



## Remediation of Nickel Ion from Soil and Water Using Nano Particles of Zero-Valent Iron (nZVI)

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### ABSTRACT

The management of nickel contaminated soil and water is a major current environmental issue. The main reason for pollution of the environment with nickel is the use of metal complexes in industry, agriculture and household. Nickel kept under environmental pollutant category due to their toxic effects in plants, human and food. There were more methods applicable for heavy metals removal are ion-exchange, adsorption by activated carbon, carbon nanotubes or bioadsorbents, membrane filtration or electrochemical processes. Each method has its limitations, from high investment or operational costs to low removal efficiency and big volume of produced sludge. Nanotechnology offers a number of emerging techniques much more effective and less costly that could work to immobilize contaminants. In the present study, nanoparticles zero valent iron was used to nickel removal from polluted soil and water. Nanoparticles of Zero-valent Iron was synthesized in lab using bottom-up with 0.1M FeSO<sub>4</sub>, 0.05M EDTA and 0.75M NaBH<sub>4</sub> solutions. TEM, SEM, DLS, DLS zeta, XRD and BET techniques were used to characterization of nZVI. The black coloured synthesized nanoparticles proved to have very small size (less than 100 nm), zeta potential -9.9mv, Surface area 20.96 m<sup>2</sup>/g. In this study we found that reduced the nickel content in spiked water up to 97% when the water is treated with nZVI (100 mg/10 ml of water) while in the case of spiked soil, nickel remediation was recorded nearly 85% after treatment of nZVI (100 mg/10 g of soil). The safely ability of iron to act as an electron donor or reducing agent.

**Keywords:** Nanotechnology, nZVI, Remediation, Nickel pollution, Soil and water.

### INTRODUCTION

The management of nickel and other pollutant in soil and water is a major current environmental issue. Nickel is naturally occurring in surface water and soil but some actives like industrialization, urbanization, use of chemical

fertilizer, pesticides and organic manures increase the nickel concentration (Alloway, 1995; Salt, 2000). Nickel is not only effect on human health as well as plants. The main toxic symptom produced by nickel is the chlorosis or yellowing of leaves usually followed by necrosis (Rathor *et al.*, 2014). There are many toxic effects on human health, like embryo

toxic effect, allergic reactions, nephrotoxic effects and contact dermatitis due to nickel (Menzel, 1987). There were more methods applicable for nickel removal are ion-exchange, adsorption by activated carbon, carbon nanotubes or bioadsorbents, membrane filtration or electrochemical processes. Each method has its limitations, from high investment or operational costs to low removal efficiency. In recent year, nanotechnology offers new things for management environmental pollution. Use of nZVI to remediate contaminated soil and water has received increasing amounts of attention within the last decade, primarily due to its potential for broader application, higher reactivity and cost effectiveness compared to conventional ZVI applications. The use of macro scale ZVI in subsurface PRBs is a well established technology for the reduction of both chlorinated hydrocarbons and toxic metals in contaminated ground water, a nZVI use exactly the same chemistry, but has advantage of having increased surface area and the rheological ability of nanoparticles to flow in the subsurface (Nurmi *et al.*, 2005) and has been found effective for the detoxification of organic contaminants such as polychlorinated biphenyls (PCB) (He and Zhao, 2005b; Wang and Zhang, 1997). The ability of iron to act as an electron donor or reducing agent is utilized in technique known as Fenton treatment techniques, where (Hong *et al.*, 2007).

## MATERIAL AND METHODS

### Synthesis of nZVI

Nanoscale Fe<sup>0</sup> particles were synthesized by adding 1.6 M NaBH<sub>4</sub> in a 1.0 M FeCl<sub>3</sub> solution with magnetic stirring (Wang and Zhang 1997). But the main drawback of this procedure, nanoparticles are not stable (colour change from black to yellow)

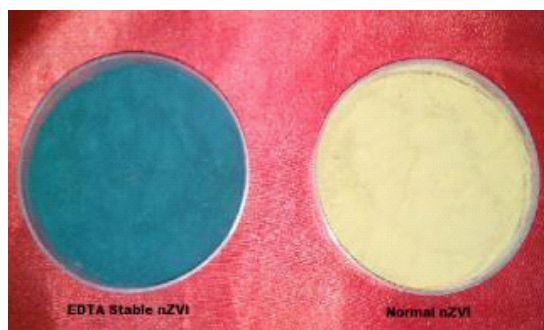


Plate-1: Photo of EDTA stable and normal nZVI

(plate 1). So we followed the procedure Murad *et al.*, 2010, in this procedure 150 mL of 0.1M FeSO<sub>4</sub> and 100 mL of 0.05M EDTA were mixed in a flask by using propeller mixing. The 100 mL of 0.75M NaBH<sub>4</sub> was added drop wise with continues staring into the mixture solution at room temperature (figure 1). Slowly the solution turned to black colour. The black coloured particles were filtered, washed twice with absolute ethanol, dried and pulverized.

### Characterization of nZVI

The particle size, size distribution and morphology of synthesized nZVI was measured with TEM (Transmission Electron Microscope) (JEOL, 100 CX, Japan TEM instrument). The phase identification of nZVI was determined by X-ray diffraction (XRD). Zeta potential and size were identified by DLS (HORIBA Scientific). The Brunauer-Emmett-Teller (BET) instrument was used for surface area measurement of sample (Model: Mumbai Surfer Ultra micropore, Trittech Instruments India Pvt.). The structural and morphological characterizations of the samples were accomplished using a SEM (scanning electron microscopy).

### Remediation of nickel in soil and water

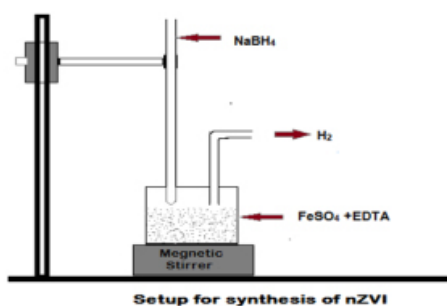
Laboratory experiments were conducted for the remediation of nickel in spiked soil and water using nZVI. The soil sample was sieved through a 2-mm sieve. Soil and water samples were spiked (levels 0, 25, 50, 75, 100 and 150 ppm) using NiCl<sub>2</sub> salt. Lindsay and Norvell (1978) method were used for determination of available nickel in soil pre and after treatment with nZVI. In this experiment 10g spiked soil was taken in a 25 mL of centrifuge tube then add 100mg of nZVI powder with 2 mL of distilled water. Sample was incubated for 7 days at 30°C. After incubation, 20 mL of DTPA solution was

Table 1: Remediation of nickel spiked water using nZVI

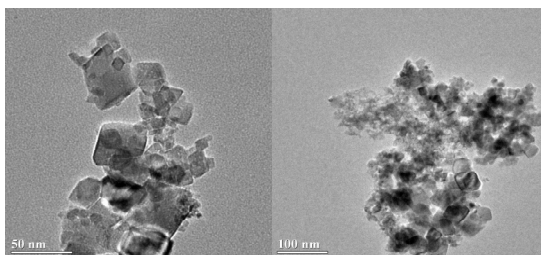
S. No	Initial concentration of Ni (mg L <sup>-1</sup> )	Final concentration of Ni (mg L <sup>-1</sup> )	Removal of Ni (%)
1	25	0.7	97
2	50	2.5	95
3	75	5.2	93
4	100	15.0	85
5	150	24.6	83

added and shaken for 30 minutes on shaker. After shaking centrifuge the sample for 15 minutes at 2000 rpm and filtered. In the case of water 10 mL of spiked water was taken in a 25mL of centrifuge tube then added 100 mg of nZVI powder. Sample was incubated for 7 days at 30°C. after incubation shaken for 30 minutes on shaker. After shaking centrifuge the sample for 15 minutes at 2000 rpm and filtered. Filtrate samples were taken for measurement of nickel on ICP-OES (Parkin Elmer Optima 2100). The removal efficiencies of nickel with nZVI were calculated using following equation-

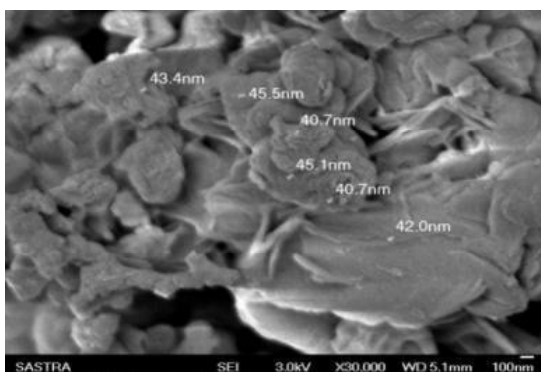
$$R (\%) = \frac{C - C_0}{C} * 100$$



**Fig. 1: Schematic diagram for synthesis of nZVI**



**Fig. 3: TEM micrograph of nZVI**



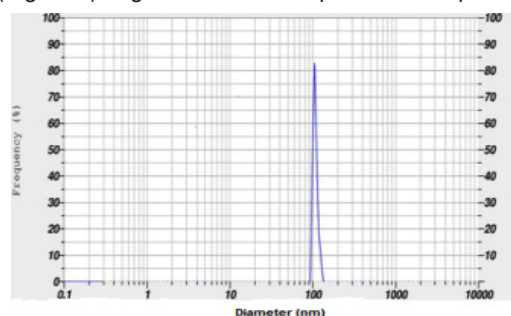
**Fig. 5: SEM micrograph of nZVI powder**

Where  $R (\%)$  is the removal efficiency,  $C$  and  $C_0$  ( $\text{mg L}^{-1}$  or  $\text{mg kg}^{-1}$ ) are the initial and final concentration of nickel treated with nZVI.

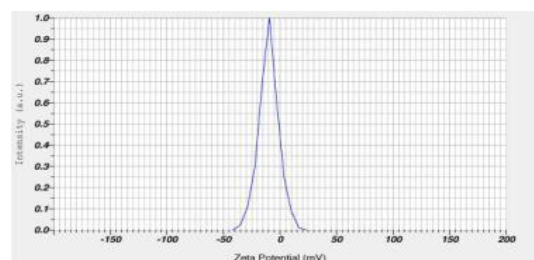
## RESULT AND DISCUSSIONS

### Characterization of nZVI

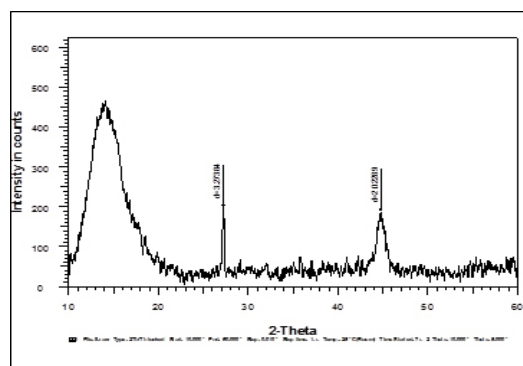
The mean hydrodynamic diameter was around 100 nm (Figure 2). TEM image of particles are spherical with the size ranging from 10 to 100 nm in diameter (Figure 3). The zeta potential value of nZVI was recorded -9.9 mv (Figure 4). The SEM micrograph of nZVI shows that the changes in particle shapes and sizes were distinctly visible (Figure 5). Figure 6 shows that powder XRD pattern



**Fig. 2: N Size (DLS) of nZVI powder**



**Fig. 4: Zeta potential of nZVI powder**



**Fig. 6: XRD of nZVI powder**

**Table 2: Remediation of nickel spiked soil using nZVI**

S. No.	Treatment Ni (mg kg <sup>-1</sup> )	DTPA Ni (mg L <sup>-1</sup> )	Final concentration of Ni (mg L <sup>-1</sup> ) treated with nZVI	Removal Ni (%)
1	0	0.60	0.02	96
2	25	4.90	0.70	85
3	50	8.30	2.50	70
4	75	9.10	2.80	69
5	100	12.40	6.17	50
6	150	18.70	12.2	35

of nZVI samples under ambient conditions. The broad peak reveals the existence of an amorphous phase of iron. The characteristic broad peak at 2 $\theta$  of 45 $^\circ$  indicates that the zero valent iron is predominantly present in the sample. The surface area of nZVI was 20.96 m<sup>2</sup>/g.

#### Remediation of nickel in soil and water

A perusal of the data presented in table 1 revealed that the application of nZVI reduced the nickel content in spiked water up to 97%. The removal efficiency of nickel in solution was recorded 51% with nZVI (Matysikova *et al.*, 2014). Stetter *et al.*, (2002) also studied that in the case of ground water; effective removal of nickel can be achieved using chelating ion exchange resins. In the case of spiked soil, nickel decontamination was recorded nearly 85% (Table 2). The removal efficiency was decreased with increasing the concentration of nickel in soil and water. Also the nZVI was used for removing of nickel from soil (Bazdanis *et al.*, 2011). Saleem *et al.*, (2011) found that the 74% nickel removed from low permeability soil using titanium electrode (Electrokinetic Remediation). Nickel concentration was reduced in spiked soil and water to (250 mg/10 g of soil) 75-92% and (500 mg/20 ml of polluted water) 99.6% respectively with CNPs (Rathor *et al.*, 2013).

Zero valent iron which is very useful tool to remove heavy metal from contaminated soil and water also have been studied in different condition (Groza *et al.*, 2009; Hojeong *et al.*, 2008; Kakarla *et al.*, 2008).

#### CONCLUSION

Nickel pollution is a very dangerous issue for environment. That nickel pollution not only affects the human health but also the quality of soil, water and plants. In this study we synthesized and characterized of nZVI powder and systematically investigated the removal efficiency of nickel from aqueous solution and spiked soil by varying concentration of nickel ion. This studied showed nickel contamination was removed up to 85% and 97% from contaminated soil and water respectively, with nZVI.

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