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SPATIAL ANALYSIS OF ADSORBENT MADE FROM ZERO VALENT IRON FOR ZINC REMOVAL FROM CERAMIC WASTE WATER

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Abstract: The pollution of water due to various toxic components especially heavy metals are causing an adverse effect on the flora and fauna and also have a potential effect on the human well-being. Due to this there is an immediate requirement to find various techniques for the removal of lethal toxins in wastewater. Amongst all of the existing methods, adsorption is one of the most effective and efficient technique for the elimination of contaminants such as heavy metals from wastewater.

The prepared nanomaterials were characterized via X-ray diffraction (XRD) spectroscopy, scanning electron microscopy (SEM), energy dispersive X-ray (EDX) analysis, and UV-Vis absorption spectroscopy. In addition, the effect of different operating parameters such as pH, contact time, and stirring rate on the colour removal efficiency was extensively studied to identify the optimum removal conditions. The reaction temperature, adsorbent dose, and initial colour concentration were fixed during the experiments at room temperature, 0.7 g/L, and 350 and 50 mg/L Pt/Co colour unit, respectively. Moreover, adsorption and reaction kinetics were analysed using different isotherms and models.

Keyword: Adsorbent, wastewater, zero valent iron, Water treatment, EDX, XRD

INTRODUCTION

Discharge from industry contains various organic and inorganic pollutants. Among these pollutants are heavy metals which can be toxic and/or carcinogenic and which are harmful to humans and other living species. The heavy metals of most concern from various industries include lead (Pb), zinc (Zn), copper (Cu), arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni) and mercury (Hg). They originate from sources such as metal complex dyes, pesticides, fertilisers, fixing agents (which are added to dyes to improve dye adsorption onto the fibres), mordents, pigments and bleaching agents. In developed countries, legislation is becoming increasingly stringent for heavy metal limits in wastewater. In India, the current maximum contaminant level (ppm–mg/mL) for heavy metals is 0.05, 0.01, 0.25, 0.20, 0.80, 0.006, 0.00003, 0.050 for chromium, cadmium, copper, nickel, zinc, lead, mercury and arsenic, respectively. Various treatment technologies employed for the removal of heavy metals include chemical precipitation, ion exchange, chemical oxidation, reduction, reverse osmosis, ultrafiltration, electro dialysis and adsorption. Among these methods, adsorption is the most efficient as the other techniques have inherent limitations such as the generation of a large amount of sludge, low efficiency, sensitive operating conditions and costly disposal. The adsorption method is a relatively new process and is emerging as a potentially preferred alternative for the removal of heavy metals because it provides flexibility in design, high-quality treated effluent and irreversible and the adsorbent can be regenerated. The specific sources of chromium are leather tanning, electroplating, nuclear power plants and textile industries. Chromium (VI) is an oxidising agent, is carcinogenic in nature and is also harmful to plants and animals. Exposure to chromium (VI) can cause cancer in the digestive tract and lungs, epigastric pain, nausea, severe diarrhoea, vomiting and haemorrhage.

Synthesized nZVI particles tend to agglomerate rapidly in water through Van der Waals forces and magnetic attraction and form particles with diameters variation from microns to several millimeters. In addition, nZVI particles can react with the surrounding environment, leading to rapid loss of reactivity.

Among these adsorbents, activated carbon particles has aroused significant interest mainly due to its high porosity, large surface area and high efficiency. Since the immobilized zero valent iron has higher activity and greater flexibility for environmental remediation applications compared to free nanoparticles, its immobilization in an activated carbon matrix could serve to preconcentrate reagents, mediate electron transfer reactions, and promote the growth of the product phases. For this reason, the objective of this work was the preparation, characterization and application of zero valence iron immobilized in powdered activated carbon (PAC) to remove hexavalent chromium from synthetic effluent, as well as obtaining useful kinetic and thermodynamic parameters to aid the understanding of the adsorption process.

MATERIALS & METHODS

MATERIAL

All chemicals required for the present study is enlisted below:

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- Zero Valent Iron
- Sodium Borohydride

METHODOLOGY

Grab method of sampling for collection of samples is to be used following safety measures while collection. Then Physico-chemical characterization was done for collected samples Measurement of different parameters like pH, turbidity, conductivity, temperature, TDS, hardness, alkalinity, COD, nitrate and chloride is done for wastewater. Measurements of different parameters in the laboratory were conducted with the help of APHA guidelines. Then experimental setup was done. Experiments were conducted to investigate the effects of initial pH, the concentration of Zn, a dose of ZVI and time for the removal of Zn. Batch experiments were carried out using 100mL of synthetic wastewater in conical flasks and the pH adjustments were done using 1M NaOH and 1M HCl. It was the followed by analytical method in which investigation of pH, COD, Electrical Conductivity, Turbidity, Hardness, Temperature, Total Dissolve Solids, Alkalinity, Chloride, Nitrate and Zinc Concentration. Furthermore, Synthesis of Nanoparticle was done. Synthesis of Zero valent iron (ZVI) was done with conventional reduction method of sodium borohydride. Further on batch study of the prepared adsorbent was conducted where Freundlich isotherm and Langmuir isotherm equation was used.

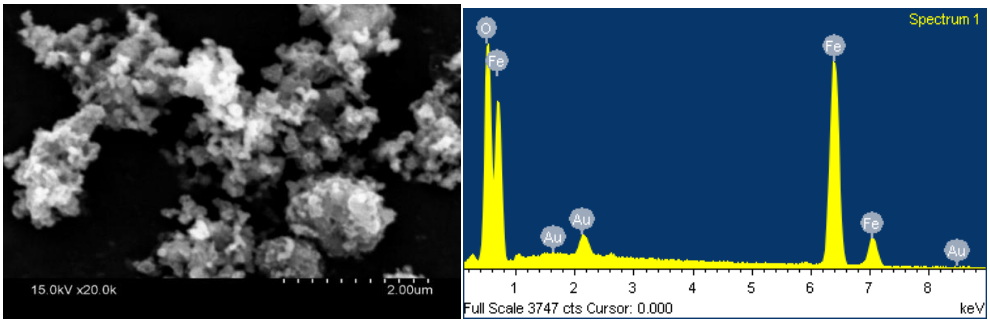
RESULT OF PHYSICO-CHEMICAL PARAMETER

The physio-chemical characterization of different water samples were done following APHA guidelines. For ceramic industry wastewater the pH is 6.63-6.65 which is in permissible range for industrial water discharge into surface water. The total solids concentration is high as 8180 mg/L. the chemical oxygen demand COD is also high 1920 mg/L. p-alkalinity in range 48-56 mg/L as $CaCO_3$ and T- alkalinity in range as 364-416 mg/L as CaCO3. The nitrate content of wastewater in the range of 11.5289- 12.1032 mg/L and chloride content as 439.86-479.85 mg/L was found.

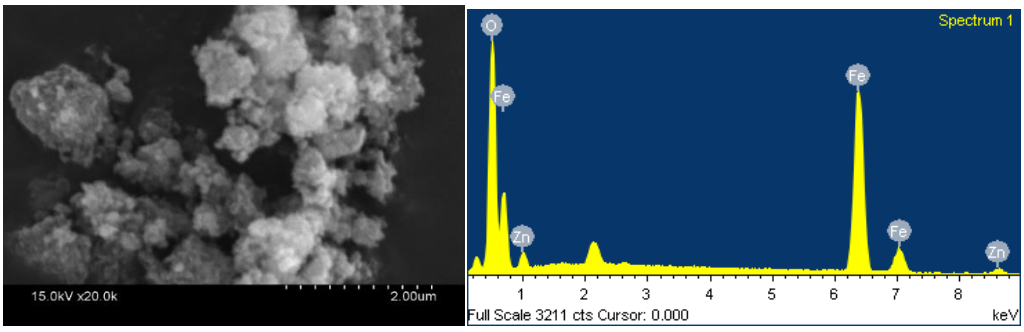
CHARACTERIZATION OF ZERO VALENT IRON (ZVI)

In order to analyze the change in the shape of ZVI particle earlier to the removal of zinc and after zinc adsorption Scanning electron microscope was employed. The ZVI particle morphology before and after adsorption is shown in Figure below.

It can be seen that morphology of surface changed from smooth and spherical to rough, bulgy and branched one after adsorption of zinc on ZVI. The X-ray Energy Dispersive Spectrometer (EDS) spectra of ZVI and ZVI used for removal of zinc shows changes in the peaks as shown in Figure 3 (right) and Figure 4 (right) respectively.



SEM image (above) and XRD spectra (Below) of ZVI



SEM image (above) and XRD spectra (below) of ZVI used for zinc removal

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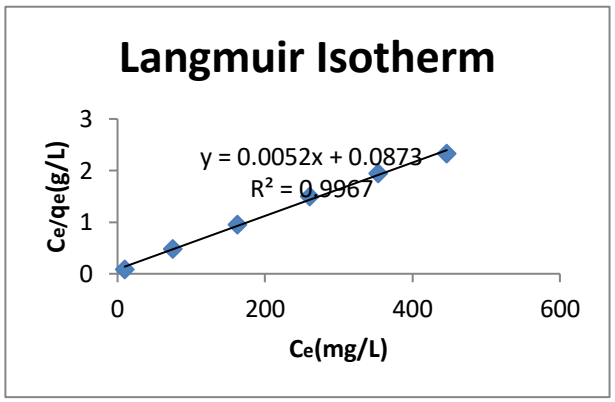
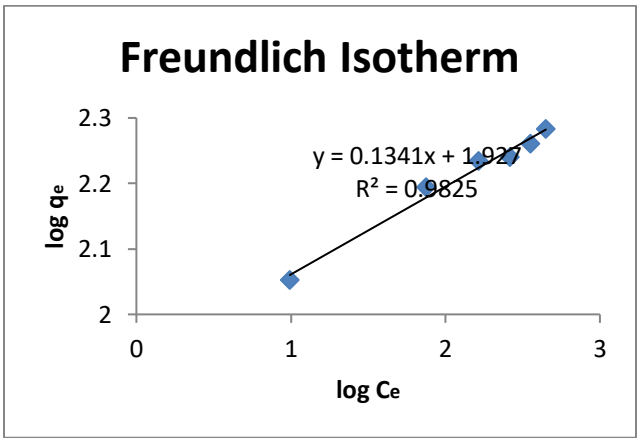
OPTIMIZATION OF ZVI

- For optimization, percentage zinc removal was fixed at "maximize" with the highest importance. ZVI Dose for optimization was fixed to "minimize", the target value for pH was fixed to"6.65" as the pH of ceramic wastewater was found to be 6.65.
- The optimized value for initial concentration of zinc, ZVI dose, Time, pH was found to be 109.9mg/L, 0.08 g/L, 218.15 min and 6.65 respectively.
- At these conditions, the % Zn removal was 92.9559 % with the desirability of 0.908. At optimized condition, the experiment conducted has 89.97% removal of zinc, which is near to the values predicted.

ISOTHERMAL STUDIES



Study of Langmuir Isotherm for Zinc at pH=6.65, ZVI Dose 0.08 mg/L and Time 220 minutes



Study of Freundlich Isotherm for Zn at pH=6.65, ZVI Dose 0.08 and Time 220 minutes

CONCLUSIONS

- With the use of central composite design, a four variable 5 level RSM software the effects of the initial concentration of zinc, pH, a dose of ZVI and time of contact was studied. The optimum results obtained were pH = 6.5, a dose of ZVI = 0.08 g/L, with the initial concentration of 108 mg/L and time of contact 218 min were obtained.
- At optimized condition equilibrium isotherm studies were done in which Langmuir isotherm was most suited for adsorption of zinc on ZVI, from this it could be indicated that adsorption of zinc as a monolayer has occurred on the surface of ZVI. The maximum adsorption capacity was estimated to be 192.31 mg/g at the optimized condition.

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