techniques for the Removal of Heavy Metals from Wastewater

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Abstract :

The presence of heavy metals in wastewater poses significant environmental and health risks. Their persistence, toxicity, and potential for bioaccumulation necessitate effective removal strategies to safeguard water resources. This review paper comprehensively evaluates various methods employed for the removal of heavy metals from wastewater. The examined techniques encompass both conventional and emerging approaches, including physical, chemical, and biological methods. Furthermore, recent advancements and promising technologies in heavy metal removal are discussed, emphasizing their efficiency, cost-effectiveness, and potential for large-scale implementation. Overall, this review aims to provide an in-depth analysis of the current state-of-the-art techniques for heavy metal removal in wastewater, aiding researchers and practitioners in selecting appropriate strategies for specific scenarios.

Rapid industrialization, with economic prosperity set as the prime goal, has always created some secondary intolerable problems such as heavy metal contamination, wastewater that need remediation. Industrial wastewater is the major contributors to contamination of aquatic and terrestrial ecosystems with toxic heavy metals like arsenic, copper, chromium, cadmium, nickel, zinc, lead, and mercury whose hazardous bio-accumulative nature in biotic systems is attributed to their high solubility in the aquatic environments. There has, therefore, always been a need for the removal and/or recovery of these toxic, non-biodegradable, and persistent heavy metals from the industrial wastewater. For several decades, extensive investigations have been performed for easy, efficient, and economic removal of heavy metals with a varying degree of success. Chemical precipitation, adsorption, ion floatation, ion-exchange, coagulation/flocculation and electrochemical methods have been the most readily available conventional methods for the removal of these heavy metals. These methods however have posed some serious shortcomings such as high sludge production needing further treatment, low removal efficiency and high energy requirements. In the present years, newer more efficient, more economic and innovative technologies are being investigated. Recently photocatalysis, electrodialysis, hydrogels, membrane separation technique and introducing newer adsorbents have beendeveloped for better adsorption. Hence in this paper, we have reviewed efforts and technologicaladvances achieved so far in the pursuit of more efficient removal and recovery of heavy metalsfrom industrial wastewaters and have evaluated their efficiency dependence on various parameters such as pH, temperature & initial dosing.

INTRODUCTION

The paper discusses several techniques that can be used for heavy metal removal, such as chemical precipitation, ion exchange, membrane filtration, adsorption, and biological treatments. Each technique is explained in detail, highlighting its advantages, disadvantages, and limitations. For instance, chemical precipitation is effective for the removal of lead, cadmium, and mercury, but it requires a high pH and is less effective for copper and zinc removal. Ion exchange is effective for the removal of multiple heavy metals, but it requires a large amount of chemicals and produces sludge that requires further treatment.

Membrane filtration is a promising technique for heavy metal removal, particularly for nanofiltration and reverse osmosis, which can remove 90-99% of heavy metals. However, thesemethods are energy-intensive and require a large amount of water. Adsorption is another effective technique that uses activated carbon, zeolites, and other materials to remove heavy metals. It is easy to use, cost-effective, and can remove multiple heavy metals simultaneously.However, it requires frequent replacement of the adsorbent material.

Lastly, the review paper discusses biological treatments, which are environmentally friendly and cost-effective. Bioremediation can use bacteria, fungi, or algae to remove heavy metals. However, it requires a longer time for the treatment, and the heavy metals are not entirely removed from the water.

Heavy metals are one of the most significant pollutants that are present in wastewater, and theirremoval is crucial for the protection of the environment and human health. This review paper aims to provide an overview of various techniques that are used for the removalof heavy metalsfrom wastewater.

NEED OF THE STUDY.

- Ultrasound causing sonochemical effect is phenomenon of acoustic cavitation which include formation, growth and collapse of bubble in liquid producing high temperature upto(5000k), high pressure (1000atm)
- Condition in small region leads to the formation of hot spot for few microseconds.
- This high pressure, high temperature condition lead to cleavage of water molecule and hydrogen (H+) and Hydroxyl (OH-) radical are formed which unselectively oxidized target pollutants.
- Currently number of treatment technologies has been employed for the removal of heavy metals present into waste water like ion exchange, chemical precipitation, chemical oxidation, reverse osmosis, ultrafiltration, electrolysis, adsorption etc.
- Analysis all the method available for removal of heavy metals. Ultrasound is emerging technology for removal of heavy metals.

MPCB pure water parameters:

Parameter	Quantity
Dissolve oxygen	8.26 milligram
Conductivity	5 microSiemen/cm
pH	7
COD	200 ppm
BOD	80ppm
Hardness	0 to 60 mg/l
TDS	50-150 in between

MPCB waste water heavy metal percentage:

Heavy Metals	Public pure water (mg/l)
As	0.3
Cr	0.05
Cu	1.5
Mn	0.5
Ni	1.5

Pb	0.1
Zn	15.0

Methedology to remove heavy metals in waste water:

1. **Chemical precipitation –**

Chemical precipitation can be used to remove contaminants from both municipal and industrial wastewaters. It can be used for water softening, heavy metal removal from metal plating wastes, oil and grease removal from emulsified solutions, and phosphate removal from wash-waters and other wastewater.

Chemical precipitation is the process of conversion of a solution into solid by converting the substance into insoluble form or by making the solution a super saturated one.

Chemical precipitation can be used to remove contaminants from both municipal and industrial wastewaters. It can be used for water softening, heavy metal removal from metal plating wastes, oil and grease removal from emulsified solutions, and phosphate removal from wash-waters and other wastewater.

2. **Ion exchange –**

Ion exchange in water treatment involves removing undesirable ion contaminants from the water by exchanging them with another ionic substance. The four methods of ion exchange are water softening, deionization, demineralization, and alkalization. It is essential to remove contaminants in water to make it safe.

Ion exchange is a reversible chemical reaction wherein an ion (an atom or a molecule that has lost or gained an electron and thus acquired an electrical charge) from a wastewater solution is exchanged for a similarly charged ion attached to an immobile solid particle.

Ion exchange resins are useful for the removal of water problems including hard water, scale buildup, nitrates and arsenic. Ion exchange resins are useful for the removal of water problems including hard water, scale buildup, nitrates, arsenic and more.

3. **Adsorption –**

Adsorption is the adhering of substances from gases or liquids onto the interface of two phases, mainly onto solids. In water and used water purification, adsorption is applied for the removal of dissolved impurities. The most common process is application of activated carbon for removal of organic substances.

The adsorption process is widely used for the removal of heavy metals from wastewater because of its low cost, availability and eco-friendly nature. Both commercial adsorbents and bio adsorbents are used for the removal of heavy metals from wastewater, with high removal capacity.

Adsorption is a mass transfer process that is a phenomenon of sorption of gases or solutes by solid or liquid surfaces.

4. **Membrane filtration –**

Membrane technology used for removing solids in wastewater treatment is usually based on ultrafiltration or microfiltration. The membranes can be introduced into the biological wastewater treatment process either as: a separate unit operation downstream of the biological step, or. integrated into a biological process.

Membrane filtration for heavy metal removal exists in various types depending on the size of the particle that can be retained. The different types count microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO)

Membranes for membrane adsorption (MA) have the dual function of membrane filtration and adsorption to be very effective to remove trace amounts of pollutants such as cationic heavy metals, anionic phosphates and nitrates. In this review article, recent progresses in the development of MA membranes are surveyed.

5. **Reverse osmosis –**

Reverse osmosis (RO) is a water treatment process that removes impurities using a semi-permeable membrane. Simple, safe and cost-effective, it radicates over 99% of contaminants from water such as dissolved solids, organics, bacteria and pyrogens.

Common chemical contaminants, metal ions, aqueous salts such as sodium, chloride, copper, chromium, and lead will be removed; arsenic, fluoride, radium, sulfate, calcium, magnesium, potassium, nitrate, and phosphorous are also eliminated.

Reverse osmosis (RO) can be used to reduce many heavy metals in water, such as chromium, copper, lead, and arsenic. RO technology uses added pressure to push water through a semipermeable membrane, which blocks contaminants larger than 0.0001 micrometers from passing through while allowing water molecules free passage.

6. **Solvent extraction –**

Solvent extraction is primarily used in waste water treatment for the removal of phenols, creosols and other phenolic acids (detailed references being given later). These waste water streams arise principally in petroleum refineries, coke-oven plants in the steel industry and the plastics industry.

Solvent extraction is the most commonly used method to separate metal ions. This technique is performed by mixing the aqueous phase containing metal salt with an organic phase containing an extraction agent.

There are two types of extraction, liquid-liquid extraction also known as solvent extraction as well as solid-liquid extraction. Both extraction types are based another same principle, the separation of compounds, based on their relative solubilities in two different immiscible liquids or solid matter compound.

7. **Electrochemical treatment –**

Electrochemical water treatment systems utilize electricity to induce the removal of dissolved contaminants in the water. Positively charged contaminants such as calcium,magnesium, sodium, lead and uranium are called cations.

The nature of the electrochemical process is the applying of electricity to pass a currentthrough an aqueous metal bearing solution, which also contains a cathode plate and aninsoluble anode. The treatment is the precipitation of the heavy metals in a weakly acidic or neutralized electrolyte as hydroxides.

8. **Cavitation-**

Cavitation is a process that involves the formation and collapse of vapor-filled cavities, or bubbles, in a liquid. It can be used in various applications, including the treatment of wastewater contaminated with heavy metals. While cavitation itself may not directly remove heavy metals from wastewater, it can enhance the effectiveness of certain treatment methods.

Cavitation can be employed in combination with other processes such as chemical precipitation, coagulation, and oxidation to improve the removal efficiency of heavy metals. The collapse of cavitation bubbles generates localized high temperatures and pressures, which can facilitate chemical reactions and physical processes that aid in the removal of heavy metals.

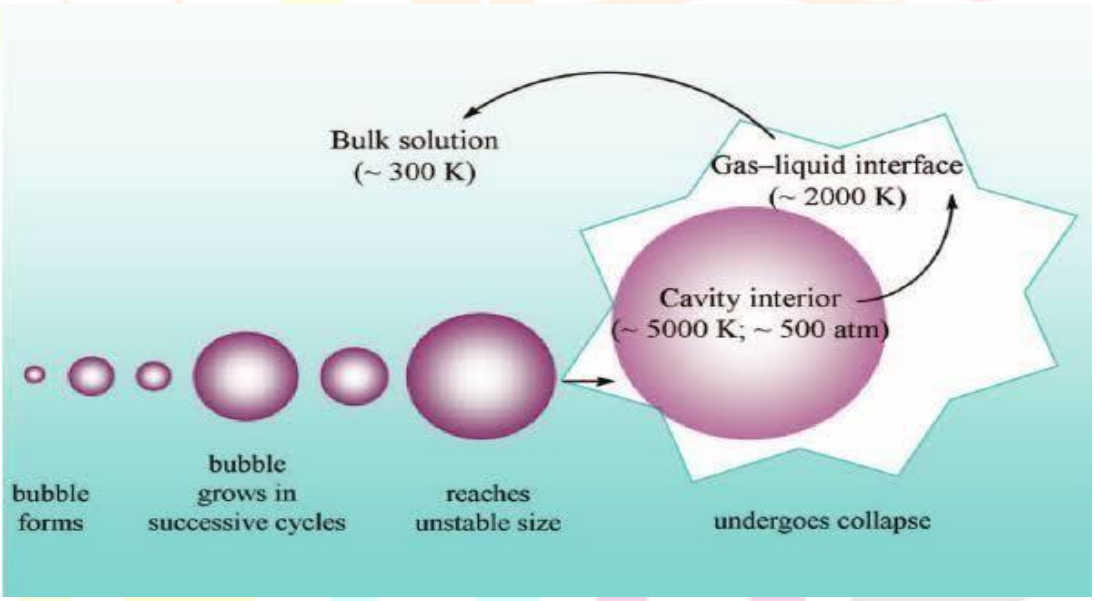

Fig: Cavitation

One method that utilizes cavitation for heavy metal removal is sonochemical precipitation. This process involves the addition of a precipitating agent to wastewaterand subjecting it to ultrasonic waves that induce cavitation. The collapse of the cavitation bubbles promotes the formation of fine precipitates, which can capture and remove heavy metal ions from the solution.

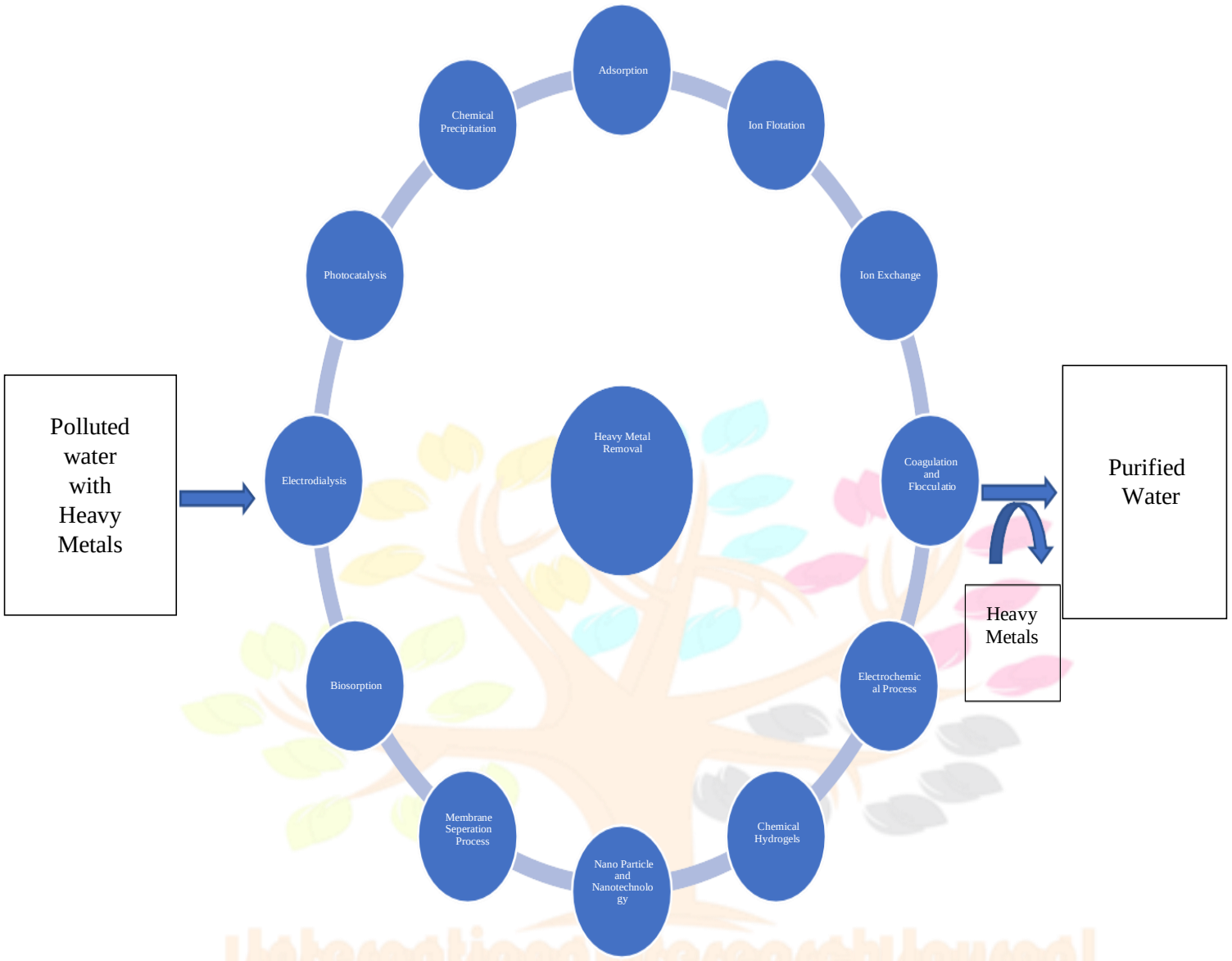

Fig : Method To Remove Of Heavy Metals

Results:

Solution label (nm)	Blank (ppm)	Waste Solution
Cd (214.439)	0.00u	0.00u
Cr (267.716)	0.00u	0.00u
Cu (324.754)	0.00u	0.00u
Mn (257.610)	0.00u	0.00u
Ni (231.604)	0.00u	0.00u
Pb (220.353)	-0.00u	-0.06u
Zn (202.548)	-0.00u	-0.01u

Conclusion:

Overall, the paper concludes that there is no one-size-fits-all solution for heavy metal removal from wastewater. The selection of a particular technique depends on the concentration and type of heavy metals, the quality of the water, the cost of the treatment, and the environmental impact. A combination of several techniques may be required to achieve effective heavy metal removal. Further research is required to optimize these techniques and to develop new ones for the removal of heavy metals from wastewater. The choice of the most suitable method for removing heavy metals from wastewater depends on factors such as the type and concentration of heavy metals present, the volume of wastewater, and the desired level of treatment. In many cases, a combination of different treatment methods may be necessary to achieve effective removal. It is crucial to consider the cost, efficiency, and environmental impact of each method before implementing it on a larger scale. Furthermore, ongoing research and technological advancements continue to contribute to the development of more efficient and sustainable methods for heavy metal removal from wastewater.

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