IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 20, Issue 5 Ser. I (Sept. – October. 2023), PP 56-63
www.iosrjournals.org

Ultrasound Assisted Advance Oxidation Process For Removal Of Nickle

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Abstract:
Nickel polluted wastewater is directly or indirectly discharged into the environment increasingly, especially in developing countries. It is difficult to remove nickel from wastewater using conventional methods. Efficient method like advanced oxidation process is an important breakthrough in the removal of nickel. This method is referred to as ultrasound assisted advanced oxidation process in the removal of nickel. This study investigated the use of Hydrogen peroxide, Fenton Reagent, ultrasound homogenously and heterogeneously. The removal efficiency of homogenous process and heterogenous process along with the process parameters like concentration of oxidant, effect of pH, Optimum dosage of Oxidants and time taken were investigated. Results indicated that removal efficiency is strongly dependent on the optimal pH and the dose of the oxidant. All the oxidants can removal nickel effectively from the wastewater but the maximum removal which provides desirable nickel quantity after treatment was obtained by heterogenous processes. At optimal pH:11Fenton reagent and Ultrasound process in combination with Hydrogen peroxide and Fenton reagent has shown 98%, 100% and 100% removal respectively.
Keywords: *Nickel; Advanced Oxidation Process; Hydrogen Peroxide, Fenton, Ultrasound; Optimum dose*

Date of Submission: 09-09-2023 Date of Acceptance: 19-09-2023

I. Introduction

Growing industrial development is leading to the production of contaminants that are seriously threatening the ecosystem and the contamination of water resources has been a worldwide environment problem. Heavy metals are the elements having atomic weights between 63.5 and 200.6 and specific gravity greater than 5 which are non bio-degradable. Toxic heavy metals of particular concern in treatment of industrial wastewater include copper, zinc, nickel, mercury, cadmium, lead and chromium. Among these different heavy metals, nickel is extensively utilized in the modern industry.

The tolerance limit of nickel in drinking water is 0.01 mg/L, and for industrial wastewater it is 2.0 mg/L. However, effluents of different industries contain higher concentrations of nickel than its acceptable limit. Nickel is well known heavy metal pollutant, which is present in effluents of electroplating industries to the tune of 20 – 200 ppm (Piyush kant pandey et al., 2007).

The intake of nickel in considerable concentrations may cause formation of free radicals in body tissue which leads to various DNA complications, serious lung and kidney problems, gastrointestinal distress, pulmonary fibrosis, headache, dizziness, dry cough, vomiting, extreme weakness, and direct exposition to nickel cause skin dermatites. So it is very essential to remove Nickel from soil, industrial wastewater and effluents.

Generally, the nickel wastewater is amenable to physical, chemical and biological treatment but is inefficient and involves high cost in removal of nickel. In this sense, procedure known as Advanced Oxidation Process (AOP) are being studied and applied to mineralize non-biodegradable organic compounds or oxidize bio degradable compounds, that converts them completely into CO_2 and H_2O (Hoffman et al., 1995). Advanced Oxidation Process (AOP) is defined as aqueous phase oxidation processes which are based primarily on the intermediacy of the hydroxyl radicals in the mechanism resulting in the destruction of target pollutant (Poulopoulos et al., 2006).

In the present work, synthetic nickel wastewater was prepared by Nickel Ammonium Sulphate for the concentration of 200 mg/L and was treated by Advanced Oxidation Process (AOP). The processes were carried out with Hydrogen Peroxide (H_2O_2), Fenton Reagent, and Ultrasound and with a combination of US + H_2O_2 and US + Fenton Reagent Further removal of nickel has been studied. Various process parameters like concentration of oxidant, effect of pH, Optimum dosage of Oxidants and time taken were investigated.

II. Materials and Methodology

Materials

Glassware: All glassware used in the study was of 'Pyrex' quality manufactured by Borosil glass work Ltd., Mumbai and marketed under the brand name 'Corning'.

Reagents and Chemicals

The reagents and chemicals used for the study were of AR grade which are Ammonium Hydroxide - concentrated (14 N) and 0.5 N, Hydrochloric Acid - concentrated (11 N) and 0.5 N, Citric Acid - 10 percent w/v in water, Dimethylglyoxime - I percent w/v in ethyl Alcohol, Ethyl Alcohol- 95 percent (v/v), Chloroform, Bromine Water- Saturated water with bromine.

Synthetic Nickel Wastewater Preparation

In order to prepare synthetic wastewater 1.35 g of ammonium nickel sulphate is dissolved in 1 liter of water to obtain concentration of 200 mg/L.

Instruments and Methods of Measurement

Nickel wastewater concentration was measured using thermo UV VIS Spectrophotometer of evolution model 201, Analytical procedure and operation of spectrophotometer is according to the procedure outline in the standards methods for examination of water and wastewater as per IS 3025 (Part 54) : 2003.

Nickel Removal

Nickel concentration of the wastewater was measured from the UV VIS spectrophotometer by using the wavelength of 445nm. Percentage reduction of nickel removal is calculated by the equation.

mg Ni/L= $\frac{\mu\text{g of Ni (in 100 mL of the final solution)}}{V}$ x 100, V = volume of the sample used in mL.

Ultrasound Reactor

Ultrasound reactor was used in this study, the tank is equipped with either 40 KHz or 25 KHz Industrials Ultrasonic, and incorporates thermostatically controlled heat. Solution was kept in a 1 liter measuring jar in the tank and tank is filled with water and digital timer is kept in the equipment to control the time.

Experimental Methodology

Experimental studies were conducted in two phases

Phase-1: In this phase, experiments were carried out by employing H_2O_2, Fenton Reagent ($Fe^{2+/}H_2O_2$) and Ultrasound. To a 500mL of sample, known amount of H_2O_2 or Fenton reagent was added and standard jar tests were conducted, sediment for 2 hrs, aliquot of sample collected and analyzed the sample for removal of nickel. Process parameters like dose of H_2O_2, Fenton reagent, pH and time were investigated to obtain optimum removal. Ultrasound reactor was filled with 1L of nickel wastewater and irradiated for 3-4 hours and time taken for nickel removal was investigated.

Phase-2: In this phase, experiments employing Ultrasound+H_2O_2 and Ultrasound + Fenton Reagent were carried out. In Ultrasound reactor filled with 1L of nickel wastewater, known amount of H_2O_2 or Fenton was added and irradiated for 3-4 hrs. Aliquot of sample collected and analyzed the sample for removal of nickel. Process parameters like dose of H_2O_2, Fenton reagent, pH and time were investigated to obtain the maximum removal of nickel.

III. RESULTS AND DISCUSSIONS

Treatment of nickel wastewater with Hydrogen peroxide (H_2O_2) process

Nickel wastewater was subjected to oxidation treatment with H_2O_2 at different dosages and pH to investigate removal of nickel and the results are presented in the form of graphs followed by description

Effect of Dosage

Varying doses of H_2O_2 from 5 g/L to 25 g/L was added to nickel solution of concentration of 200 mg/L, subjected to Jar Test procedure and analyzed for the percentage removal of nickel and the experimental results were shown in Figure 1.

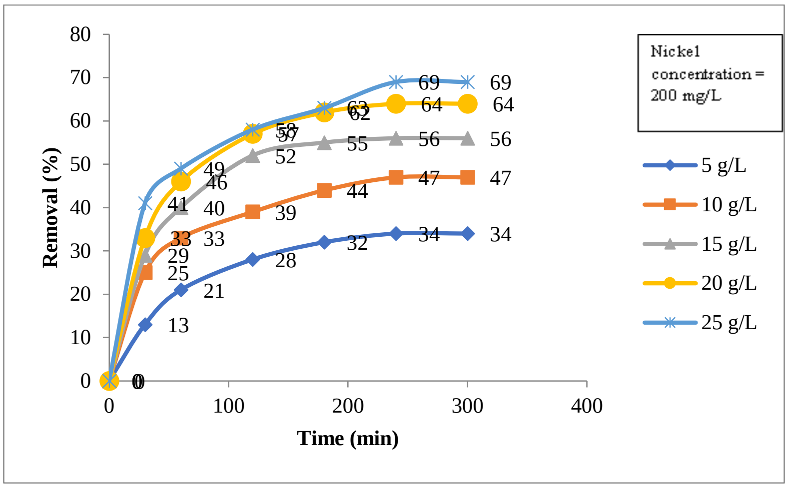

Figure 1. Effect of H_2O_2 Dosage on removal of Nickel

From figure 1, it was observed that 34% nickel removal was achieved at a dose of 5 g/L, 47% nickel removal was achieved at 10 g/L, 56% nickel removal was observed at 15 g/L, 64% of removal was observed at 20 g/L and 69% of removal was obtained at 25 g/L. As the dose increases, the removal of nickel also increasing and 69% removal were achieved in 240 min and with further increase of time the removal remained constant.

Effect of pH

Hydrogen peroxide dosage of 25 g/L which produced maximum removal of nickel was considered as favorable dose and the pH of wastewater was varied from pH: 3 to pH: 11 and was subjected to jar test to find the percentage removal of nickel and the experimental results are presented in figure 2.

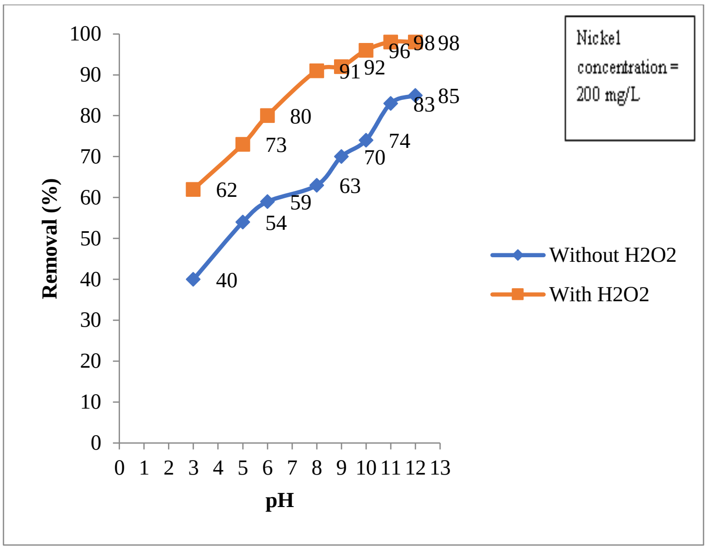

Figure 2. Influence of pH on the removal of Nickel by H_2O_2

From the figure 2, it was observed that maximum Nickel removal of 85% was observed at pH: 11 without H_2O_2 and 98% was observed with H_2O_2 at pH 11. Hence the pH: 11 were considered as favorable pH for the removal of Nickel from wastewater.

Optimum Dose

At optimum pH: 11, further experiments were conducted to determine the optimum dose by varying hydrogen peroxide dosage from 5 to25 g/L and were subjected to jar test to find the percentage removal of nickel and the results are as shown in figure 3.

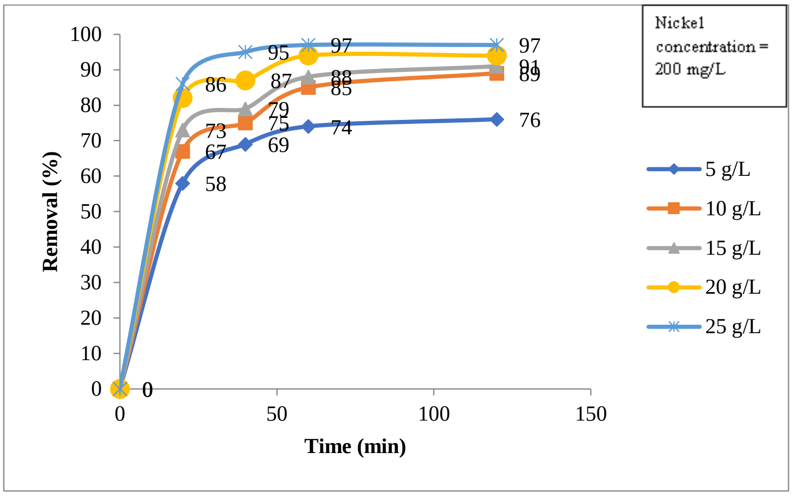

Figure 3. Effect of H_2O_2 dosage on removal of Nickel from wastewater at favorable pH

From figure 3, it was observed that 76% nickel removal was achieved at a dose of 5 g/L, 89% nickel removal was observed at 10 g/L, 91% nickel removal was achieved at 15 g/L, 94% of removal was achieved at 20 g/L and 97% of removal was achieved at 25g/L in 120 minutes. As the dose increases, the removal of nickel also increasing at optimum pH: 11. 97% removal is achieved in 60 min at 25 g/L at pH: 11. 25 g/L of H_2O_2 was considered as optimum dose and time taken for 97% removal was 60 min and with further increase of time the removal remained constant

Treatment of Nickel wastewater by Fenton (Fe^{2+}/H_2O_2) Reagent

Nickel wastewater was subjected to oxidation treatment with Fenton reagent at different doses and pH to investigate removal of nickel. In the Fenton Reagent process Ferrous Sulphate and Hydrogen Peroxide (Fe^{2+}/H_2O_2) was mixed in the proportion of 1:50 and the experiments were carried out and the results are presented in the form of graph.

Effect of Dosage

Varying doses of Fenton reagent was added and subjected to Jar test procedure and analyzed for the nickel removal, the experimental results are as shown in Figure 4.

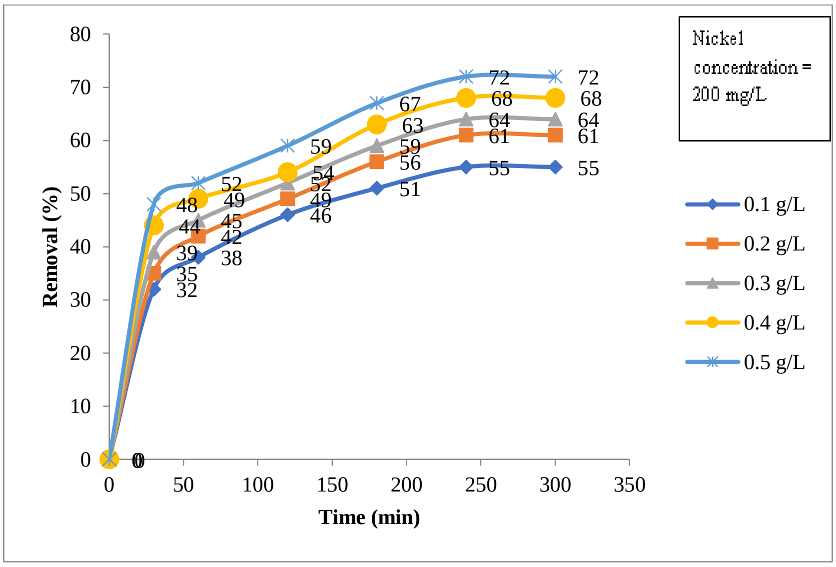

Figure 4. Effect of Fenton Reagent Dosage on removal of Nickel

From figure 4, it was observed that 55% nickel removal was achieved at a dose of 0.1 g/L, 61% nickel removal was observed at 0.2 g/L, 64% nickel removal was observed at 0.3 g/L, 68% of removal was observed at 0.4 g/L and 72% of removal was obtained at 0.5 g/L in 300 minutes. As the dose increases, the removal of nickel also increasing and 72% removal was achieved in 240 minutes and remained constant with further increase of time.

Effect of pH
From figure 2, favorable pH for removal was taken as 11 for 200 mg/L nickel concentration.

Optimum Dose
At optimum pH: 11, further experiments were conducted to determine the optimum dose by varying Fe^{2+} from 0.1 to 0.5 g/L and was subjected to jar test to find the percentage removal of nickel and the results were shown in figure 5.

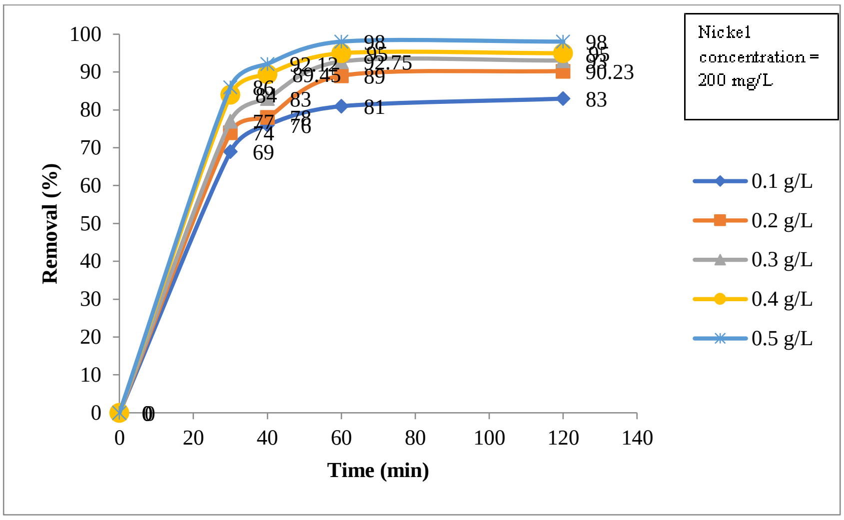

Figure 5. Effect of Fenton Reagent dosage on removal of Nickel from wastewater at favorable pH

From figure 5, it was observed that 83% nickel removal was achieved at a dose of 0.1 g/L, 90.23% nickel removal was observed at 0.2 g/L, 93% nickel removal was observed at 0.3 g/L, 95% of removal was observed at 0.4 g/L and 98% of removal was obtained at 0.5 g/L. As the dose increases, the removal of nickel also increasing at optimum pH: 11 and 98% removal is achieved in 60 min at 0.5 g/L at pH: 11. 0.5 g/L of Fenton reagent was considered as optimum dose.

Treatment of Nickel wastewater by Ultrasound (US) Irradiation
Ultrasound (US) experiments were conducted with US alone for treatment of nickel wastewater. Wastewater was irradiated under Ultrasound (US) alone and was observed for 5hrs of US treatment. The results are as shown in figure 6.

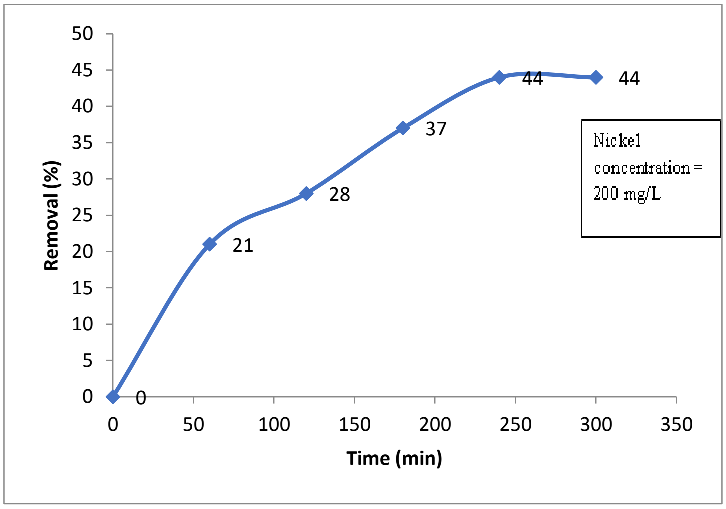

Figure 6. Removal of Nickel by Ultrasound Process

It was observed from the figure 6, that maximum removal of nickel of 44% was observed in 240 minutes of time.

Effect of pH

Nickel wastewater was subjected to oxidation treatment with ultrasound process at different pH values of pH: 3 and pH: 11 for two hours to investigate the removal of nickel and results are presented in figure 7.

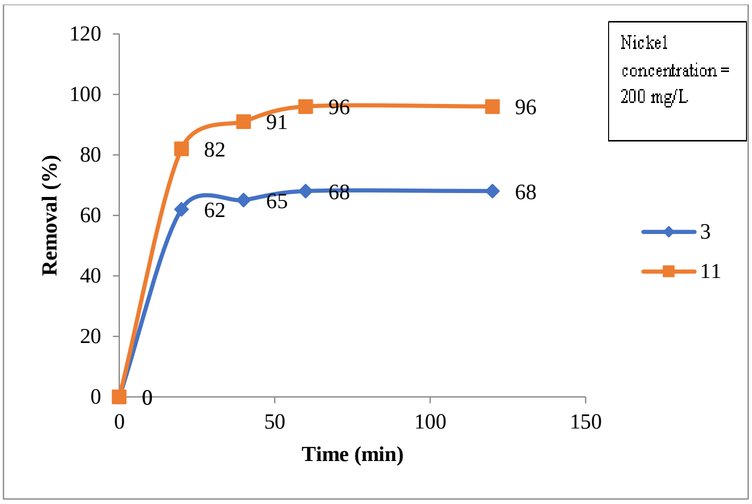

Figure 7. Removal of nickel by ultrasound process at pH: 3 and pH: 11

From the figure 7, that the maximum nickel removal of 96% was observed at pH: 11. However the pH: 11 were considered as favorable pH for the removal of nickel for further studies of oxidation assisted with ultrasound.

Treatment of Nickel wastewater by US+H_2O_2 process

Nickel wastewater was subjected to oxidation treatment with US+H_2O_2 process at different doses and pH values to investigate removal of Nickel and results are presented in the figure 8.

Effect of Dosage:

H_2O_2 dosage of 10 g/L and 15 g/L were added to two different nickel solutions of 200 mg/L concentration and subjected to US irradiation and analyzed for nickel removal and the experimental results were shown in Figure 8.

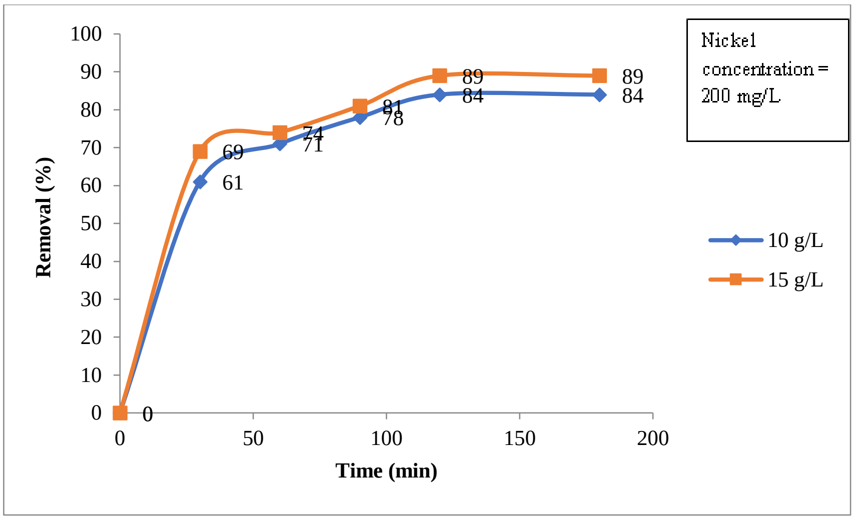

Figure 8. Removal of Nickel from wastewater varying the US irradiation period by US+H_2O_2 process.

From figure 8, it was observed that 84% removal was achieved at 10 g/L and 89% removal was achieved at 15 g/L of H_2O_2 dose coupled with ultrasound oxidation process in 60 minutes and remained constant with further increase of time.

Effect of pH

The percentage removal of nickel at optimum dose of H_2O_2 in combination with Ultrasound irradiation process maintained at pH: 11 is as shown in figure 9.

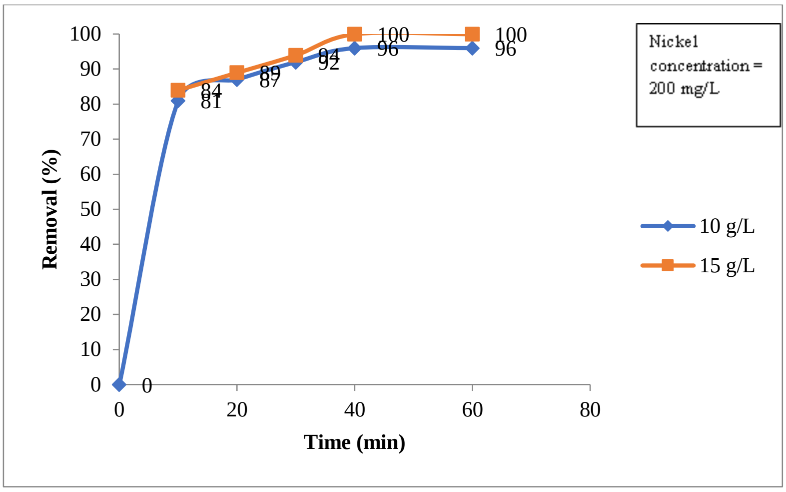

Figure 9. Removal of nickel from wastewater keeping H_2O_2 dosages of 10 g/L and 15 g/L as constants and varying the US irradiation period by US+H_2O_2 process for pH: 11

From the figure 5.33, it was observed that 96% removal of nickel was achieved at 10 g/L and 100% removal of nickel was achieved at 15 g/L in 40 minutes when H_2O_2 coupled with US at pH: 11 and with further increase of time the removal remained constant.

Treatment of Nickel wastewater by US + Fenton Reagent Process

Nickel wastewater was subjected to oxidation treatment with US + Fenton process at different doses to investigate removal of nickel and results are presented in the form of graph.

Effect of Dosage

Fenton dosage of 1:50 proportion was used. Fe^{+2} of 0.2 g/L and 0.3 g/L were added to two different nickel solutions of 200 mg/L concentration and subjected to US irradiation and analyzed for nickel removal and the experimental results were shown in Figure 10.

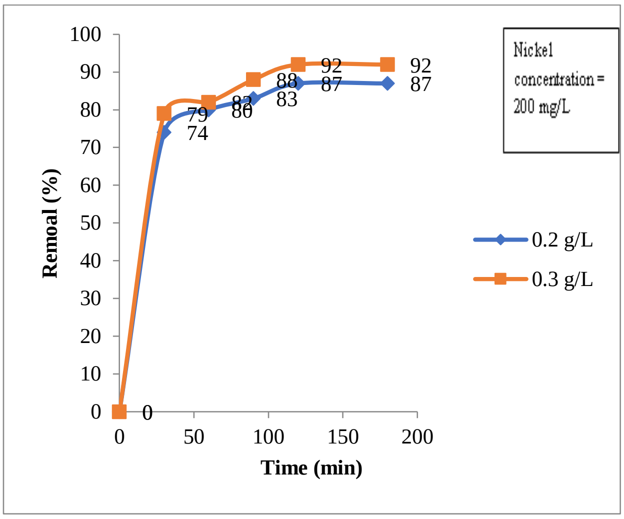

Figure 10. Removal of nickel from wastewater keeping Fe^{+2} = 0.2g/L and Fe^{+2} = 0.3 g/L as constants and varying the US irradiation period by US + Fenton process.

From figure 10, it was observed that 87% removal of nickel was achieved at 0.2 g/L and 92% removal was achieved at 0.3 g/L in 60 minutes when Fenton reagent coupled with US and with further increase of time the removal remained constant.

Effect of pH

The percentage removal of nickel at optimum dose of Fenton reagent in combination with Ultrasound irradiation process maintained at pH: 11 is as shown in figure 11.

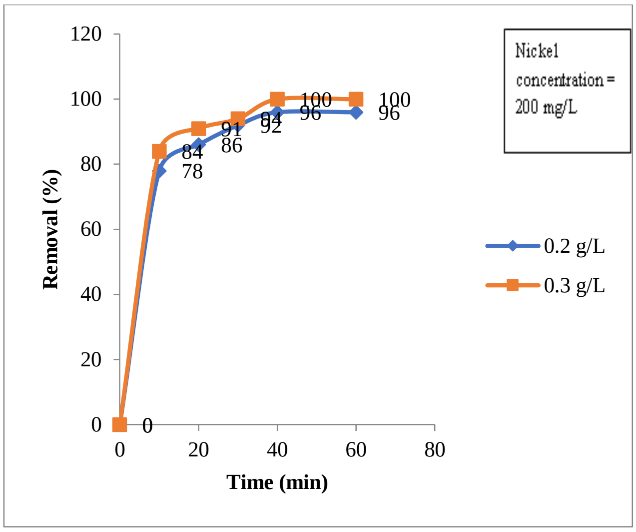

Figure 11. Removal of nickel from wastewater keeping Fe^{+2}=0.2 g/L and 0.3 g/L as constants and varying the US irradiation period by US + Fenton process at pH: 11.

From the figure 11, it was observed that 96% removal of nickel was achieved at 0.2 g/L and 100% removal of nickel was achieved at 0.3 g/L in 40 minutes when Fenton reagent was coupled with US at pH: 11 and with further increase of time the removal remained constant.

IV. CONCLUSIONS

It can be concluded from the from the data obtained through the present study, that the Advanced oxidation process are eco-friendly to reduce the pollution load of wastewater as bio recalcitrant waste constituents are degraded rather than concentrated are transferred into different phases. No secondary waste materials were generated and there is no need to dispose of materials. The oxidants like Hydrogen Peroxide, Fenton reagent, ultrasound process individually and combinedly are effective in removal of Nickel from wastewater. Even in case of not meeting required maximum concentration after treatment by some methods such as H_2O_2, Fenton, Ultrasound, H_2O_2+Ultrasound and Fenton + Ultrasound, at optimal pH: 11, heterogenous processes such as Fenton, H_2O_2+Ultrasound and Fenton + Ultrasound have shown desired quality in effluent or 100% removal in the less time and at optimum dosages.

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