

# Removal Efficiency of Heavy Metals through Modified Jute Fiber Adsorbent

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**Abstract:** The benefits of expanding the life cycle of an adsorbent can reduce the cost and environmental impacts in waste adsorbent disposal and adsorbent fabrication, which gives value to the waste. In this study, the extending lifetime of jute fiber-based biosorbents for sequentially remedying heavy metal ions was demonstrated by a simple and practical chemical conversion. The potential of a lignocellulose fiber, jute, was assessed for adsorption of heavy metal ions like Cu (II) and Ni (II) from their aqueous solutions. The fiber was also used as an adsorbent after chemically modifying it, by oxidizing with hydrogen peroxide. The modified jute fibers gave higher metal ion adsorption. Sorption of metal ions was studied as a function of time, temperature, pH and concentration of metal ions in solution. The metal ions sorption was best fitted in the Langmuir adsorption isotherm model. At the optimized conditions, almost complete sorption of Cu (II) and Ni (II) ions was observed for oxidized jute fiber. The pH effect was investigated between 6-9. The optimized dosage of the adsorbent was 2g and the optimized contact time was 120 minutes. The removal efficiency of metals through modified jute fiber at optimum condition was 88.6% and 97.4% respectively. The most meaningful contribution of this study was to provide a new approach to an adsorbent regeneration and waste disposal for developing a sustainable water treatment technology.

**Keywords:** Jute fibers; Heavy metals; Adsorption; Langmuir; Sustainable technology

## I. INTRODUCTION

Globally the demand for water is increasing day by day to satisfy the enhancing requirements of food production, development, and sustenance of human population growth. In this respect, Fast trail industrialization and uplifting values of living have authorized their own role. Currently, water accessibility has become a job of social, environmental, political, and economic factors [1]. Water from domestic, industrial, and agricultural activities is released as wastewater into the environment. It is contaminated with a large assortment of contaminants dependent on its source. Metal contamination, in the aquatic environment as well as for human beings, has engrossed global attention due to its ecological toxicity, persistence, and abundance in recent times[2]. Hazardous chemicals waste like heavy metals has been disposed into rivers in abundance because of the rapidly growing population, increasing domestic activities and expanding agricultural and industrial productions [3]. Heavy metals are components of the earth's crust. Water sources are contaminated due to erosion and alteration in geological conditions of weather that brings traces of metals from sediments to the sources ([4]. In addition to this, water contamination is also caused by effluent disposal of liquids, deposition due to atmospheric conditions, and terrestrial run-off [5]. The metallic behavior in natural water results due to the composition of substrate sediment and the chemistry of water. Heavy metals may face various changes in their composition during transport. These changes occur due to precipitation, sorption, dissolution and complexation phenomena which also affect their bioavailability and behavior [6]. The heavy metals such as (Cu), (Zn), (Ni), (Pb), (Cr), and (Cd) are found in streams, often encountered in chemical industries and factories. In this study, heavy metals Copper and Nickel having strong metallic properties are discussed and also exist in various oxidation states such as Cu (II) and Ni (II). The excessive amount of Copper Cu (II) is accumulated in the liver and also results in gastrointestinal problems. The exposure of Nickel Ni (II) can elevate the risk of lung cancer and Paranasal sinus and nasal cavity cancers. Due to its increasing generation rate and the adverse health effects toward humans, it's going to receive special attention at present and in the future [7]. World Health Organization permits 0.07 mg/L of Nickel and 2 mg/L of Copper concentration in drinking water at the maximum level. Therefore, the removal of copper and nickel from wastewater is essential for human consumption and for aquatic life survival. Various techniques are developed for copper and nickel removal under a different set of experimental conditions such as chemical precipitation, membrane filtration, and oxidation. The advantage and disadvantages are also reported under applied techniques where the economical factor is also considered on top priority for the applications of these techniques. There is a need for techniques that should be environment-friendly, low costing and easy in operation. The adsorption technique is getting more interest from the researchers owing to its low cost and quick accessibility of raw material organic and inorganic origin to remove trace metals from water and wastewater. Moreover, there is a need to manage and recycle waste products and or use these products for fruitful results. The adsorption method is more effective over others due to its several advantages like wide application, economic, environmental friendliness, and ease of operation. Furthermore, it does not cause secondary pollution. Bio-adsorption is the most efficient and economical because it does not need any sort of energy for wastewater treatment

[8]. From literature reviews, the different adsorbents used for the removal of Cu (II) and Ni (II) from aqueous solutions such as Orange peel and Sunflower hull [9], Barley straw modified with citric acid [10], Coconut shell [11], Garden grass (raw) [12], Lentil shell, Wheat shell and Rice shell [13], Sawdust [14], Olive stone (raw) [15] and Rice straw (HNO<sub>3</sub>-NaOH) [16]. The biopolymeric waste of agriculture holds a variety of functional groups such as the hydroxyl groups, which can be reached for conceivable improvement in the removal of metal ion adsorption [17]. Amongst these adsorbents' jute fiber is one of them which is used for the water treatment for the removal of trace metal. Jute fiber falls in the category of abundant, widespread, cost-effective and easily available raw materials encompassing cellulose, rich in hydroxyl functional group (OH, 58–63 %), as the main component [18]. In recent decades Pakistan has been facing basically in natural difficulties related to an imbalanced financial and social improvement. Every city of Pakistan is facing erratic, impromptu extension because of a move of the population from rural to urban zones which decline the circumstance to adapt up to this test. Access to clean drinking water is restricted in creating nations and individuals may, along these lines, devour polluted water [18], [20] In Pakistan, the surface and groundwater contaminations are the side-effects of different industries and commercial activities, for example, electro plating, passing on synthetics, manures, pesticides, concrete, petrochemical, mining, and others. The release of waste water effluents, metropolitan sewage, ranch, and urban squanders conveyed by channels and trenches to waterways exacerbates and widens water contamination [21],[22]

Its availability and the lower cost make it very easy to adopt for the water treatment with simple modification before application. In this study, simply modified jute fiber was used for the water treatment to determine the removal efficiency of trace metal concentrations from the synthetic water. This study was carried out to evaluate the adsorption performance of Modified jute fiber adsorbent for the removal of Cu (II) and Ni (II) in water. The objectives of this study were to prepare Jute fiber as adsorbent modified by H<sub>2</sub>O<sub>2</sub> (50%) and to evaluate heavy metal removal using Modified Jute adsorbent.

## II. MATERIALS & METHODS

### A. Materials

CuSO<sub>4</sub> 5H<sub>2</sub>O, NiSO<sub>4</sub> 7H<sub>2</sub>O were the substantial metal salts. All the additional chemicals used were H<sub>2</sub>O<sub>2</sub> (50%), NaOH and HCL. The solutions of copper and nickel around 1000 mg/L in nitric acid were bought from Fisher Scientific, UK. The solutions of aqueous metals were organized in the laboratory grounded on metal adsorption. Every metal solution was watered down with distilled water to get the anticipated initial concentrations.

### B. Preparation of Adsorbent

Jute fiber collected from a local market of Hyderabad city. Then the fiber cleaned, dried, cut into the uniform length of 1 cm and subjected to chemical modifications

#### a) De-hydration Jute fiber

The jute fiber collected from the local market. The first method was the dehydration of other jute fiber. For this, the jute fiber cut into small pieces. Then it washed with distilled water for removal of suspended impurities and dirt. The next step was to dry the jute fiber for twenty-four hours so that the moisture content removed from it. After that, the jute fiber kept on chemical oxidation

#### b) Oxidation of jute fibers

The higher amount of H<sub>2</sub>O<sub>2</sub> used than its normal amount used in oxidative bleaching of jute so that the desired whiteness could be achieved [23]. The objective was to modify the jute fiber. The oxidation of the functional OH groups of celluloses that were present in jute to COOH groups, which resulted in a weak cationic ion-exchanger. 100 g of the jute fiber added in 2 liters solution that contains 12 g (50 %) of H<sub>2</sub>O<sub>2</sub> and 1g of NaOH at room temperature and a pH of 11. After that, slowly the temperature raised to 85°C. The treatment process continued for the time period of 2 h. Then, the material was filtered. The material washed with hot water thoroughly. Then again the material washed with cold water. Finally, the material dried in an oven at 50°C overnight and used as an adsorbent.

### C. Batch Adsorption Studies

Different concentrations ( 0.5ppm, 1ppm, 5ppm, 10ppm, 20ppm) of Cu (II) and Ni (II) solutions working volume of 100 ml were prepared and then brought in a round bottom flask with the weighted amount of 2g of adsorbent (Modified Jute fiber) and stirred at 100 rpm for 120 minutes on Shaker. NaOH and HCl were used to adjust the pH of the solution. The effect of different metal concentrations, adsorbent dose, shaking time and pH values were investigated and the residual Cu (II) and Ni (II) concentrations were analyzed on the atomic absorption spectrophotometer (AAS).

#### Adsorption Capacity Calculation

The percent adsorption was calculated by using the following equation;

$$Q_e = \frac{(C_o - C_e)}{m} \times V \dots\dots\dots \text{Equation 1}$$

Where:

- Q<sub>e</sub>=Removal Capacity (mg/g),
- C<sub>o</sub>= Initial concentration (mg/l),
- C<sub>e</sub>=Final concentration (mg/l),
- V= Volume of the solution (l),
- m= Mass of nano particles (g).

### III. RESULTS

#### A. Characterization of Adsorbent

Fourier Transform Infrared Spectrometry (FTIR): The infrared spectrum of absorption or emission of a solid, liquid or gas is obtained through this technique. It simultaneously collects over a wide range of spectral and high-spectral-resolution data. This measures intensity over a narrow range of wavelengths at a time. From the FTIR analysis, the acidic utilitarian gatherings present on the jute fiber surface were: carboxyl, carbonyl, lactones, and sulfur gatherings. These gatherings had been accounted for to upgrade metals adsorption [24], [14]. In Fig. 1, the FTIR range of the crude /raw fiber obviously shows the different peaks and bands in the area of 3332 cm<sup>-1</sup>, 1732 cm<sup>-1</sup>, and 2919 cm<sup>-1</sup> because of O-H extending vibration, C=O extending vibration and C-H extending vibration separately. These functional groups are because of the hydroxyl bunch in cellulose, carbonyl gathering of acetyl ester in hemicellulose and carbonyl aldehyde in lignin [8]. In Fig. 2, the top peak at 1732 cm<sup>-1</sup> and also different peaks for example 1594 cm<sup>-1</sup> and 1244 cm<sup>-1</sup> have totally vanished upon compound treatment with Hydrogen peroxide H<sub>2</sub>O<sub>2</sub> (50%). This perception shows that Hydrogen peroxide H<sub>2</sub>O<sub>2</sub> (50%) effectively cooperated with jute fiber and evacuated some surface debasements/waxy substances from the surfaces of the filaments which prompted improve the attachment and similarity of jute fiber to the overwhelming metals.

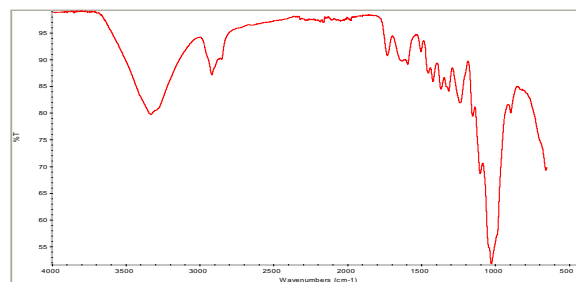


Fig. 1: FTIR Spectrum of Raw Jute Fiber

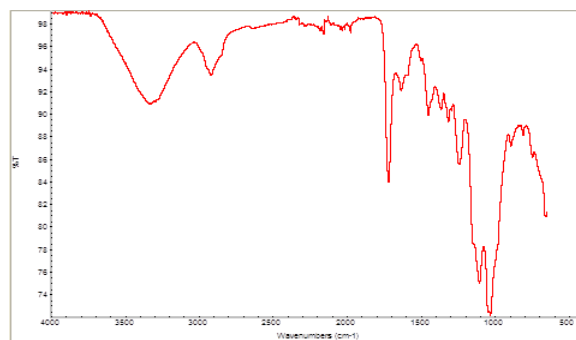


Fig. 2: FTIR Spectrum of Modified Jute Fiber

#### B. Adsorption Isotherms

The Langmuir adsorption isotherms of copper and nickel adsorption are displayed in Fig 3 and Fig 4. From the graph (C<sub>e</sub>/q<sub>e</sub>) vs. C<sub>e</sub> showed a straight line. The empirical constant could be obtained from the kinetic data using the equation. The ‘C<sub>e</sub>’ (mg/L) represents the equilibrium concentration, ‘q<sub>e</sub>’ (mg/g) represents the amount adsorbent at equilibrium, ‘a’ represents the constant related to adsorption capacity, and ‘b’ is the constant about the energy of adsorption [24].

$$\frac{1}{q_e} = \frac{1}{q_m} + \frac{1}{q_m b} \cdot \frac{1}{C_e} \quad (\text{Langmuir Isotherm}) \dots \dots \dots \text{Equation 2}$$

Table 1: Isotherm constants			
Isotherm Model	Isotherm Constant		R <sup>2</sup>
Langmuir Isotherm	Adsorption capacity q <sub>m</sub> (mg/g)	Adsorption rate b (lit/mg)	0.968
	0.457	129.40	
Langmuir Isotherm	Adsorption capacity q <sub>m</sub> (mg/g)	Adsorption rate b (lit/mg)	0.995
	0.408	47.387	

The adsorption equilibrium data of Cu (II) and Ni (II) by using Modified Jute fiber adsorbent fit the Langmuir Isotherm Model. In the present work, the Langmuir model gives better values of adsorption for both heavy metals. The use of the Langmuir model to the adsorption isotherm demonstrated that model furnished magnificent acceptable wellness with high R<sup>2</sup> values (0.968 and 0.995) as appeared in Fig 3 and Fig 4 individually.

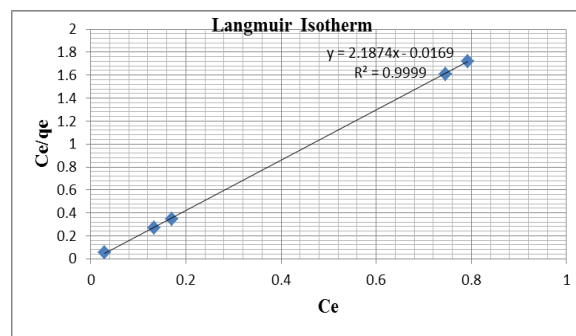


Fig 3: Langmuir Isotherm Model for Cu (II)

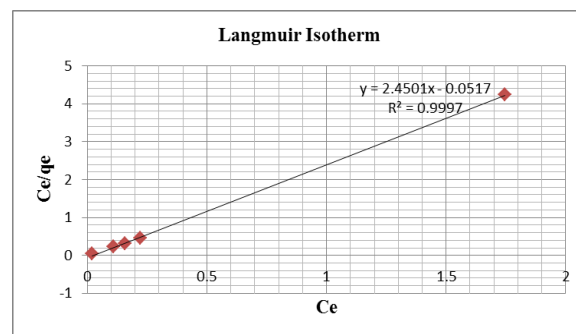


Fig 4: Langmuir Isotherm Model for Ni (II)

C. Removal of Copper Cu (II) and Nickel Ni (II) by Modified Jute Fiber

a) Effect of Contact Time

Time is a major factor in the adsorption of heavy metals from their respective solutions until equilibrium is reached. This experiment was carried out in order to detect the time needed for the biosorption process between modified jute fiber (MJF) and heavy metals (Copper and Nickel) to reach equilibrium. Time intervals studied were 30 min, 60 min, 90min, and 120 min. As literature review depicted that the contact time for adsorption is taken 2 hours [25], [26]. As appeared in Fig 5, the sorption of Cu (II) by means of MJF was fast. During an initial couple of moments, the rate was exceptionally quick; 89% removal was accomplished in the initial 30 min, thereafter the pace of sorption eased back down until it arrived at equilibrium. This presentation could be because of the way that quick mass exchange on the external surface of the adsorbent has occurred first, a while later a slower inner dispersion process has begun to happen [27]. The removal % has marginally expanded up to 89.65%

after 90 mints. The sorption of Ni (II) by means of MJF was exceptionally quick at pH 5.5 as appeared in Fig 5. The 94% removal efficiency was accomplished in initial 30 mint At the start of the sorption procedure, the dynamic locales on the outside of the sorbent are as yet vacant; in any case, alongside time the dynamic destinations begin to get immersed by the overwhelming metal particles; in this way, the sorption rate gets slower[28]

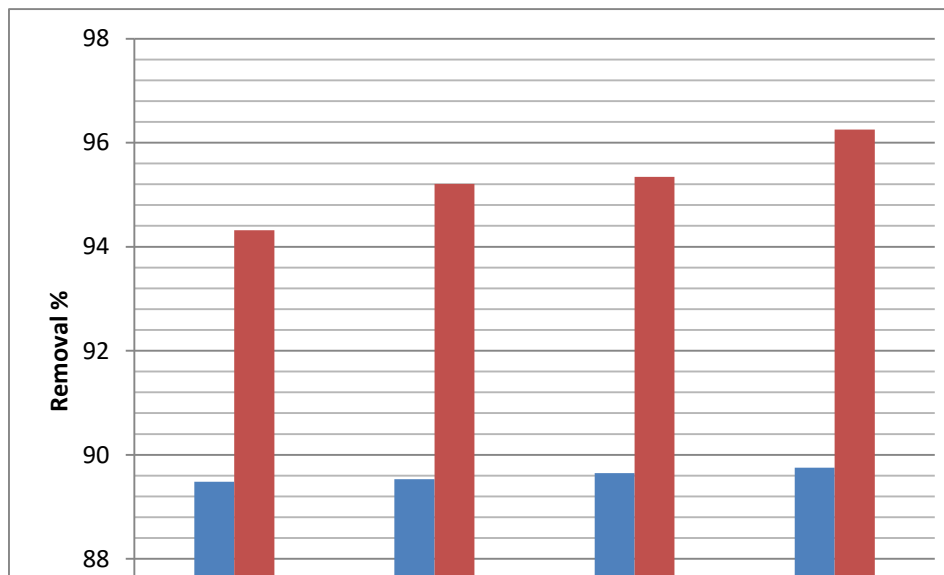


Fig 5: Effect of Contact Time

b) *Effect of Adsorbent Dosage*

A batch study was conducted for a range of doses of modified jute fiber adsorbent, in order to assess the impact of the sorbent dose on the Cu (II) and Ni (II) uptake. The doses were selected as; 0.5 g, 1g, 1.5 g, 2.0 g, and 2.5 g respectively. The effect of adsorbent dosage is an important parameter in deciding the economy of material. The economy of the material was studied on five different dosages from 0.5 to 2.5g/l while keeping the other parameters constant i.e. 10ppm at pH 3.5 of Cu (II) and pH 5.5 of Ni (II) agitated for 120 minutes for finding the metal removal efficiency. As indicated the percent of Cu (II) removal was expanding with the expansion in the MJF portion until it stretched around 29.43 to 88.6% at the portion 2.5g/l as shown in f. The percent of Ni (II) was also expanding with expanding the MJF portion. The removal efficiency at 0.5 to 2.5 g/l was 90 to 97%. At that point would, in general, keep steady as altered jute fiber was expanded up to 2.5 g/l, as introduced in Fig 6. This could be because of a condition of balance between the bio-sorbent and the overwhelming metal forestalling the bio-sorbent from further bio-sorption [29].The starting augmentation in adsorption limit with increment in adsorbent measurements was normal, since the number of adsorbent increments and in this manner progressively surface regions were accessible for metals connection. The same pattern was accounted for by[30]

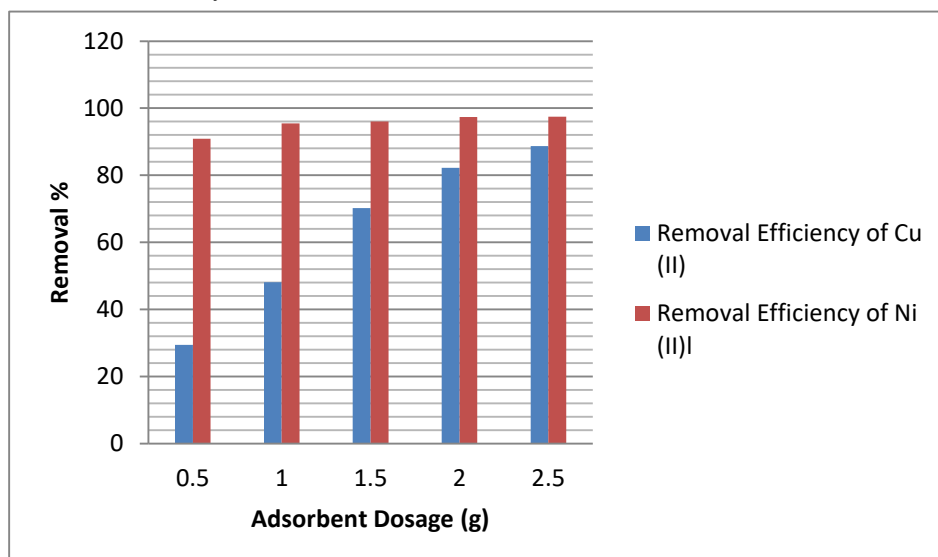


Fig 6 : Effect of Adsorbent Dosage

c) *Effect of pH Value*

The pH value of the solution is a significant parameter in the adsorption process. Fig 7 delineates that at low pH, in the scope of 4-5, adsorption of Cu (II) by using MJF was moderately low in the removal efficiency of 29%-48%. At higher pH 5.5 to 8.5, the removal % of Cu (II) has amazingly expanded to stretch around 90%. While at pH 7 the removal% has additionally expanded to arrive at 96%. The removal of metal particles from solution arrangement by adsorption has relied upon the pH of the

arrangement since it influenced adsorbent surface charge, level of ionization of the practical gatherings, and metal particle speciation[31]. Fig 7 likewise showed that at low pH of 5, adsorptions of Ni (II) by using MJF was generally high in removal efficiency of 90%. At higher pH in the scope of 6.5 to 8.5, the removal % of Ni (II) has amazingly expanded to stretch around 97%. Though pH 7 the removal % has additionally expanded to arrive at 97%. Also, the pH of a solution has an impact on the solubility of the metal ions. To illustrate, as the pH increases, the solubility of metal ions decreases; hence, facilitating the sorption process [32], through co-precipitation on the surface of the adsorbent [33]

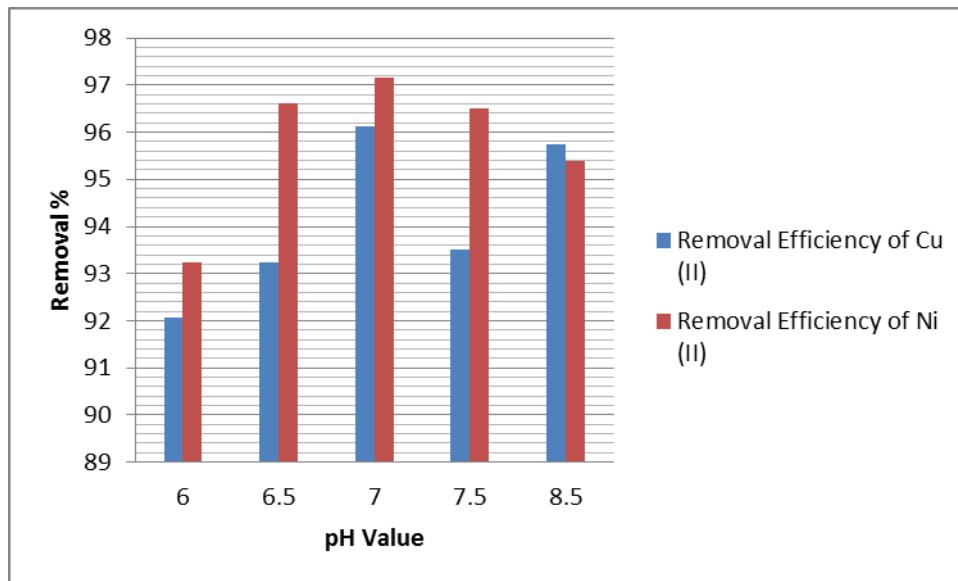


Fig 7: Effect of pH Value

d) *Effect of Initial Concentration*

Adsorbate concentration is an important factor in the adsorption process. The effect of initial concentration was analyzed by adding a fixed amount of Cu (II) and Ni (II) concentration ranging from 0.5 - 20mg/l, While the other optimized parameters 2g/l of adsorbent dose at pH 7.5 was agitated for 120 minutes at rotary shaker for studying the behavior of metal removal efficiency respectively. It is obviously shown from Fig 8 that the % removal relatively decreased with the continuously increasing Cu (II) concentration. At high concentrations of Cu (II), such as 20 mg/l the metal uptake was low compared to lower concentrations of Cu (II). As the initial concentrations of metals were increased, the uptake by MJF has increased to reach 92.0% at an initial concentration of 10 mg/l. This is attributed to the competition between the increasing metal ions on the available active sites on the surface area of the adsorbent. Upon the increase of metal ions, while the dose of adsorbent is kept constant, the available active sites get rapidly saturated [34]. It is obvious from the figure that the % removal relatively decreased with the continuously increasing Ni (II) concentrations. To illustrate, at a high concentration of Ni (II), such as 20 mg/l the metal uptake was low compared to lower concentrations of Ni (II).

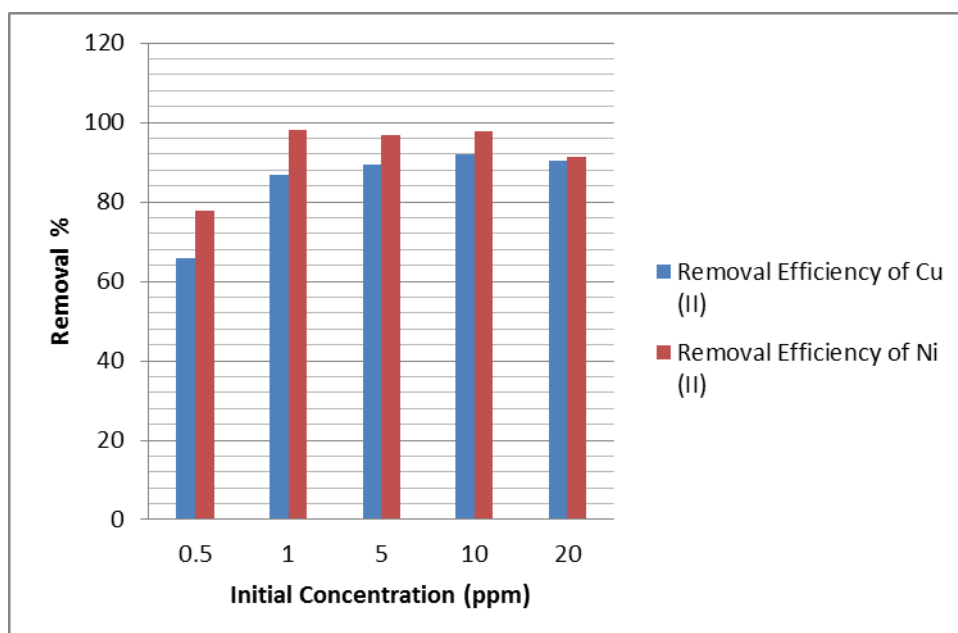


Fig 8: Effect of Initial Concentration

#### IV. CONCLUSIONS

The outcomes from the present examination showed the capability of hydrogen peroxide H<sub>2</sub>O<sub>2</sub> (50%) adjusted jute fiber for the removal of substantial metals, for example, copper and nickel. The aftereffect of this investigation demonstrates that the adsorption of both metal particles in Modified Jute fiber is an adsorption procedure. MJF was modified by hydrogen peroxide H<sub>2</sub>O<sub>2</sub> (50%). Arrangement of new utilitarian groups including nitrile, Carbonyl, carboxyl was affirmed by FTIR. Group study was done and MJF at upgraded states of starting fixation 10mg/l at pH 7 with adsorbent dose 2 grams removed 90% of Cu (II) and Ni (II) from their solutions. The adsorption information was investigated utilizing the Langmuir isotherm model. The estimations of R<sup>2</sup> discovered were (0.968 and 0.995) for the Langmuir.

#### V. RECOMMENDATIONS

In current study, the modified jute fiber used as adsorbent for removal of Cu (II) and Ni (II) metals. Different parameters analyzed through batch adsorption. In future column study analysis can be done using Modified Jute Fiber. Making this beneficial for local community at domestic level filters can be made to address to reduce heavy metals levels from wastewater. The regeneration of adsorbent can be done for further use and cost effective.

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