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Remediation of Wastewater using ZnO Nanoparticles

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Abstract — *Industrialization serving as a medium of development is vital to a nation's economy. However they are also responsible for introducing industrial waste products to the environment. Such wastewater generation demands for implementation of effective and advanced treatment technologies. Nanotechnology being a green innovation attracts the attention. The manuscript reviews the variety of potential applications of ZnO nanoparticles in form of nano-adsorbents, nano-sized plates, nano-composites film, Hybrid or doped nanoparticles for the treatment of industrial wastewater having color and heavy metal contents. It also specifies various parameters influencing the nano-remediation using ZnO nanoparticles.*

Keywords- *Nano-adsorbents, nano-sized plates, nano-composites film, Doped nanoparticles, nano-remediation*

I.INTRODUCTION

Scarcity of water demands effective and efficient treatment technologies. Continuous contamination of fresh water resources by variety of organic and inorganic pollutants is a major challenge for water supply chain. Many technologies are emerged in some last decade, they are not at par for effective reductions in concentration of pollutants. Moreover, the existing technologies of wastewater treatments have several drawbacks such as high-energy requirement, incomplete pollutant removal and generation of toxic sludge. Hence more research needs to be carried for such innovative, eco-friendly, low energy requirement and effective technologies for wastewater remediation.As a green innovation, Nanotechnology may emerge as an essential part in numerous modern applications. In terms of wastewater treatment, nanotechnology is applicable in detection and removal of various pollutants. Heavy metal pollution poses as a serious threat to environment because it is toxic to living organisms, including humans and non-biodegradable.

Incredible potential decontamination for waste water is expected by the advancement of nanotechnology. All the phenomenon takes place on a nanometre scale Level. Nano materials have been developed in variety of forms such as nanowires, nanotubes, nanofilms, nanoparticles, quantum dots, colloids.

In terms of wastewater treatment, nanotechnology is applicable in detection and removal of various pollutants. Heavy metal pollution poses as a serious threat to environment because it is toxic to living organisms, including humans and non-biodegradable. Nanofiltration techniques are now widely used to remove cations, natural organic matter, biological contaminants, organic pollutants, nitrates and arsenic from groundwater and surface water. Nano-membranes are used to treat contaminated water by filtration or separation techniques. Nanosorbents are widely used as separation media in water purification to remove inorganic and organic pollutants from contaminated water.

Nanosorbents:
Two fundamental properties make nanoparticles highly productive as sorbents. On a mass basis, they have much larger surface areas compared to macro particles. They can also be enhanced with various reactor groups to increase their chemical affinity towards target compounds [8]. These properties are increasingly being used by workers to develop highly selective and efficient sorbents for removal of organic and inorganic pollutants from contaminated water. Many materials have properties dependent on size. Hematite particles with a diameter of 7 nm, for example, adsorbed Cu ions at lower pH values than particles of 25 or 88nm diameter, indicating the enhanced surface reactivity for iron oxides particles with decreasing diameter, indicating the enhanced surface reactivity for iron oxides particles with decreasing diameter [9].RGO and GO supported materials have higher binding capacity compared to those free nanoparticles. Interestingly, reduced graphene oxide also has antibacterial property and this property may help in preventing the development of biofilm on the filter surface due to bacterial growth, which can cause unwanted tastes and odors or prematurely clogging of filters [10].

Nanofiltration:
Membrane processes such as nanofiltration (NF) are emerging as key contributors to water purification [11]. Nanofiltration membranes (NF membranes) are widely used in water treatment for drinking water or wastewater treatment. It is low pressure membrane process that separates materials in the 0.001-0.1 micrometer size. NF membranes are pressure-driven membranes with properties between those of reverse osmosis and ultrafiltration membranes and have pore sizes between 0.2 and 4 nm. NF membranes have been shown to remove turbidity, microorganisms and inorganic ions such as Ca and Na. They are used for softening of groundwater (reduction in water hardness), for removal of dissolved organic matter and trace pollutants from surface water, for wastewater treatment (removal of organic and inorganic pollutants and organic carbon) and for pretreatment in seawater desalination. Studies concluded the use of nanofiltration to remove cations, natural organic matter, biological contaminants, organic pollutants, nitrates and arsenic from groundwater and surface water [12].

Nano-Composite Membranes:
Incorporation of nanoparticles into a polymeric membrane matrix has gained attention for water and wastewater treatment applications [15]. The fabrication of nanocomposite membranes that conserve the advantages of polymeric membranes yet overcome their disadvantages by incorporation of nanoparticles is a highly desired outcome for membrane development. Nanocomposite membranes are a new class of membranes consisting of both organic polymers and inorganic nanoscale materials, which are believed to exhibit enhanced performance in comparison to standard membranes [16].The membrane that merges the beneficial properties of both organic and inorganic materials to create a new membrane with enhanced hydrophilicity, permeability, thermal and chemical stability, porosity and mechanical properties has been sought by many research groups [17]. However, many processes and environmentally troublesome issues can arise from incorporation of nanoparticles into polymeric membranes, such as disruption of membrane morphology and particulate leaching which will impact on process efficiency. Choosing application-specific nanomaterials with an optimum composition is essential to overcome limitations in polymeric membrane applications [14].

Nanoparticles emerging for wastewater decontamination:

Sr. No.	Nanoparticles	Potential Properties
1	Iron based nano-particles	High affinity for removal of pollutants like Cr^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Cd^{2+}, Pb^{2+}, As^{3+}
2	Manganese Oxides	Adsorption efficiency for Pb^{2+}, Cd^{2+} and Zn^{2+}
3	Zinc Oxide	High removal efficiency for Pb^{2+}, Hg^{2+}, Ni^{2+} and Cd^{2+} as photocatalyst
4	Magnesium Oxide	Efficient adsorption of Pb^{2+} & Cd^{2+}
5	Carbon Nanotubes	Removal of Pb^{2+} & Mn^{2+}
6	Graphene Oxide	Pb^{2+}, Zn^{2+} & Cd^{2+} can be removed
7	Titanium Oxide	Efficient Photodegradation of methyl orange and phenol

Table 1:Various Nanoparticles in wastewater treatment as emerging candidate

II.ZnO Nanoparticles for Wastewater Remediation

This part jots out the applicability of ZnO as nanocatalyst in various remediation methods. Characteristics and properties of ZnO nanoparticles are briefed out showing its potential for nano-remediation.

Table 2: ZnO Nanoparticles in different forms for Wastewater Remediation

Sr. No.	ZnO Nano-form	Results	Comments	Reference
1	Nano Photocatalyst	The photocatalytic decomposition of methyl orange was most efficient in the solution at pH 10.	Except for size, morphology and fabrication methods of the photocatalysts are the other crucial factors that influence the degradation efficiency severely.	Wang et al. (2007)
2	Membrane photocatalytic reactor (MPR)	The optimum dosage of ZnO-PVP-St nanoparticles has a great potential in MPR for industrial dye waste water treatment with very minimum NF membrane fouling	Antibacterial property of ZnO gives minimum membrane fouling.	Hairom et al (2014)
3	Zeolite/Zinc Oxide Nanocomposites	The optimum parameters for removal 93% and 89% of Pb (II) and As (V) from 100 mg/L aqua solution were pH 4, 0.15 g and 30 min	Zeolite/ZnO NCs adsorbent was found to have high adsorption capacity and it could be employed as an efficient and low-cost adsorbent for removal of heavy metals from water. It can be easily regenerated by 0.005 M HNO3 and used for several cycles.	Alswata et al. (2017)
4	Nano-particles	The decolorization efficiency increases with increase in pH, attaining maximum value at pH 10.	The efficiency is inversely related to the dye concentration; increasing dye concentration enhances dye adsorption on the active sites of the catalyst surface, and consequently hinders OH− adsorption on the same sites, this results with a decreasing OH• formation rate.	Akyol et al. (2004)
5	Zeolite/zinc oxide nanocomposite	The efficiency of the antibacterial increased with increasing the wt.% from 3 to 8 of ZnO NPs, and it reached 87% against Escherichia coli E266.	The enhanced antibacterial activity can be attributed to surface defects on the ZnO, an abrasive surface texture and to the presence of the zeolite support, which prevents the agglomeration of the nanoparticles.	Alswat et al. (2016)
6	Zinc Oxide Nanoparticles Impregnated Polymer Hybrids	n-ZPFR composite is economical, eco-friendly and capable to remove Pb(II), Hg(II), Cd(II) and Bi(III) from natural water resources.	It is not only able to increase the surface area and average pore radius but also reinforce the chemical strength of adsorbents in acidic medium. It is interesting to note that n-ZPFR composites showed higher surface area compared to other nanocomposites	Beaulah Angelin (2015)

7	Photocatalytic decolorization of Remazol Red RR inaqueous ZnO suspensions	The decolorization efficiency increases with increase in pH, attaining maximum value at pH 10	The impact of catalyst loading on the process efficiency is stronger at low dye concentrations.	Akyol *et. al.*
8	ZnO nanoparticles in MPR for industrial dye wastewater treatment using NF and UF membrane	In NF, Dye degraded after photocatalysis process (68 %)Dye removal after filtration (100%), COD reduction (92%), Turbidity reduction (100%), TSS reduction (94%)	In MPR, the Initial pH is important for improving the efficiency of the photocatalytic degradation process which also reduces the membrane fouling.	Nur Hanis *et. al.*

III. Conclusion

Various classes of ZnO nanomaterial like nanoadsorbent, nanorods, nanoplates, nanosheets have ensured high removal efficiency of heavy metal removal Pb (II), Cd (II) and Hg (II). ZnO as photocatalyst can decolorise dye effluents. ZnO as nanocomposite enhances the conventional membrane technology giving new functionalities like high permeability, fouling resistance, catalytic reactivity tuning their porosity and mechanical stability. Also ZnO particles being impregnated in polymer matrix do not get discharged with effluents. Nano-composites can be reused by regenerating it with desorption agent 0.1 M HNO3 or 0.1 M NaOH increasing the membrane life. The modified catalyst material can provide the capability of using visible region of solar light instead of high cost artificial UV light. There is significant need to ensure the green synthesis of nanoparticles to reduce the eco-toxicity potential for successful field future applications.

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