Use of Zero Valent Iron Based Nano Particle for the Removal of Zinc from Wastewater

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***Abstract*: Heavy metals in effluent wastewater from industries is a big concern for the environment. Zinc, a heavy metal from ceramic wastewater if directly released to a natural water body may cause a problem. This heavy metal may be self-contained by the river up to its saturation but may create a problem at the later stage. The use of Zero valent iron (ZVI) for adsorption of different heavy metals has shown satisfactory result. In this work the use of ZVI for removal of zinc from ceramic wastewater was done. In order to know the effect of different variable parameters like pH, time, ZVI dose and initial concentration of zinc, central composite design of a response surface methodology called was used. The design was used to know the significant factor and to optimize the process parameters for efficient adsorption. This study also includes batch adsorption experiments including adsorption capacity, adsorption isotherm study and kinetic study for zinc adsorption process. In order to determine isotherm parameters Langmuir and Freundlich equilibrium models were applied. The adsorption of zinc onto zero valent iron was conformed to change in morphology before and after adsorption with help of scanning electron microscope and change in spectra of energy dispersive x-ray spectroscopy.**

Index Terms: Nanoparticle, ZVI, Turbidity, COD, Freundlich Isotherm, Heavy metal, Zinc

I. INTRODUCTION

Industrialization is evolving very quickly in last couple of decades which has caused the spike in the content of all types of pollution and especially in the water. Thus the quality of water supply has to be maintain in such condition as water is the prime requirement for the living of human being. Due to globalization the quality of water is decreasing day by day and it is effecting the day to day life of human being. Therefor it is primarily requirement of an effective water treatment method which could remove the pollutant. Due to urbanization and industrialization the accumulation of heavy metal in industrial discharge water or industrial wastewater are the primary reason for the pollution. Only those heavy metals pollutants are examine whose density acceded to 5 g/cm3. The element that belongs to this category are highly soluble in water and are well known toxin and carcinogenic in nature. The metals belong to heavy metals category are Pb, Cu, Zn, Cd, Cr, Ni, As, Sn, Fe, Se, Mo, Ag, Au, Hg, Co, Al & Mn. Presence of these element is a threat to human being, plants and animal receiving through water bodies. These elements got soaked up and accumulate in human body and ultimately results in various serious health problems such as cancer, nervous problem, organ damage problem and in many seviour problems cause death, it has also been noticed that in order to decrease growth and evolution. heavy metals are produced while the working of tannery industry, textile industry, metallurgical industry, zinc industry, emissions out from automobile, cement, battery industries, waste from construction sites and insecticide factory etc.

Heavy amount of heavy metals are found in construction site waste, paint factory and wire manufacturing company. Wood processing industry produce Selenium. A Selenium contain organic as well as inorganic pigment. Petroleum industry generate catalyst which contain vanadium, chromium and Nickel. Waste generated by photographic operations are Ferro cyanide and silver. Manufacturing industry produce cadmium sulfide and chromium by producing pigment. The ill effects of heavy metal results in many type of serious health problem such as growth retardation, changes in reproductive cycle, tumor, chronic disease, organ damage such as kidney and liver, deterioration of bones and teeth. These repercussion can be lower down by lowering the heavy metal concentration in wastewater so there is a urgent requirement of a treatment process that can treat contaminated water or contaminated water or waste water for its disposal. Heavy metal removal from industrial wastewater can be achieved by various treatment process and very frequently. Heavy metal removal can be done by various treatment process such as filtration sedimentation coagulation, flocculation, precipitation, centrifugation and membrane process. Membrane treatment process include reverse osmosis, electro-dialysis, Ion exchange and adsorption.

II. MATERIALS AND METHODS

Materials

All chemicals used in this study were of analytical grade and are acquired from Merck India and Sisco Research Laboratories Pvt. Ltd. (SRL), India. Following chemicals were used for this study:

- Zero Valent Iron
- Sodium Borohydride

Methods

The sampling was done at ceramic industrial area which is located at sector 51, Noida. Grab method of sampling for collection of samples was used. After sampling characterization was done by performing various tests such as pH, Electrical Conductivity, hardness, total dissolve solids, alkalinity, nitrate, chloride etc. afterwards experimental setup was organise and it was done by Central Composite Design (CCD) and Response Surface Methodology (RSM) where effect of pH, concentration of Zinc and doses were calculated and lower and upper limits of different variable was decided.. Further on synthesis of Nanoparticle was done in order to conduct batch study and isothermal study. For the synthesis of nanoparticle conventional reduction method was followed by reacting Zero Valent Iron with Sodium Borohydride. Then this was followed by batch study and isothermal study. This study was conducted by the help of two constant equation of Freundlich Isotherm and Langmuir isotherm. Then characterization of obtained nanoparticle was done.

III. RESULT

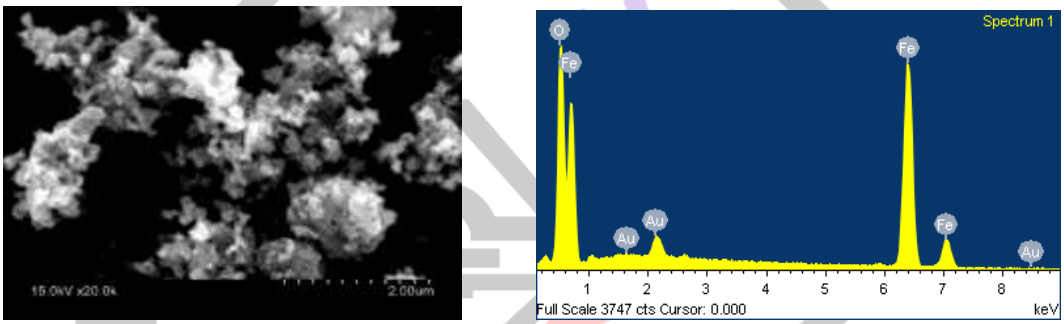
Result of Physico-chemical Parameter

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.

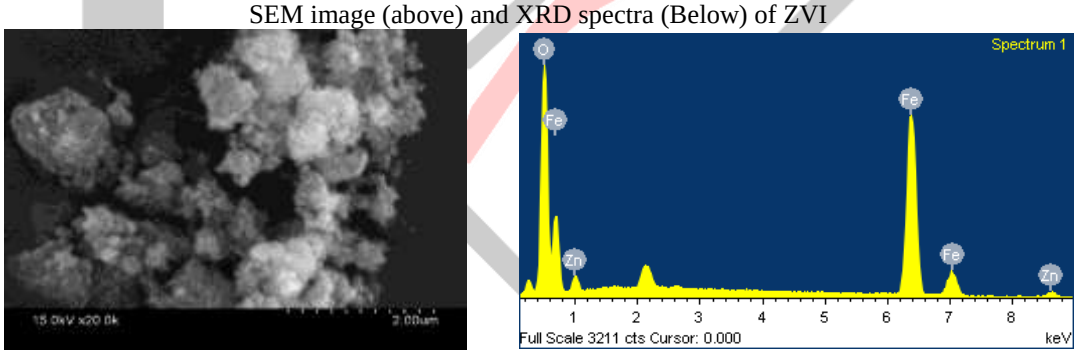
Characterization of zero valent iron (ZVI)

In order to analyse 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

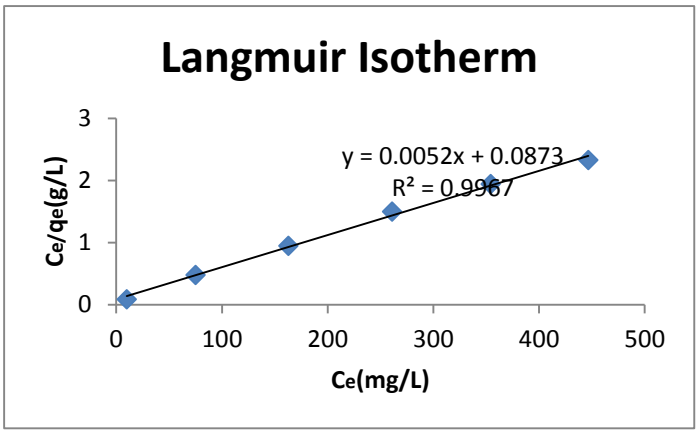


SEM image (above) and XRD spectra (below) of ZVI used for zinc removal

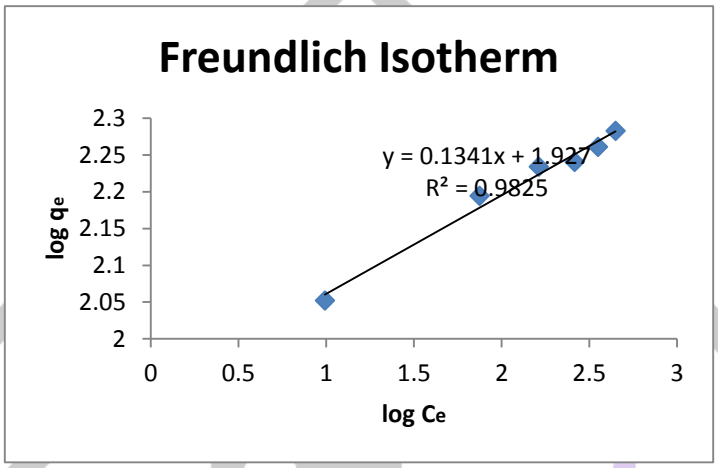
Optimization of ZVI

- 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

IV. 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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