RESEARCH ARTICLE OPEN ACCESS

An Insight into the Selection of Nano Particle for Removing Contaminants in Waste Water

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ABSTRACT
Waste water treatment is a major challenge in automobile industries and manufacturing sectors. In past few decades, research in waste water treatment has gained significant importance. Feasibility of nanoparticles for removing impurities is explored. However the major challenge lies in the synthesis of these nanoparticles. But with the advancements in nanotechnology, non-hazardous nanoparticles of size less than 10nm can be synthesized and morphological characteristics can also be successfully studied. Owing to their extremely smaller size, good absorption characteristics, better chemical reactivity, large surface to volume ratio, nanoparticles are highly suitable for removing metal/non-metal, organic/inorganic contaminants from water. This paper provides an extensive literature survey on the suitability of various nanoparticles for waste water treatment
Keywords: Water treatment, nanoparticles, adsorption, contaminants

I. INTRODUCTION

Waste water Management has become a crucial challenge due to increased population and industrial pollution. Hence waste water treatment is the need of the hour. Considerable research is carried out in this area to treat water contaminated with heavy metals, hazardous organic and inorganic chemicals, radionuclides and microorganism. Various water treatment techniques are cited in literature. In recent years, paradigm has shifted to the use of nanoparticles for waste water treatment. In past, synthesis and fabrication of nanomaterial is a major issue. With the advancements in nanotechnology, complexity in the synthesis of nanomaterial has reduced. Methods used for the synthesis of nanoparticles are chemical and physical methods that include sol-gel process, arc discharge method, laser ablation etc. As the chemical reactivity and absorption are dependent on the morphological characteristics of the nanoparticles, their properties are studied through Scanning Electron Microscopy, Transmission Electron Microscopy/ Scanning Transmission Electron Microscopy and Focused ion beam before using these particles. However the selection of a suitable nanoparticle and a technique for a particular contaminant is still an unsolved problem. This paper provides an insight into the different methods and choice of nanoparticles for removing not only metallic/non-metallic, organic/inorganic contaminants but al so microorganisms in water.

This paper is organized as follows: Section2 describes techniques for removing metal/non-metallic contaminants.Section3 focuses on the literatures for removing organic/inorganic impurities in water. Survey on various methods and nanoparticles used for removing microorganisms are also discussed in Section3.In Section4 selection of nanoparticle for removing a particular contaminant is tabulated and section5 concludes the work.

II. SURVEY ON NANOPARTICLES FOR REMOVING METAL/ NON-METAL CONTAMINANTS

Yantasee et al (2007) used thio functionalized super paramagnetic nanoparticles for removal of heavy metals from aqueous systems. Iron oxide (Fe_3O_4) nanoparticle combined with dimercaptosuccinic acid (DMSA) was used to create an efficient dispersible or bent that can be magnetically collected. It had high capacity and selectivity for the softer heavy metals. Experimental procedure included synthesis of nanoparticles, batch metal sorption and distribution coefficient measurement. Modification of nanoparticle surface with DMSA was anticipated to increase the efficacy of the magnetic nanoparticle for heavy metal removal. Khaydarov et al (2010) used Carbon nanoparticle for waste water treatment. An aqueous dispersion of carbon nanoparticles in the range of 1-100nm was obtained with a concentration of 150-400ppm.The pH is maintained from 2.8 to 3.1 using an efficient synthesis method. The synthesized carbon nanoparticles were proved to be effective in removal of metal ions from contaminated water samples. The process involved two stages namely electrolysis and electrolyte stirring. Twin timer was also used to control the process.

Warner et al (2010) suggested a method for removal of contaminants from natural water using high performance super magnetic nanoparticle based heavy metal sorbents. Here iron oxide nanoparticles using a straight forward precursor synthesis was followed by a facile ligand exchange process. It bound the readily available affinity ligands onto the nanoparticle surface. Methodology involved, synthesis of Fe_3O_4-LA precursor nanoparticle, synthesis of water soluble ligand-stabilized nanoparticle by ligand exchange and nanoparticle characterization. The resultant functionalized magnetic Fe_3O_4 nanoparticles were easy to synthesis and were excellent sorbents for a variety of heavy metal contaminants depending on the surface ligand installed.

Chalew et al (2013) studied the breakthrough of common NPs — silver (Ag), titanium dioxide (TiO2), and zinc oxide (ZnO)—into finished drinking water following conventional and advanced treatment. Breakthrough of NPs into treated water by turbidity removal and inductively coupled plasma–mass spectrometry (ICP-MS) was monitored. Conventional treatment resulted in 2–20%, 3–8%, and 48–99% of Ag, TiO2, and ZnONPs, respectively, or their dissolved ions remaining in finished water. Breakthrough following MF was 1–45% for Ag, 0–44% for TiO2, and 36–83% for ZnO. With UF, NP breakthrough was 0–2%, 0–4%, and 2–96% for Ag, TiO2, and ZnO, respectively. Although a majority of aggregated or stable NPs were removed by simulated conventional and advanced treatment, NP metals were detectable in finished water.

Esfahani et al (2013) performed Lead Removal from Aqueous Solutions Using Polyacrylic acid-Stabilized Zero-Valent Iron Nanoparticles (PAA-ZVIN). It was found that the efficiency of removal was directly proportional to the concentration of PAA-ZVIN. On the other hand, enhancing the initial Pb2+ concentration decreased in Pb2+ removal efficiency. In addition, Pseudo zero-order, Pseudo first-order and Pseudo second-order kinetic models were used to fit the experimental data of Pb2+ removal. Results of kinetic experiments indicated that Pseudo first-order kinetic model compared to other kinetic models had more ability to fit the experimental data of Pb2+ removal. In conclusion, this study revealed that PAA-ZVIN can be used as a promising adsorbent to remove Pb2+ from aqueous solutions.

Ahmed et al (2013) studied the preparation and characterization of a Nanoparticles Modified Chitosan Sensor. A biosensor electrode based on the incorporation of super nanoparticles paramagnetic iron oxide (α-Fe_3O_4) in chitosan (CS) film coated on platinum electrode, was developed for the determination and removal of heavy metals. The morphological properties of the homogenous α-Fe_3O_4/CS nanocomposite were studied with scanning electron microscopy (SEM), Energy Dispersive X-ray analysis (EDX), and thermal gravimetric analysis (TGA). The morphological results indicated the successful formation of α-Fe_3O_4/CS nanocomposite and high stability of the film. The α-Fe_3O_4/CS nanocomposite showed a great efficiency for the determination of As, Pb and Ni ions from aqueous solution using various electrochemical techniques. The presence of α-Fe_3O_4 nanoparticles resulted in increased active surface area and enhanced electron transfer. Results showed that this novel α-Fe_3O_4/CS nanocomposite was successfully applied for sewage water and human urine samples with very low detection limit.

Xu et al (2012) explored iron oxide magnetic nanoparticles and Ca-alginate immobilized Phanerochaete chrysosporium, for the removal of Pb (ii) ions. Iron oxide magnetic nanoparticles and Ca-alginate adsorbent were prepared and wrapped them in the P.Chrysosporium Hyphae pellets. Absorption studies was analysed intra-particle diffusion analysis using and Fourier transform infrared spectrophotometer (FTIR) analysis of the encapsulant was performed. The adsorbed Pb (ii) ions on the surface were chelated by the presence peptides or polysaccharides existing on the surface of P.Chrysosporium. Followed by this, desorption studies and statistical analysis for reusability of the adsorbent were carried out. A 90% adsorption capability with good reusability promises its application in heavy metal containing waste water treatment. MNPs–Ca-alginate immobilized P.Chrysosporium was a good adsorbent for efficient removal of Pb (ii) from contaminated waste water.

Zeinali et al (2012) fabricated an efficient chitosan coated magnetic nanoparticle for the removal of mercury from aqueous solution. Methodology is as follows: initially magnetic nanoparticles were prepared and the carboxyl methylated chitosan was bound to the ferromagnetic nanoparticles by carbodiimide activation. The characterization study of the nanoparticles was carried out using dynamic size scattering and transmission electron microscopy and found that chitosan bound Fe^3O^4 nanoparticles had low dispersity and high adsorption rate. The mercury was rapidly adsorbed by the chitosan bound magnetic nanoparticle with an adsorption equilibrium rate of 1 minute due to the absence of internal diffusion resistance and high specific surface area It was found that chitosan bound nanoparticles with a diameter less than 10nm was a good adsorbent and the adsorbed particle was recovered back from the nanoparticle using EDTA. The proposed method could efficiently remove 80% of mercury (II) ions from aqueous solution.

Bhargav et al (2013) proposed iron oxide nanoparticles for the removal of arsenic and copper metal from contaminated water. By applying external magnetic field the contaminants in waste water is removed by using Fe^3O^4. pH within 8 to 14 makes precipitation of Fe^3O^4. Chemicals used here are Arsenic (III) oxide (As^2O^3), sodium hydroxide (NaOH), arsenic (V) oxide hydrate ($As_2O_5.3H_2O$),stock solutions of Zn^{2+}, iron (II) chloride tetrahydrate ($FeC_{l2}.10H_20$). This process includes Preparation of Magnetite nanoparticles, Preparation of carboxymethyl-β-cyclodextrin, Preloading CM-β-CD and Zn2+ over the magnetite nanoparticles. For the removal of Cu(II) and As(V) from contaminated water the same nanoparticle is used and for removing the nanoparticle external magnetic field was used.

III. SURVEY ON NANOPARTICLES FOR REMOVINGORGANIC/ INORGANICPOLLUTANTS AND MICROORGANISMS

Elliott et al (2008) proposed a technique using Zerovalent Iron Nanoparticles, for treating water contaminated with Hexachlorocyclohexanes. More than 95% of the HCHs were removed from solution with 2.2 to 27.0 gL–1 iron nanoparticles within 48hrs. Then ZVI particles were synthesized by mixing equal volumes of 0.50 mol L−1 sodium borohydride (98.5%) and 0.28 molL−1 ferrous sulphate heptahydrate solutions. Sorption was the principal removal mechanism that was indicated by little HCH remaining in solution after the reaction.

Lisha et al (2009) proposed an efficient method for removing inorganic-mercury from water using a novel adsorbent gold nanoparticle supported on alumina. The experimental process includes synthesis of gold nanoparticles by reducing $HAuCl4.3H_2O$ with trisodium citrate, uptake of mercury, characterization of gold-mercury system, detection and removal of boron. Column experiment was used to study absorption capacity and was monitored using UV-vis spectroscopy. The morphology of the Au-Hg system were studied using TEM, SEM. The Au-Hg alloy formation was confirmed by EDAX and XRD techniques. It was studied that pure alumina alone is unable to remove mercury from water.

Sharifabadi et al (2013) used the modified surfactant sodium dodecyl sulphate of magnetic nanoparticles and treated the adsorptive tendency towards Citalopram drug for efficiently removing Citalopram drug from waste water. FeO_3 nanoparticles were prepared by the chemical co–precipitation method and characterization study of the magnetic nanoparticles were carried out using transmission electron microscopy (TEM).pH, amount of the surfactant, contact time and temperature was investigated and optimized for parameters influencing the extraction efficiency and the extracts were analysed using ultraviolet spectrophotometry at 239nm. High adsorption capacity of SDS–coated Fe_3O_4 Nanoparticles was efficiently used for removing Citalopram drug from waste water.

Pacheco et al (2003) proposed removal of inorganic mercury from water using alumina nanoparticles which were prepared by the sol-gel method. Dynamic light scattering was used to monitor the particle growth. Atomic absorption spectroscopy was used to determine the amount of metal ion adsorbed on the surface of the alumina sols. Experimental procedure included Sol Preparation and pilot test. The alumina nanoparticles can remove extremely low or high concentrations of mercury due to their chemical property. Ion size and charge regulates metal ion adsorption; Due to difficult interpretation of the binding processes and stoichiometry the adsorption mechanism of metal ions had little information. 2.4g of aluminium tri-sec-but oxide with 14.34mL of isopropyl alcohol and 26.24 mL of ethanol mixture was used to prepare alumina nanoparticles. Large variety of structures and sizes of the sol corresponds to instabilities of there action due to nonlinear effects.

Nair and Pradeep (2007) proposed an efficient method for extraction of Chlorpyrifos and Malathion from water using metal nanoparticles. Two common pesticides Chlorpyrifos and Malathion found in ground water was removed using silver and gold nanoparticle by adsorption process. For this anon-line water filter was made using columns of activated alumina powder loaded with silver nanoparticle were used for extended period. UV-Visible spectroscopy and infrared spectroscopy was used for monitoring time dependent removal and adsorption of pesticides from water. The method offers a convenient and cost-effective means of removing pesticides from drinking water. Pure alumina alone is unable to remove pesticides.

Monyatsi et al (2012) studied the feasibility of removing pathogenic bacteria in groundwater. Filter materials coated with Silver Nanoparticles were used. Silver nanoparticles were deposited on zeolite, sand, fibreglass, anion and cation resin substrates in various concentrations (0.01mM, 0.03mM, 0.05mM and 0.1mM) of $AgNO_3$. The performance of the substrates as antibacterial water filter system was checked and no bacterium was detected in the output water when the Ag/ cation resin substrate was used as a filter system. Low bacterial removal by Ag/zeolite, Ag/sand, Ag/ fibrelass and Ag/anion resin filter systems was observed, which led to the conclusion that these systems are not ideal systems for the disinfection of drinking water.

Thill et al (2006) proposed an effective cytotoxicity mechanism of CeO_2 Nanoparticle for Escherichia coli bacteria. In Cytotoxicity mechanism, stable CeO_2 nanoparticles were used as astable solution to react with Escherichia coli which is an test organism. Nanoparticle surfaces adsorbed the small organic materials very easily. This mechanism had the following steps: construction of the isotherm of adsorption by plotting the amount of adsorbed CeO_2 per bacteria versus the non adsorbed amount. Study of samples using Electron microscopy resulted in Physico chemical Interaction and Cytotoxicity. Chemical Modifications of the Nanoparticles involved three types of interactions between Nanoparticles and the bacteria namely adsorption, oxireduction, and toxicity.

Ma et al (2013) proposed an efficient method for waste water treatment and for processing of biosolids using silver nanoparticles. Metallic silver nanoparticles (AgNPs) and zinc oxide nanoparticles (ZnONPs) due to its toxicity to various terrestrial and aquatic organism were used as anti microbes and thus implemented for waste water treatment. When primary and activated sludge of silver nanoparticles (AgNPs) and zinc oxide nanoparticles (ZnONPs) was fed to Anaerobic digestion, it dissolved metalions and no more metals were added to the sludge in this step. Lime and heat treatment on metal speciation converted Ag to Ag_2S, regardless of the form of Ag added (NP v sionic). Zn was transformed to three Zn-containing species, ZnS, $Zn_3(PO_4)2$, and Zn associated Fe oxy/hydroxides. Waste sludge from the Waste Water Treatment Plant (WWTP) an aerobic digester was dewatered and dried to 20−50 wt% solids content. The dewatered biosolids were then further dried, subjected to lime addition and heat treatment, and/or composted before being applied to agricultural fields. As structural differences between NP and $AgNO_3$ resulted in differences in the partitioning and Mobility in biosolids, structural information (amicroscopic investigation) for the metal nanoparticles formed in biosolids has to be performed.

Nassar et al (2012) proposed a batch adsorption technique using Goethite nanoparticle for the removal of methylene blue from waste water. Goethite nanoparticle undergoes protonation or deprotonation, in aqueos solution. The deprotonated surface of Goethite nanopartic lead sorbed the Methylene blue from aqueous solution with an adsorption equilibrium rate of 20 minutes. The positively charged MB functional groups were electrostatically attracted to the negatively charged Geothite nanoparticle.The thermodyanamic studies and adsorption kinetics were performed on the adsorbed particle. Finally desorption of methylene blue from MB loaded Geothite was conducted. The Langmuir type MB was adsorbed effectively and can be completely desorbed from the surface of Geothite nanoparticles.

Ulucan et al (2013) studied α-Fe_2O_3 sintered in zeolite form for the removal of Trihalomethanes (THMs) from drinking water dichlorobromomethane, dibromochloromethane and bromoform were ordered. The absorption capacity of zeolite was increased due the nanoparticle in zeolite form. When the time was altered it showed low decrement in removal rate. In removal of THMs it was found that more than sintered form the unsintered form of α- Fe_2O_3 was more effective. The reason for this was the presence of more nanopores in unsintered form of α-Fe2O3. They concluded that suitable sintering processes must be used to obtain the same results as in the unsintered form and also the synthesizing method should be improved in order to enhance the surface area and particle size of nanoparticles.

IV. SELECTION OF NANOPARTICLES

Selection of a suitable nanoparticle for the removal of a particular contaminant is always a major problem. Choice of the nanoparticle for removing a specific contaminant is shown in Table 1.

V. CONCLUSION

In this paper an extensive literature survey is carried out on waste water treatement using nanoparticles. Suggestions are also provided for selecting a nanoparticle for a specific contaminant. Ferromagnetic nanoparticle are ideally suited for removing metal contaminants while gold nanoparticle are capable of removing organic/inorganic contaminants. Microorganism can be removed using silver nanoparticle due to their physical, chemical and surface particles, nanoparticles are the ideal choice for removing contaminant. Selective adsorption properties and increasingly large surface area of the nanoparticles help in speedy treatment of water.

TABLE1: Choice of nanoparticles for removing specific contaminant.

Nature of the contaminant	Contaminant to be removed	Nanoparticle NP
Metal/non metal	Pb(ii)	Ca-alginateIronoxide magnentic nanoparticle
	Hg(ii)	carboxymethylatedchitosenFerromagneticnanoparticle
	Hg	Thiol-FunctionalisedSilica Ferromagnetic Nanoparticle
	Heavymetals	ThioFunctionalizedsuperparamagnetic nanoparticles
	Arsenic	Zincoxidenanoparticles
	cobaltand iron	Iron(Fe)nanoparticles
	Metal ions	Carbon nanoparticle
	Lead	Polyacrylicacid-Stabilized Zero-Valent Iron Nanoparticles (PAA- ZVIN).
	Arsenic and copper metal	Iron(Fe)nanoparticles
	Zerovalent Iron Nanoparticles	Hexachlorocyclohexanes
Organic/ inorganic	Methylene blue	Geothite nanoparticle
	tri-chloroethane (TCE)	Metallic goldnanoparticle coated with palladium
	chlorinated ethane,	Metallic goldnanoparticle coated with palladium
	Chlorinatedmethane	Metallic goldnanoparticle coated with palladium
	inorganic-mercury	GoldNP supported onalumina
	methylene blue	Goethite nanoparticle
	Trihalomethanes (THM)	α-Fe2O3sinteredin zeolite form
Microorganism	Pathogenic Bacteria	SilverNanoparticles (Ag Nps)
	Escherichia colibacteria	CeO_2Nanoparticle
	Escherichia coli and Bacillus megaterium bacteria	MgOnanoparticles
	Bacillus subtillus	magnesium(Mg)nanoparticles
	Ecoli,Staphylococcs aureus	Agnanoparticles
	Chlorpyrifosand Malathion	silver and goldnanoparticle

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