CHAPTER – II

LITERATURE REVIEW
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Wastewater from Industries and residential areas must ultimately be return to receiving waters or to the land. The complex question of which contaminants in wastewaters must be removed to protect the environment and to what extent must be answered specifically for each case. This requires analysis of local conditions and needs together with the application of scientific knowledge, engineering judgment based on past experience. Thus, in this chapter, an attempt has been made to review the literature covering sources of metals and their impact on environment and human health, treatment options available, feasibility of the systems and work carried out by researchers in the related areas.

2.1 INTRODUCTION

Metals are elements and cannot be destroyed. But they do bound to other elements and then show properties different from the parent metal. In aquatic systems, the trace metals may be present in both soluble and insoluble forms within the water column, sediments and the biotic tissues. The presence of heavy metals in the environment is a major concern due to their toxicity to many life forms. Unlike organic pollutants the majority of which are susceptible to biological degradation. Heavy metals will not degrade into harmless end products and hence are accumulated by living organisms. Therefore, it is necessary to treat the wastewater before being discharged into receiving bodies.

2.2 SOURCES OF METALS

Even though the natural sources contribute metals to environment, mobilization of heavy metals in the environment due to industrial activity is of serious concern. The amount of heavy metal ions released to the environment has been increasing significantly resulting from industrial activities and technology development. Increased use of metals and chemicals in processed industries as resulted in generation of large quantities of effluent that contain high level of toxic heavy metals. The industrial effluents from mining, electroplating, mineral
processing, extractive metallurgical operation, fertilizer industry, paper and paper board mills etc., commonly contain copper, nickel, zinc, cadmium, chromium which are not biodegradable and their accumulation in ecological system can cause harmful effects to human, animal and plants. Thus, mainly the human activity is responsible for addition of enormous quantities of metals into environment and for more clarity the sources are summarized in further sections.

2.2.1 NATURAL SOURCES

Natural sources include volcanoes, forest waste etc. But the emission from these natural sources is not so significant compared to human activities that are increasing the metals load on the environment.

2.2.2 FOSSIL FUEL COMBUSTION

An important source of heavy metals is the combustion of fossil fuels. However, even coal, the fossil fuel with the highest metal content contain only trace amount, so emissions at any moment are small. But, the large quantities of coal are burned, year – in year – out, even trace emission built up especially near combustions source. For example, at the present rate of coal consumption in power generation units is more than half of the total production in India, almost 15 million tons of ash being added into the environment annually.

As a consequence of consumption of large quantities of fossil fuels, urban localities around the world possess a higher concentration of heavy metals and trace elements in their soil, atmosphere as well as plants, animals including man. For example, atmosphere concentration of 0.03 – 0.65 µg of lead is present per cubic meters of air sample in busy streets of Kanpur while in samples taken from about 30 km away it was barely detectable. In soil samples from the city 350 – 400 µg per gram of lead was detected, while soils collected from fields 30 km away from the city only 100 – 85 µg per gram of lead could be found. Casiatora plants growing in the city were found to contain about 3 times as much lead as was found in plants collected from rural areas about 30 km away.
2.2.3 INDUSTRIAL ACTIVITY

Industrial processes generate wastewater containing heavy metals. The source of metals in these effluents is due to burning of huge amount fossil fuels for energy and extensive use of number of compounds of toxic trace elements. Metal contamination exists in waste of many industries such as metal plating, mining industries, tannery, chloric alkali, radiator manufacturing, smelting alloy industries and storage batteries manufacturing.

2.2.4 MINING

Most of the mineral deposits occur as complex mixtures of number of elements. In the process of mining and extraction of a particular metal the entire mass is excavated, laid bare and exposed to environmental agencies of weathering, degradation and transportation. This results in extensive contamination of surrounding areas. During concentration and processing of the ore for extraction of the metal plenty of useless finely powered stuff or tailings are left which are disposed of in the vicinity of the mining and processing establishments. Moreover, smelting and subsequent treatment of ores results in emission of arsenic, lead, cadmium, mercury, sulphur dioxide etc., in large quantities. Thus, mining of minerals and their processing to obtain the required metal have created enormous ecological disaster area at many places around the globe.

2.2.5 OTHER SOURCES

The other sources of metals pollution include municipal and industrial wastewater- treatment plants and are point sources of metal pollutants to water. Paved roads and construction sites are among the sources from which metal particulates can be blown away in the wind or run off with rain water. Metal containing wastes disposed of on land are a source of pollution. Some fertilizers, pesticides, sewage sludge and animal waste applied to soil have higher metal concentrations than natural soil levels.
2.3 PROBLEMS ASSOCIATED WITH METALS POLLUTION

Trace metals such as copper, iron, zinc, manganese are essential to metabolism under micronutrient for the maintenance of aquatic life. But the exposures of aquatic organisms to these trace metals at levels that exceed nutritional requirement can adversely affect development and health or cause death.

Excess of heavy metals can lead to disease, such as Wilson’s disease, Argyria, Cancer, heart and liver diseases, nervous system disorders and hypertension. Heavy metals from compounds in the body that can be carcinogenic and mutagenic even at very low levels. Therefore, not only first generations are affected by heavy metals, but also the effects can be passed onto second and third generations in the genetic abnormalities and birth defects.

Trace metal toxicity occurs when a receptor is exposed to available form of a trace metal for a sufficient duration at a concentration that elicits an adverse response. The potential for trace metal toxicity to aquatic organisms depends on numerous factors, including the chemical and physical characteristics of the water and sediment, composition and health of the biological communities present, and the magnitude and availability of the trace metal.

Upon exposure, uptake occurs by three main processes: from the water column through respiratory surfaces (e.g., gill); adsorption from water onto body surfaces, and from ingested food, particles, or water through the digestive system.

Further, the environmental significance of the enhanced levels of these elements is judged in terms of degree of toxicity, the extent of exploitation of the element, their application and consequent mobilization into the air, water and soil. Problems caused by trace elements may be summarized in brief as follows:

- Higher levels of trace elements are injurious to plants, animals and microbial component of the biosphere.
- Chronic and sub-lethal effects of trace element pollution at low concentrations may at times evade detection and general non-specific type of ailments follow which in turn evade redressal.
• Their persistence in the environment and subsequent transformation into more toxic state are distinct possibilities.

• Many trace elements and heavy metals are rendered lipophilic in nature as a consequence of formation of conjugates with organic molecules. This provides them a free access into a biological system and makes them more dangerous as they can be readily taken up by living organisms.

• Bio-concentration and magnification in the biosphere may confront human beings with highly toxic levels of trace elements. This may substantially damage our global food supplies, water resources etc.

Chronic lead toxicity is marked by a general feeling of unwellness, fatigue and pain in limbs. Anemia is usually the first symptom in animals including man following low level lead intake over long durations. It has been shown that lead inactivates aminolevulinic acid dehydrates and porphyrobilinogen decarboxylase which cause suppression of haem-synthesis. However, the toxic effects of lead are probably more significant in terms of human ability and performance. Degenerative changes in motor nerves and ganglia occur which result in decreased speed of conductance of nerve impulses to and from the muscles. The individual becomes dull, slow and inactive. In growing child degeneration of intellect and mental retardation may occur (Kannan and Menakadevi : 2005). Excretory mechanism of kidney is affected by this metal which may cause discharge of proteins and even blood through urine. Irreversible lead induced chronic kidney pathology is characterized by degeneration of tubular cells, interstitial fibrosis, glomerular sclerosis etc. Lead reduces uric acid excretion and chronic lead toxicities have been associated with development of gouty conditions in the hapless patients. Hypertension has also been found to be associated with a high percentage of lead in blood stream.

Severe lead toxicities have long been associated with sterility and gameto-toxic effects in both male and female animals. Lead is capable of passing through the placenta to foetus to cause developmental anomalies and still births. Some clinical studies have found increased chromosomal defects in workers with high levels of lead in blood. Suppression of immune system has been observed in laboratory animals even at such low doses which do not cause any apparent symptoms of toxicity (Kishore et.al, 2008).
Lead poisoning usually causes the presence of characteristic nuclear inclusions which appear as dense, homogeneous eosinophilic bodies under light microscope, while cells containing them are usually swollen. Under electron microscope these bodies are seen to possess a dense core and an outer fibrillary region. They are composed of lead-protein complex and contain a large amount of aspartic and glutamic acids and a little cystine (Semra et.al, 2004). Experimental studies have pointed out that nuclear inclusion bodies are earliest evidence of lead exposure which may be observed before any of the functional changes of intoxication in the system are detectable. It is thought that the sequestering of lead in these bodies is helpful in protecting other susceptible organelles.

About 20-30 % of the ingested zinc is absorbed. Within mucosal cells zinc forms metal-protein complexes. More than 70 different enzymes require zinc as a co-factor and its deficiency results in a wide spectrum of clinical effects. Toxicity consequent upon excessive intake of this metal is rather uncommon. Gastrointestinal distress and diarrhea have been reported following intake of liquids stored in galvanized cans or from the use of galvanized utensils. After ingestion of about 12 gm of elemental zinc, evidence of haemolytic, hepatic, and renal damages have been noticed in humans barely within two hours after the intake. Metal fume fever, resulting from excessive inhalation of freshly formed zinc oxide fumes in industrial workers, is characterized by chills, fever, profuse sweating and weakness after four or five hours. Other aspects of zinc toxicology are not yet well understood. Experimental animals given about 100 times more zinc than their dietary requirement failed to show any discernible effects (Goyer et.al, 1979). Though testicular tumors have been produced by direct intra-testicular injections in chickens and rats, there is no convincing evidence of teratogenic, mutagenic or carcinogenic action of zinc in humans.

Zinc is an important plant nutrient. Paddy cultivated in soils with less than 20 ppm of zinc develops symptoms of zinc deficiency. Zinc content of an average paddy field in India ranges between 35-90 ppm. However, zinc content of about 460 ppm may result in an appreciable reduction in yield. A higher calcium and magnesium content in the soil is helpful in reducing zinc toxicity.
Nickel is present in small quantities in plants and animals and also occurs in trace amount of sea water, petroleum and coal. Common nickel compounds when present in large amount will produce toxic effect in human beings and other animals. Nickel ions bind to nutrit acid and produce significant effect. A commonly recognized local reaction to nickel is dermatitis. The higher concentration of nickel causes poisoning effect like headache, giddiness, nausea, tightness of the chest, dry cough, vomiting, chest pain, shortness of breath, rapid respiration, sinuses and extreme weakness.

Accumulation of excess copper in the levels of human beings and animals results in hemocromatosis and gastro intestinal diseases. Copper consumption in high doses can cause serious toxological concern, since it can be deposited in the brain, skin, liver and pancreas. It will be then leads to nausea, vomiting, headache, diarrhea, respiratory difficulties, liver and kidney failure and death.

Zinc generated from phosphate fertilizers, distillery, pharmaceuticals and electroplating cause depression cough, vomiting, headache and metal fume fever.

The absorption of ingested zinc takes place in small intestines, particularly through the distal duodenum and proximal jejunum. It is equally well adsorbed as oxide, carbonate and free metal, but poorly sulphate or as mixed oxides of zinc, iron and manganese. Metallothionein plays an important role in the homeostatic regulation of zinc absorption and metabolism.

Ingestion of large doses causes irritation and corrosive damage to the gastro intestinal tract, with symptoms of nausea, vomiting, cramps, colic, diarrhea, fever and fatal shock. Its toxicity may occur from an intake of acidic fruit juices stored in galvanized, i.e., Zinc plated containers where Zinc concentration may reach upto 2 g/l.

The carcinogenic properties of Zinc have not been fully investigated. Like other chromates, Zinc chromate is a carcinogen. Application of hydrocarbon carcinogens causes a decrease in skin Zinc content. The metal is needed for cellular proliferation of existing tumors. Tumor growth is, therefore, retarded in zinc deficiency. The metal does not posed a risk for carcinogenesis in humans. However, significantly low concentrations of zinc in blood, plasma or serum have been reported in bronchial
carcinoma, Hodgkin’s disease, lymphoma, multiple myeloma and chronic lymphocytic leukemia. In cases of carcinoma of prostate glands, the organ contained low zinc concentration but the values will be high in hyper plastic prostate glands. Significantly high zinc levels were found in the liver of carcinoma patients. No comparable increase in the zinc content of kidney, spleen, heart, or pancreas was observed in autopsy samples of these patients.

2.4 TREATMENT TECHNIQUES

In recent years increasing awareness of the environmental impact of metals as prompted a demand for the purification of industrial water prior to discharging to natural waters. In these days the researchers are focusing on the development of materials with increased affinity, capacity and sensitivity for removal of target metals from wastewaters. The existing methods for the removal of metals from the wastewaters can be grouped into biotic and Abiotic. Abiotic methods include physiochemical processes such as precipitation and adsorption. On the other hand, biotic methods are based on accumulation of heavy metals by microorganisms and plants.

In advanced countries removal of heavy metals from wastewaters is commonly achieved by advanced technologies such as ion exchange, chemical precipitation, ultra filtration or electrochemical deposition.

Chemical precipitation of metals is achieved by the addition of coagulants, such as alum, lime, iron, salts and other organic polymers. the large amount of sludge containing toxic compounds produced during the process is the main disadvantage. In electro dialysis process, the ionic components (heavy metals) are separated through the use of semi permeable, ion selective membranes. Application of an electrical potential between the two electrodes causes migration of cations and anions towards respective electrodes. Because of the alternate spacing of cation and anion permeable membranes, cells of concentrated and dilute salts are formed. The disadvantage is the formation of metal hydroxides, which clog the membrane. In ion exchange process, metal ions from dilute solutions are exchanged with ions held by electrostatic forces on the ion exchange resin. The disadvantages include high cost and partial removal of certain ions. Reverse osmosis is a process in which heavy metals are separated by a
semi permeable membrane at a pressure greater than osmotic pressure caused by the dissolved solids in wastewater. The disadvantage of the method is that is expensive. Ultra filtration is pressure driven membrane operations that use porous membranes for the removal of heavy metals. The main disadvantage of this process is the generation of sludge and selection of proper membrane.

Hence, the disadvantages like incomplete metal removal, high reagent and energy requirements, generation of toxic sludge or other waste products that require careful disposal has made it imperative to look for cost – effective treatment method, that is capable for removing heavy metals from aqueous effluents. As alternatives, slowly biological tools are being substituted in pollution abatement programmes. This technology has been loosely grouped together under the term ‘bioremediation’. Biological methods such as biosorption, bioaccumulation and phytoremediation for the removal of heavy metal ions may provide an attractive alternative to physico-chemical methods. Phytoremediation is the use of certain plants to clean up soil, sediment, and water contaminated with metals. The disadvantage include that it takes a long time for removal of metals and the regeneration of the plant for further biosorption is difficult.

Therefore, there is a need to look into alternative to investigate a low cost method which is effective and economical and can be used by industries. To overcome this difficulty, there is a strong need to develop economical adsorbents which can be used in developing countries.

2.5 ADSORPTION TECHNIQUES

Adsorption involves partitioning of the contaminant from one phase into another phase. Hence, adsorption is a surface phenomenon. The interface may be liquid – gas, liquid – liquid or liquid – solid.

The researchers across the globe have made an attempt to remove metals from wastewaters using various adsorbents. The materials developed for this purpose range from industrial waste to agricultural waste products. These materials tried include activated carbon, peat, marine algae, clays, begasse, palm fruit bunch, fly ash, metal oxide, geolytes, biomass, peanut hulls, coral sand and so forth. Different types of
agricultural waste such as banana peel, saw dust, neembark, wheat straw, corn cobs etc., also have been studied for the removal of heavy metal ions from wastewaters. However, the capacity is low compared to commercially available ion exchange resins or activated carbon.

The effluent treatment methodologies generally employed on Alkali treatment to precipitate out copper in the form of its hydroxide, cementation leading to solid waste generation of other metal hydroxide, oxalate treatment or ion exchange resin treatment. But, all of which are found to be expensive (Kapadia et al, 2000). Rout et al, (2008) cited that during past few decades different low cost adsorbents such as Chitosen, agricultural waste, marine algae, peanut hull, treatment mangrove root, biomass and crop shell have been tested for copper removal.

2.5.1 FACTORS AFFECTING ABSORPTION

The factors affecting adsorption are:

- **Surface area:**
  Adsorption is proportional to specific surface area. The specific surface area is one which is available on the total surface area for adsorption. If the grain size of the adsorbent is smaller, the surface area will be higher and vice-versa.

- **Nature of adsorbate:**
  There is an inverse relationship between the extent of adsorption of a solute and its solubility in the solvent from which adsorption occurs. Greater the solubility, stronger the solute – solvent bond and smaller the extent of adsorption.

- **Molecular size:**
  It relates to the rate of uptake of solute by porous media. The reaction will proceed more rapidly with smaller adsorbate molecules.

- **pH:**
  Hydrogen and hydroxyl ions influence the adsorption process because they themselves get adsorbed quite strongly. Ionization of an acidic or basic compound
affects the adsorption, so that pH affects adsorption in that it governs the degree of ionization.

- **Temperature:**
  Since the adsorption reactions are exothermic the extent of adsorption generally increases with decrease in temperature.

- **Nature of adsorbent:**
  Physico-chemical nature of adsorbent can have profound effect on both rate and capacity of adsorption. The adsorption process is a function of surface functional group and structure of adsorbent.

### 2.5.2 ADSORPTION ISOTHERMS

Adsorption occurs in series of steps / mechanisms. Due to these varied mechanisms it is extremely hard to predict the nature of actual adsorption process. To determine the rate controlling step, extensive data concerning the specific adsorption application should be available. Therefore empirical design procedures based on adsorption equilibrium conditions is the most common method to predict the adsorber performance. The underlying thermodynamic assumptions of these equilibrium models and the equation parameters often provide some insight into both the sorption mechanism and the surface properties and affinity of sorbent (Ho et al: 2002).

By the use of an adsorption isotherm the adsorption capacity of any adsorbent can be determined. Thus the adsorption isotherms are equilibrium equations and apply to conditions resulting after the adsorbate containing phase has been in contact with the adsorbent for sufficient time to reach equilibrium.

The various isotherm equations for the gas phase adsorption such as Freundlich, Langmuir, Dubinin Reduskevich, Redlich Peterson, BET, Temkin and Sips isotherm can in principle be extended to liquid phase adsorption. Of these Langmair and Freundlich isotherm equation are the two most commonly used equations by many researchers across the globe.

#### 2.5.2.1 Freundlich Equation

The Freundlich adsorption equation is perhaps the most widely used equation for adsorption in aqueous systems, although this equation is thermodynamically
unsound, the equation fits experimental adsorption equilibrium data for a number of aqueous systems, and conventional and unconventional adsorbents. The Freundlich equation takes into account the effect of surface heterogeneity and the exponential distribution of sites and their energies.

The Freundlich equation has the following form (Weber, 1972):

\[
\frac{X}{m} = q_e = K_F C_e^{1/n} \quad \ldots \quad (1)
\]

Where

\[
\frac{X}{m} = q_e = \text{Amount of metal adsorbed per unit weight of adsorbent (mg/g)}
\]

\[C_e = \text{Equilibrium concentration (mg/l)}.
\]

\[K_F = \text{Adsorption capacity constant.}
\]

\[n = \text{Adsorption intensity constant.}
\]

The linearized form of above equation is

\[
\log q_e = \log K_F + \frac{1}{n} \log C_e \quad \ldots \quad (2)
\]

Equation (2) is used to find \(K_F\) and \(n\) from experimental data

**2.5.2.2 Langmuir Equation**

The Langmuir isotherm takes adsorbent surface coverage (monolayer coverage) into account by equilibrating the relative rates of uptake and the release of the adsorbed substance. Uptake rate of the adsorbate is proportional to the fraction of vacant surface, whereas the rate of release of the adsorbate is proportional to the covered surface.

It is expressed as (Weber, 1972)

\[
\frac{X}{m} = q_e = \frac{Q_0 b C_e}{1 + b C_e} \quad \ldots \quad (3)
\]
Where

\[ \frac{\chi}{m} = q_e = \text{Amount absorbed per unit weight of adsorbent (mg/g)} \]

\[ Q_o = \text{Amount adsorbed per unit weight of the adsorbent in forming a complete monolayer.} \]

b = Constant related to the energy (l/mg)

\[ C_e = \text{Equilibrium concentration of solute in solution (mg/l)} \]

The two convenient linear forms of the Langmuir equation are as follows:

\[ \frac{C_e}{q_e} = \frac{1}{bQ_o} + \frac{C_e}{Q_o} \]

\[ \frac{1}{q_e} = \frac{1}{Q_o} + \left[ \frac{1}{bQ_o} \right] \times \left[ \frac{1}{C_e} \right] \]

These equations can be used to determine \( Q_o \) and \( b \) from experimental data.

The essential characteristics of a Langmuir isotherm can be expressed in terms of a dimensionless constant separation factor or equilibrium \( R_L \), which is defined as

\[ R_L = \frac{1}{1 + bC_1} \]

Where

\[ C_1 = \text{Initial pollution concentration (mg/l)} \]

b = Constant expressing energy of interaction at the surface.

The adsorption process is irreversible if \( R_L = 0 \), favorable if \( R_L \) value lies between 0 and 1, and

Linear if \( R_L = 1 \).
2.5.2.3 BET (Branauer, Emmet, and Teller) Isotherm Equation

This is a generalized form of ideal localized monolayer treatment which accounts for multilayer adsorption. The BET isotherm reduces to Langmuir model when the limit of adsorption is a monolayer. The BET isotherm assumes that:

- A number of layers of adsorbate accumulate at the surface and Langmuir isotherm.
- A layer need not completely form prior to the initiation of subsequent layers.
- Layer beyond the first have equal energies of adsorption.

The model is represented by

\[ q_e = \frac{bC_xQ_o}{(C_s - C_e)\left[1 + \left(b - 1\right)\frac{C_x}{C_s}\right]} \]  

Rearranging the above equation to facilitate its application to experimental data, a linear form can be obtained i.e.

\[ \frac{C_x}{q_e(C_s - C_e)} = \frac{b - 1}{bQ_o} \left[\frac{C_x}{C_s}\right] + \frac{1}{bQ_s} \]  

2.6 DISPOSAL STANDARDS

The Indian standards for safe disposal of industrial effluents (metals studied) into receiving water bodies are shown in Table 2.1.

Table 2.1: Indian Standards for Disposal of Industrial Effluents

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Metal</th>
<th>Limits for discharge with inland surface water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hexavalent chromium (as Cr+6), mg/l</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>Nickel (as Ni), mg/l</td>
<td>3.0</td>
</tr>
<tr>
<td>3</td>
<td>Copper (as Cu), mg/l</td>
<td>3.0</td>
</tr>
<tr>
<td>4</td>
<td>Zinc (as Zn), mg/l</td>
<td>5.0</td>
</tr>
</tbody>
</table>
2.7 SPECIFIC REVIEWS

Tariq, et.al., (2009) carried out studies to evaluate the efficiency of pile fruit powder for removal of copper and ferrous ion from aqueous solution. They have also developed adsorption isotherms. They have investigated the influence of contact time, pH of the solution and initial concentration of metal ion on removal efficiency. The results indicated that, the copper will be better removed at pH 7 and at contact time of 120 minutes. They have recorded 94 to 96% of removal of copper ion for the whole range of initial concentrations of metal studied. The maximum adsorption capacity for copper was 14.1 mg/gm at 57.6 mg/l of metal concentration. The data was found to be best suited to Freundlich Isotherm model.

The feasibility of using the chemically modified mangrove bark (MBB) for the removal of nickel and copper ion from aqueous solutions was carried out by Rojainiet.al., (2010). The study revealed that, the removal efficiencies are clearly affected by the operational parameters like initial pH, contact time and initial concentration of metal ions. They have recorded 7.25 and 6.95 mg/gm of monolayer adsorption capacity of MBB for nickel and copper ion. The findings of study suggested that MBB can be a potential adsorbent for the removal of nickel and copper ion from aqueous solutions.

The uptake of copper, zinc and lead on to the media viz., raw peanut hulls and a commercial grade ion exchange resin was investigated by Pauline Brown et.al., (2000). Over 90% of metal ion removal was found to occur within the first 20 minutes of contact which is confirmed by Kinetic studies. The authors are of the opinion that even though the removal capacity of raw peanut hulls and peanut hull pellets is lower than that of the commercial grade ion exchange resin tested, the low cost make them an attractive option for the treatment of low strength metal ion waste streams. The ratio of grams metal removed per media cost for the resin / pellets ranged from 1:13 to 1:17.

Investigative studies to compare to different Turkish fly ashes for their ability to remove nickel, copper and zinc from an aqueous solution have been carried out by Belgin Bayat (2002). He observed that, there is good prospect for the adsorption of these metals on fly ash with high calcium content. He also suggested that the fly ash
after use as an absorbent can be used as a filling material in roads and construction sites, in soil stabilization in concrete and cements industry without any subsequent danger and sub surface water contamination. The adsorption data was better fitted to Langmuir isotherm than Freundlich isotherm. Adsorption densities of zinc > copper > nickel for both the fly ashes has been observed by the investigator. For each type of fly ash, maximum nickel removal at pH 7 to 8, copper at pH 5 to 6 and zinc at pH 6 to 7 has been reported by the researcher.

Industrially applicable and viable technique of biosorptive removal of nickel from wastewater has been studied by Piyush Kant Pandey et.al., (2007). They have demonstrated that biomass of calotropis – procera is successful in removing nickel with 85% sorption efficiency from aqueous solution containing 260 mg/l of nickel. It was observed that, adsorption is pH dependent and maximum adsorption occurred at pH 3. The studies also reveal that column type biosorption is more efficient as compared to batch mode adsorption study and is due to more close packing of adsorbent sites. The maximum nickel uptake capacity of 15.75 mg/gm for batch adsorption and 20.75 mg/gm in column adsorption mode has been documented.

Vinod Gupta (1998) investigated the effect of particle size distribution, contact time and surface loading of copper and nickel ion on activated slag, a low cost adsorbent for their removal. The optimum removal is observed at pH 5 for copper and at pH 4 for nickel. The result showed that, the waste material can be fruitfully employed for the removal of copper and nickel in the wide range of concentration. Sorption data have been correlated with both Langmuir and Freundlich adsorption models. The paper also throws light on some feasibility experiment performed with a goal to recover adsorbent and chemical regeneration of the spent columns.

A simple and cost effective treatment procedure has been proposed for the removal of heavy metal through the adsorption on sand (Mohammed et.al.,: 2004). Sand has showed very high adsorption capacities and hence authors opined that, sand can successfully be used for metal removal from electroplating wastewaters. Increase in removal efficiency with increase in pH and decrease in removal efficiency with increase in metal concentration have been observed. A 91% of copper removals at a solution pH of 10 with an initial metal concentration of 25 ppm have been reported.
Adsorption experiments were conducted to evaluate the adsorption of copper by Herbaceous Peat under varied experimental conditions (Recep et.al., 2004). About 97% adsorption of copper ion by the peat was observed at lower concentrations of metal. Remarkable effectiveness of temperature and pH on the adsorption has not been noticed. The adsorption was found to follow both Freundlich and Langmuir isotherms.

Substantial removal of chromium and copper from the composite wastewater (Chrome and Bronze containing wastewater) within a short contact time by adsorption on activated alumina has been reported by Debbrata Mazumder et.al., (2011). The adsorption Kinetics followed mostly BET-Isotherms.

50%, 50%, 61% and 60% removal of copper, lead, chromium and nickel using activated carbon of rice husk has been reported by Abdul Zameel and Zahir Hussain (2009). Removal efficiency was found to have linear relationship with contact time. Batch experiments to evaluate the removal of copper, iron and lead ions from simulated waste effluents by adsorption on coconut husk, a low cost natural adsorbent has been carried out (Oyedej and Osinfade – 2010). They have reported 94 % removal of lead and iron and 92 % of copper by 1 gm adsorbent, pH range being 5 to 7. Langmuir isotherm was found to be suitable for adsorption of lead while Freundlich isotherm was suitable for copper and iron.

Nasim Ahmad Khan et.al., (2004) reviewed feasibility of some of the agricultural adsorbent for the removal of heavy metals from wastewater. The adsorbent reviewed include rice husk, sugar cane, saw dust, soya bean hulls, cotton seed hulls, rice bran and straw. The review suggested that there is a great potential for the elimination of heavy metals from wastewater by agricultural adsorbents reviewed. Further, the authors suggested the need for more studies to better understand the process of low cost adsorption and demonstrate the technology effectively.

Ability to remove heavy metals from aqueous solutions by several sorbents viz: Geolyte, Powdered activated carbon (PAC), Granular activated carbon (GAC), Crabshell and Cation Exchange resin (CER) has been investigated by AN et.al., (2001). Among these sorbents, crab shell was found to be satisfactory biosorbent for the heavy metal removal. The metals tried by the authors include lead, cadmium,
copper and iron. The order of heavy metal removal capacity by crab shells as reported by the authors is Cd > Pb > Cr ≥ Cu. They also reported the order of removal capacity by the absorbent and is Crab shell > CER > Geolyte > PAC ≥ GAC.

Batch mode studies have been carried out to evaluate the effectiveness of fly ash in adsorbing soluble copper present in the effluent of printed circuit board manufacturing plant (Kapadia et al., 2000). The study revealed that, the fly ash will be efficient in adsorbing copper at effluent pH of around 6, contact period being one hour. The initial concentration of the metal in the effluent was found to affect the removal efficiency. 98% of removal efficiency was recorded with initial metal concentration upto 2 mg/l while removal efficiency of 62% has been recorded at metal concentration of 60 mg/l. The authors also stated that, the fly ash could be repetitively used with several times with reasonable removal at low copper concentration.

Bilquees et al., (1999) carried out adsorption studies on phosphate treated saw dust to evaluate the removal efficiency of zinc, nickel and copper metal ions from electro plating wastewater. They have recorded maximum adsorption of zinc, nickel and copper at pH 7 to 8 and removal efficiency remained 80% even upto their initial concentration of 30 mg/l. Applicability of Langmuir and Freundlich adsorption isotherms for zinc and nickel has been observed from the data, while copper has not followed these isotherms in the concentration range studied.

Batch experiments carried out by Murali and Susheela (2001) at different contact time, stirring time and initial concentration of nickel to evaluate nickel removal by adsorption process using Tephrosia Purpurea leaf powder revealed that, removal is most effective at 40 rpm and at 60 minutes of contact time. They have recorded 58.6% of nickel removal at lower dosage (1.5 gm) and 93% of nickel removal at higher dosage (4.5 gm).

Batch processes conducted to evaluate the adsorption of nickel using rice husk at varied experimental condition like contact time, adsorbent dosage, pH, initial concentration of metal revealed that, removal efficiency increases with increasing contact time, adsorbent dosage and pH and decreases with increase in metal
concentration. 89% of metal removal at optimum conditions of variables has been recorded. The adsorption data fitted well into Freundlich adsorption isotherm.

Rout et.al., (2008) evaluated adsorption of copper by some low grade ores. The ores studied include iron ore slime (IOS), low grade red Bauxite (LGRB) and low grade manganese (LGM). At pH 5.25 adsorption of 12.8, 7.68 and 9.36 mg/gm of copper by IOS, RB and LGM respectively are recorded. The adsorption was found to have a linear relationship with temperature for all the adsorbents and thus it suggested endothermic nature of the process.

Biosorption potential of biomass of Blue green Algae for copper ions in aqueous solutions has been investigated by Nedumaran and Velan (2008) by conducting batch study. The copper biosorption capacity has been found to be 8.93 mg/gm of dry weight of biomass at an optimum pH of 4.5. Precipitation of insoluble metal hydroxides observed at pH higher than 5.4 indicating limitation of pH in biosorption. However, the authors opined that the biomass they have studied can be used as an effective and economic biosorbent material for the removal and recovery of heavy metals from wastewaters.

The batch operations carried out by Arti Nigam and Rama (2003) to evaluate the removal of chromium by sugarcane leaves showed that, the removal is optimum at pH 2, initial concentration being about 20 mg/l, adsorbent dosage being 1 gm/100 ml. Linear increase in the percent removal of chromium with increase in temperature has been observed by the authors. The paper documents that, the reason for better adsorption capacity at low pH values may be attributed to the large number of H+ ions present at the low pH values which intern neutralize the negatively charged adsorbent surface, their by reducing hindrance to the diffusion of chromium ions. At higher pH, the reduction in adsorption may be possibly due to the abundance of OH ions causing increased hindrance to the diffusion of chromium ions.

The ability of bicarbonated coconut husk to adsorb mercury from the aqueous media has been demonstrated (Anirudhan and Sreedhar : 1998). Solution pH of 5.5 was found to be optimum and removal of mercury by coconut husk was found to increase with increase in temperature.
The effect of various processed parameters like contact time, dose of adsorbent, pH etc., has been investigated by following the batch adsorption technique at room temperature to remove copper ions by adsorption onto indigenously prepared coconut shell (CSC) and dates nut (DC) carbons. DC was found to be more effective in removing copper compare to CSC. About 70 and 45 percent of copper removal by DC and CSC respectively with contact time of about 40 minutes has been recorded. Direct relationship between removal efficiency and contact time and dose of adsorbent has been observed.

Studies on adsorptive removal of copper and nickel ions from water using chitosan coated PVC beads were carried out by Srinivasa et.al., (2009). The effect of pH, agitation time, concentration of adsorbent and amount of adsorbent in the extent of adsorption was investigated. The experimental data were fitted to Langmuir and Freundlich adsorption isotherms. The data were analyzed on the basis of Lagergren pseudo first order, pseudo-second order and Weber-Morris intraparticle diffusion models. The maximum monolayer adsorption capacity of chitosan coated PVC sorbent as obtained from Langmuir adsorption isotherm was found to be 87.9 mg/g for copper (II) and 120.5 mg/g for nickel (II) ions respectively. In addition, breakthrough curves were obtained from column flow experiments. The experimental results demonstrated that chitosan coated PVC beads could be used for the removal of copper (II) and nickel (II) ions from aqueous medium through adsorption.

The removal of Zinc (II) ions from dilute aqueous solution using maize (zea mays) leaf as the adsorbent is reported by Adesola Babarinde et.al., (2008). The batch biosorption studies have shown that the biosorption is pH dependent and the optimum pH for the removal is in the range of 4-7. The amount of zinc ions biosorbed increased with increased initial metal ion concentration. Maximum adsorption was obtained within the first 40 minutes and on an average 90-92% zinc removal was recorded. Thus, the authors recommended the use of maize leaf biomass, an agricultural waste as potential biosorbent for the removal of zinc (II) from aqueous solutions.

The batch removal of heavy metals lead (Pb), zinc (Zn) and copper (Cu) from industrial wastewater effluent under different experimental conditions using hydrogen peroxide was investigated (Badmus et.al., 2007). Removal of heavy metals was
optimum at pH 7.6, a temperature of 30° C, 1.5% hydrogen peroxide concentration and 60 min holding time, reducing the amounts of Pb, Zn and Cu by 83.5, 85.5 and 82.23% respectively.

Studies on removal of copper and zinc by adsorption on activated peel waste biomass have been carried out in synthetic wastewater by **Kanimozhi and Merline Sheela (2008)**. Various parameters such as pH, contact time, initial concentration adsorbate and adsorbent dose were optimized. Optimized values for copper and Zinc were more or less same. As compared to the commercial activated carbon the removal efficiency was approximately same but as compared to the cost it is cheap.

A simple and cost effective treatment procedure was proposed for the removal of heavy metals through the adsorption on sand. **(Muhammad Masud Aslam et.al., 2004)**. This study records lab scale experiments to test efficiency of sand on removing a heavy metal, zinc (II) from wastewater of electroplating industry. This method of heavy metals removal proved highly effective as removal efficiency increased with increasing pH ranging from 71-87% and maximum adsorption occurred at depth 1 m as compared to 0.6 m and 0.8 m depth. Since sand is cheap and easily available, the authors concluded that the sand filtration, which is efficient and effective, has the potential to be used for removal of heavy metals from water and industrial wastewater.

The possibility of cadmium (Cd^{2+}) and zinc (Zn^{2+}) toxic cations removal from simulated liquid effluents by a relatively innovated treatment, named galvanochemical, using the galvanic pair iron-carbon, was investigated by **Prochaska et.al., (2001)**. The study showed that there is a great potential for the application of galvanochemical method to the purification treatment of metal-laden wastewaters from small-to-medium industrial units, as the residual metal concentrations were found to be below the legislation limits, under the optimized operating conditions.

**Scott et.al., (2000)** tested four filtration media in controlled laboratory experiments to determine their effectiveness for concurrent metals removal and toxicity abatement in synthetic storm water. Media tested included commercially available leaf compost (CSF®) media, a zeolie/perlite mix, and a polyamine sponge, as well as the recently developed citric acid modified soybean hull media. The CSF®
media removed up to 75% of the zinc and reduced toxicity significantly for influent concentrations of up to about 300 ppb zinc. Variations of the CSF® media improved zinc removal modestly compared to the standard version. The soybean hull material removed 80 to 99% of the zinc over all influent concentrations though it reduced pH to toxic levels. After pH adjustment, the effluent from the soybean material was non-toxic overall concentrations tested. Augmenting the soybean material with leaf compost media or activated carbon effectively buffered effluent pH to circum-neutral ranges. Other media tested removed modest amounts of zinc and were capable of sufficiently reducing toxicity only in the lowest concentrations tested, while some media appeared to generate toxicity.

Studies on the removal of zinc by adsorption on two types of flyashes, namely Bokaro Thermal Power Plant Fly ash and fluidized bed combustion fly ash from Tata steel, Jamadoba were carried out by Srivastava, et. al., (2007). Batch adsorption experiments were done. The effects of various parameters such as contact time, initial concentration, pH, flyash dosage on the removal of zinc ions were studied. In case of fluidized bed combustion flyash the maximum removal capacity was 0.0515 mg of Zn$$^{2+}$$/gm of ash, in thirty minute whereas; in case of Bokaro Thermal Power Plant flyash the maximum removal capacity was 0.0925 mg of Zn$$^{2+}$$/gm of ash. The loss on ignition of fluidized bed combustion fly ash was 17.15% and that of Bokaro Thermal Power Plant fly ash was 6.67%. So the quantity of zinc by the two types of flyash may be related to the difference in their unburnt carbon. Higher the unburnt carbon better is the adsorption capacity. At low pH values the flyash particle is positively charged while at high pH value the flyash particle is negatively charged. So adsorption is favored when the particles are negatively charged, that is in alkaline medium.

Semra Iihan et. al., (2004) investigate selective biosorption of chromium, lead and copper ions by microorganism from industrial wastewater. The effects of pH, temperature and initial concentration of metal ions on the biosorption capacity were investigated. The optimum pH values for chromium, lead and copper biosorption was found to be 2.0, 4.5 and 3.5 respectively. The maximum adsorption was observed for Cr$$^{6+}$$ Pb$$^{2+}$$ and Cu$$^{2+}$$, at the initial concentrations of 193.66 mg Cr$$^{6+}$$/l; 100 mg Pb$$^{2+}$$/l and 105 mg Cu$$^{2+}$$/l and 44.94 Cu$$^{2+}$$/l, respectively.
The effectiveness of soluble starch Xanthate (SSX) for removal of Cd (II), Chromium (VI) and Cu (II), insoluble starch Xanthate (ISX) for Chromium (VI) and Cu (II) have been evaluated under different aqueous phase conditions (Vinod Tare et.al., 1998). Comparison between ISX and SSX, based on the equivalents of metal removed per mole of ISX/SSX added indicated that ISX has better binding capacity for metals. However, with due consideration to yield and chemical requirements for the synthesis of ISX and SSX, SSX appears to have higher capacity for metal removal. The order of preference of metal binding capacity of SSX is found to be as Cr (VI) > Cu (II) > Cd (II) whereas of ISX as Cr (VI) > Cu (II).

Bilquees Ara Siddiqui, et.al., (1999) Carried out series of experiments in batch process to determine the adsorption studies on phosphates treated saw-dust for removal of Cr(VI), nickel and zinc removal from aqueous solution of electroplating waste. The effect of initial concentration pH and adsorption doses were studied and they observed that the removal of these metals were dependent on the contact time, pH, Adsorbent dosage.

Experiments were conducted to assess the influence of various parameters, such as adsorbent dose, contact time, effects of pH and dilution for SAC and CAC on adsorption (Raju and Saseetharan et.al., 2008). The results of the experiment provided that SAC was found to be efficient in removing the nickel bearing effluents. The maximum percentage of nickel (II) removal was observed (92%) with a optimum contact time of 20 min. For SAC the percentage removal increases with increase in pH and the removal was optimum at the original pH 4.3. It is also noted from the present study that the granular form of SAC was more efficient when compared to the costlier conventional CAC.

An attempt was made to remove nickel using live bacterial cultures from single metal aqueous solutions by Khasim Beebi, et.al., (2007). The result obtained from the bacterial studies showed that the live bacterial biomass of gram positive Bacilli, Diplococci, and Pseudomonas species have the potential to remove nickel from single metal solution.

Nickel biosorption ability was evaluated in two bacterial strains: Acinetobacter baumannii UCR-2971 and Pseudomonas aeruginosa UCR-2957,
resulting in greatest adsorption at pH 4.5 and a residence time of 100 minutes (Carlos et.al., 2006). The maximum adsorption rates were 8.8 and 5.7 mg/g for A. baumannii and P. aeruginosa, respectively; it is suggested that both strains could be used for wastewater treatment, as long as the concentration of Ni\(^{2+}\) is within the range of 4-13 mg/l.

The adsorption isotherm of Ni (II) on the test of groundnut shell was carried out by the batch adsorption process (Mohammad Ajmal et.al., 1996). Various parameters such as initial concentration, pH and amount of the adsorbent doses were studied. The experimental adsorption data obtained followed both Langmuir as well as Freundlich isotherms. Maximum adsorption (85%) was observed at pH 6. The monolayer adsorption capacity was found to be 8.79 mg/g, which is greater than most of the low cost adsorbents reported.

Investigations were conducted on the topic titled Studies on Removal and Recovery of Cr (VI) from Electroplating Wastes by Mohammad Ajmal et.al., (1996). Authors inferred that phosphate treated saw dust shows remarkable increase in sorption capacity of Cr (VI) as compared to untreated saw dust. The adsorption process is pH dependent. 100% adsorption of Cr (VI) was observed in the pH range < 2.0 for the initial Cr (VI) concentration of 8-50 mg/l. The effect of various adsorbent doses at pH-2.0 confirms Langmuir adsorption isotherms. 100% removal of Cr (VI) from synthetic waste as well as from electroplating waste containing 50 mg/l Cr(VI) was achieved by batch as well as by column process. The adsorbed Cr (VI) on phosphate treated saw dust was recovered (87%) using 0.01 molar sodium hydroxide.

Feasibility studies of using treated fly ash in the removal of nickel from aqueous solutions were performed by Suwan et.al., (2006). Batch adsorption experimentation was used to investigate the adsorption efficiency of treated fly ash for the removal of nickel. Concentrations of nickel varied in the range of 1-10 mg/l. The adsorption efficiency was found to increase with increasing tested fly ash concentration. At treated fly ash concentrations above 1.25 g/l the removal was almost instantaneous. Adsorption equilibration was usually attained within 30 min at a pH of 3-5. 86 to 92% removal of nickel (II) from industrial wastewaters was recorded.
Studies on the removal of metal ions, like nickel (II) by adsorption on surface of orange peel (OP) was carried out at room temperature (30±1°C) by Kannan and Inbaraja et al., (2006). The effect of process parameters like initial concentration, contact time, dose of adsorbent (op) and initial pH was studied for the removal of metal ions. The studies revived the 20 to 35% removal of nickel (II) at optimum pH, adsorbent dosage and contact time of 5.0, 110 gm/l and 50 minutes respectively.

Activated carbon prepared from silk cotton hull was used to remove nickel (II) from aqueous solution by adsorption (Shanmugavalli et al., 2006). Batch mode adsorption experiments were carried out by varying contact time, metal-ion concentration and pH to assess kinetic and equilibrium parameters. The adsorption capacity of 56.40 mg/g of activated carbon at initial pH of 5.0 for the particle size 125 – 250 μm was observed.

Removal of nickel ions from industrial effluents has been studied using activated alumina prepared by the galvanic oxidation of aluminum at ambient temperature as the adsorbent (Revathi et al., 2005). The effect of various factors, such as initial concentration of nickel, contact time, dose of adsorbent and pH of the solution has been investigated. Batch and column type of adsorption studies have been made. The results indicate that the adsorption process is favored at pH 9.0. The following conclusions are drawn from the present investigation. The percentage of nickel removal from the effluent increases with increasing amount of alumina. The optimum dosage for effective nickel uptake of nickel ions in the adsorbent sites increase with increasing contact time. The optimum contact time for effective nickel removal is 60 minutes. Column type of adsorption process is more efficient (99.6%) compared to batch process (86%) because of more close packing of adsorbent sites. The adsorbent used in this process could be regenerated at the end and can be used for subsequent treatment process, thereby eliminating the need of new adsorbent. It is also noted from the present investigation that the Gibbsite form of activated alumina was more efficient in removing nickel ions compared to commercially available alumina, which could remove only 40% of nickel ions from the effluent.

Anima et al., (2004) have carried out investigations to study the removal of nickel using a non-conventional adsorbent, rice husk. The effects of contact time, adsorbent dosage, pH, concentration of the metal ion and isotherm models are studied
in a batch process. A steady trend was observed for all variables. The adsorption percentage increased with increase in contact time, adsorbent dosage and pH, but there was a decrease in adsorption with increase in concentration of the metal ion. Adsorption intensity values showed that rice husk, a non-conventional adsorbent is efficient in removing nickel (II) from an aqueous solution. The adsorption data fitted well into Freundlich adsorption isotherm.

Adsorption characteristics of nickel on activated carbon at different pH values have been evaluated by Amal Raj (2004). The adsorption capacity of activated carbon was found to be dependent on pH of influent solution and better at pH below 4.5. The author reports 85 to 95% removal at pH below 4.5.

Murali and Susheela (2001) studied the removal of nickel from aqueous solution by using Tephrosia purpurea leaf powder as an adsorbent. The study was carried out in batch experiment in three phases to find-out the effect of concentration of nickel at different concentrations different contact time, rpm and dosage of adsorbent. Each phase was involved with different contact time, rpm and dosage and results of each phase were recorded. In the third phase at a contact time of 60 min. and at 40 rpm with a dosage of 4.5 gm the removal of nickel from aqueous solution was found effective with 97.86% of removal and with same set at 1.5 gm of adsorbent the removal of nickel was found to be 58.65%. They revealed that the percentage of removal increased with increased doses; hence the Tephrosia purpurea can be useful adsorbent for removal of nickel from industrial wastewater.

The biosorption of Zn$^{2+}$, Ni$^{2+}$ and CrO$_4$ was studied over a range of metal ion concentrations, adsorption time, pH and co-anions, by fungal mycelium pellets of Aspergillus niger 405 as an adsorbent (Zeljka et.al., 2000). The results showed better biosorption for the ions at pH ranging from 4.0 to 6.0. On the contrary, pH values from 3.0 to 7.0 had no influence on sorption of chromium. Comparison of metal uptake in single and multi-component solutions Zn-Ni-Cr was discussed. Fungas Aspergillus niger 405 showed a good affinity for binding of Zn$^{2+}$ and Ni$^{2+}$ ions in single, while in multi-component solution it occurred only for zinc.

Studies were carried out for the removal of zinc metal from synthetic stock solution, by the adsorbent material bentonite, (Prasanna Kumar et.al., 2006).
Parameters studied include time of contact, size of bentonite particles, and dosage of the adsorbent, initial concentration of the solution, initial pH of the solution and volume of the solution.

The saw dust used for adsorption was sieved (50-60 mesh) and washed several times with distilled water. It was then treated with 0.1 M aqueous solution of Di-sodium hydrogen phosphate for 24 hrs. The material was then filtered and washed several times with distilled water to release phosphate and dried at 40°C in an oven. Then 50 ml of solution containing required amount of metal ions was treated with 1 liter of this adsorbent in 250 ml conical flask. The mixture was filtered after contact time of 24 hrs and filtrate was analyzed for heavy metals in Atomic Absorption spectrophotometer.

They found that percentage adsorption of Zn (II), Ni (II) and Cr (VI) is maximum in neutral media. The percentage of adsorption remains 80% even upto their initial concentration of 30 mg. maximum adsorption is observed at pH 7.0 - 8.0, the adsorption of these metals follow the trends at various pHs

\[ \text{pH} 7.0 = \text{Cu(II)} > \text{Zn(II)} = \text{Ni(II)} >> \text{Cr(VI)} \]

\[ \text{pH} 2.0 = \text{Cr(II)} >> \text{Cu(II)} > \text{Ni(II)} > \text{Zn(II)} \]

The studies were carried out to examine a possible strategy for the removal of Chromium (VI). Employing dead biomass of Aspergillums Niger in batch experiments. (Sneha Narvekar and Varsha K. Vaidya 2008). Evaluation of the effect of pH (2.0-9.0) on biosorption indicated that a decrease in the pH of the solution increased the rate of removal of Chromium (VI), showing highest biosorption of 20.17% Chromium (VI) removal at pH 2.0. Optimization indicated that the rate of removal of Chromium (VI) increased with a decrease in Chromium (VI) concentrations and with increases of biomass concentrations.

The adsorption studies on the removal of nickel (II) and zinc (II) from aqueous solution using treated GAC (Granular Activated Carbon) and carbon aerogel were carried out under varying experimental conditions by Ajay Kumar Meena et.al., (2005). Treated GAC showed 98% and 94% and carbon aerogel 92% and 96% adsorptive removal of Nickel (II) and Zinc (II), respectively under optimized
conditions of pH 8.0 and dosage 1.2 gm/100 ml for 3 mg/l Nickel and Zinc (II) from aqueous solutions in 48 hr contact time. The adsorption was found to be pH dependent and maximum adsorption occurred at pH 8.0 and 6.0 for treated GAC and carbon aerogel, respectively. Authors concluded that, these experimental studies on low cost adsorbents would be quite useful in developing an appropriate technology for the removal of Nickel (II) and Zinc (II) from contaminated plant effluents.

Akira OTSUKI et.al., (2004). Reported that Nickel (Ni) and Zinc (Zn) found in wastewater from industrial factories can be effectively removed by physicochemical adsorption using mainly natural zeolite. They achieved best results while 50 mg/l of natural zeolite and 0.5 mg/l of aluminium ion were added into solution at pH 10. More than 98% of nickel and zinc and more than 94% of phosphorous were removed from the wastewater.

Sing et.al., (2000), polymer grafted used tea leaves (PGUTL) has been used as adsorbent in this study for removal of 7 heavy metals Mi, Mn, Cu(II), Zn, Cd(II), Hg, Pb from an aqueous solution. Adsorption isotherms and thermodynamic parameters were also studied. The effects of contact time, initial concentrations, pH and temperature for removal of heavy metals have been studied in these experiments.