STUDY OF BIOACCUMULATION OF HEAVY METAL FROM SEWAGE WASTEWATER AND DEVELOPMENT OF ADSORBENT BASED REMOVAL TECHNIQUE

A Thesis Submitted to
Babu Banarasi Das University
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in
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Certificate of the Supervisor(s)

This is to certify that the thesis, entitled **"Study of bioaccumulation of heavy metal from sewage wastewater and development of adsorbent based removal technique"** submitted by **Lal Ji Verma** for the award of **Degree of Doctor of Philosophy** to Babu Banarasi Das University, Lucknow, are record of authentic work carried out by Lal Ji Verma under my supervision. To the best of our knowledge, the matter embodied in this thesis is the original work of the candidate and has not been submitted elsewhere for the award of any other degree or diploma.

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DECLARATION BY THE CANDIDATE

I, hereby, declare that the work presented in this thesis, entitled **"Study of bioaccumulation of heavy metal from sewage wastewater and development of adsorbent based removal technique"**. in fulfillment of the requirements for the award of Degree of Doctor of Philosophy of Babu Banarasi Das University, Lucknow is an authentic record of my own research work carried out under the supervision of **Dr. Pramod Kumar Singh** (Associate Professor) Department of Environmental Science, Babu Banarasi Das University, Lucknow, India- 226025

I also declare that the work embodied in the present thesis is my original work and has not been submitted by me for any other Degree or Diploma of any university or institution.

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PREFACE

Wastewater is the biggest issue now a days for the treatment prospective due to the operation and chemicals cost is too high. Untreated wastewater is most dangerous for our environment and living things. The degradation of surface water quality and aquatic life due to wastewater which was generated by industry as well as municipal corporation. There is highly need to treat wastewater which are containing heavy metals such as cadmium waste water generation increased due to rapid growth of population, rapid urbanization with change in lifestyle, growing industrialization and agricultural activities, which have deteriorated the surface water and groundwater quality in the last few decades. Cadmuim containing minerals spread out more than twenty states of the country and both are largely contaminate these precious resource. WHOhave reported in 2012, 748 million peoples are yet relied on contaminated drinking water resources worldwide. 200 million peoples are face serious issue of surplus fluoride in drinking water in the region of 27 country across the global and 66.64 million people in India.

The present research work done at Noida Drain district Gautam Budh Nagar UP (India) situated at Indo-Ganga basin. For this two wastewater samples were collected during research work for the bioaccumulation of metal in water hyacinth Total four plant was cultivated in each basket and fodder plant sample plant was collected from drain.

For the identification of cadmium and other chemical parameter of wastewater variation in drain water, the water sample were collected in can and putted it on basket for the growth of plants. Sampling stations were selected considering the distance from our pilot project was installed and wastewater was collected from downstream of drain. These samples were analyzed for various parameters in the laboratory according to standard procedures of APHA and Indian Standard.

Various hydrochemical parameters such as pH, Electrical Conductivity (EC), ,Total Dissolved Solids (TDS), Turbidity, Salinity and Cadmium were analyzed.

The drain water was used for the irrigation purpose by the formers and the major resource of drinking water for the wildlife animals and aquatic animals like Neelgai and others. Low concentration cadmium or metal was very dangerous when they are entering to the food chain and affecting the lifecycle of living thing such as animals and human beings. When the concentrations of Heavy metal was low then the conventional treatment process are not being used due to the economical feasible in the treatment system. For the optimum treatment and removal of cadmium with economical was identified to develop low cost adsorbent and treat the waste water.

In this process we had developed biosorbent by the water hyacinth which was easily available in environment and it is helpful to crate ecological balance in the environment. This study have also used for the absorption of the cadmium itself. Which was helping to the environmental and further it can be used as alternative fuels. This is natural purification process and water hyacinth was used for the development of activated carbon for the adsorption process. Activated carbon was made by different part of water hyacinth and analysis the removal efficiency of activated carbon. This process also implemented on the iron powder and oxidized iron powder which was used as adsorbent to adsorb the cadmium from wastewater. India is having wide range of river and drains length which can be used and natural wastewater treatment process to develop ecology and feasible in economical point of view.

DEDICATED

TO

TEACHERS

&

MY FAMILY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF THE FIGURES

Chapter – 1

Chapter 1

Introduction

1.1 Introduction

Over the years, the quality of water is deteriorating mainly due to the anthropogenic activities, population growth, unplanned urbanization, rapid industrialization and huge exploitation of natural water resources. Industrial wastewater contains high levels of heavy metals that may pollute the water once it is discharged in to the nature without proper treatment. These metals include arsenic, chromium, copper, zinc, aluminium, cadmium, lead, iron, nickel, mercury, and silver. Heavy metals are elements that have equal or more than five times the specific gravity than that of water. They are one of the most toxic types of water pollutants (Haung *et al.*, 2007). At least 20 metals are considered to be toxic, and approximately half of these metals are emitted to the environment in quantities that are hazardous to the environment, in addition to the human health (Inthorn *et al.*, 2007).Heavy metals are among the toxic substances reaching hazardous levels (Vieira, 2000). Metal ions such as Cd, Cr, Co, Cu, Zn, Pd, Hg, Ni, Ag, and Sr and metalloids such as Se, As, and Sb are toxic if consumed beyond permissible limits (Arivoli et al., 2008). Heavy metals even at low concentrations can cause toxicity to humans and other forms of life, its adverse effects on human health are quite evident. It is well known that in human being heavy metals are toxic and they can damage nerves, liver and bones, and they can block functional groups of vital enzymes too. Heavy metals ion toxicity is due to their ability to bind with protein molecules and prevent replication of DNA and thus the subsequent cell division (Kar et al., 1992).

Heavy metal pollution in aquatic systems has become a serious threat and has a great potential to cause environmental-derived cancer because these metals are non-biodegradable and therefore persist in to environment for long time. Metals are mobilized and carried into the food web as a result of leaching from waste dumps, polluted soils and water. These metals increase in concentration at every level of the food chain and are passed onto the next higher level ina phenomenon called bio-magnifications (Paknikar et al., 2003; Pandey et al., 2008). The contamination of water with substances that have an adverse effect on human beings, animals and plants is calledwater pollution. Water pollution is a worldwide problem, and its control has become increasingly important inrecent years (Robinson et al., 2001).

Municipal or industrial effluents treated by wastewater treatment plants contain large amounts oforganic matter and pollutants, including metals such as Cu, Zn, Cd and Pb. The uptake of metals by sludge flocksis of great significance in pollution control (Guibaud et al., 2006). Lead is avery toxic heavy metal, and its target organs are bones,the brain, blood, kidneys, and the thyroid glands. The presence of lead in discharge and its toxic nature cause other adverse effects on receiving waters in the aquatic system. Even a very low concentration of heavy metals in water can be very toxic to aquatic life. When the heavy metal concentration exceeds the tolerance level, it will show harmful effects on human physiological and other bio-logical systems (Horsfall et al., 2004).

The main source of lead and cadmium in water is the effluents of processing industries, *i.e.*, electroplating, paint, pigment, basic steel work, textile industries, metal finishing and electric accumulators’ batteries (Ansari et al., 2011). Cadmium is one of the most toxic environmental and industrial pollutants because it can damage almost all important organs. (ATSDR, 2008) Cadmium and its compounds are also used in paints, pigments, plastics, electroplating, equipment's, machineries, baking channels and photography (Csuros and Csuros, 2002). Even small quantity of Cd assimilation by the body can cause severe high blood pressure, heart disease and can lead to death (Pan et al.,2010). The acute over exposure to Cd fumes can cause pulmonary diseases while chronic exposure causes renal tube damage and prostate cancer (Jarup & Akesson, 2009).

Thus, waste water treatment *i.e.*, sewage generated from municipal area or effluent from industrial area must be treated before discharge in main water stream. During the industrialization in developing country trend has been for more mechanized wastewater treatment system with almost every aspect of the various processes and technologies which are under the direct control of the operations, after the enactment of Water (Prevention and Control of Pollution) Act 1974, in India. Alternate methods of wastewater treatment once again become recognized because of its nature of ecological and eco-environment friendly as valid means of achieving the required level of effluent quality.

Some of the treatment processes that have been used to remove heavy metals from wastewater include precipitation with coagulation and flocculation, ion exchange, complexation of dry biomass and adsorption (Inthorn *et al.,* 2002). However, there are limitations: Precipitation produces large quantities of heavy metals rich waste sludge while ion exchange and biomass methods are costly and cannot be readily applied to large scale applications. Adsorption as a process, employed due to its low cost and applicability on large scales. Adsorption is commonly being done using activated carbon, which adsorbs dissolved organic substances in the water treatment (Lodeiro *et al*., 2006). Although activated carbon has its advantageous, such as its effectiveness in removing colours and its applicability on wide variety of organic compounds, it has limitations that prevent it from treating highly soluble organics, and high concentrations or organic and inorganic compounds. In addition to these, cost of operation is high. Other adsorbents that have been used include synthetic polymers and silica-based substances (Inthorn *et al.*, 2002). However, these materials are more costly compared to activated carbon. Hence, there is a perceived necessity and growing interest in finding adsorbents that are more cost-effective and produce fewer limitations including high temperatures and pressures. Therefore, finding suitable materials and operating conditions are essential to addressing the concerns of heavy metal pollution (Lodeiro *et al*., 2006).

Removal of heavy metals from contaminated water is major challenge. Conventional methods for removing metals from aqueous solutions include chemical precipitation, chemical oxidation and reduction, ion exchange filtration,electrochemical treatment, reverse osmosis, membrane technologies and evaporation. Most of them involve high capital costs with recurring expenses, which are not suitable for small scale industries. Inspite of these the major disadvantage of conventional treatment technologies is the production of toxic chemical sludge, whose disposal/treatment becomes a costly affair and is no eco-friendly. Therefore, removal of toxic heavy metals to an environmentally safe level in a cost-effective and environmentally friendly manner is of great importance (Ahluwalia et al., 2007 and Hanif et al., 2007).

Adsorption method is considered to be one of the preferable methods for the removal of heavy metal ions from aqueous solution due to it significant advantages such as low operational cost, wide applicability and creation of relatively low sludge(Venkateswarlu et al., 2007; Shafaghat et al., 2012; Mengistie et al., 2012; Pandharipande et al., 2012).In recent years, considerable attention hasbeen devoted to the study of the removal of heavymetal ions from solution by adsorption using agricultural materials. Natural materials that are available inlarge quantities or certain wastes from agricultural operations may have the potential to be used as low-costadsorbents, and they represent unused resources, whichare widely available and are environmentally friendly.Some investigations on the removal of heavy metalions with agricultural by-products have been previously reported (Mohan et al., 2002). According to Ali et al., (2012), low-cost sorbents have been divided into the following groups: (i) Agricultural and household byproducts, (ii) industrial by-products, (iii) sludge, (iv) sea materials, (v) soil and ore materials and (vi) novel low-cost adsorbents.

Use of agricultural by-products as adsorbents for heavy metal removal from industrial waste water has been increasing nowadays. Most of the studies were focused on plant wastes such as rice husk and neem bark (Bhattacharya et al., 2006; El-Said, 2012), Black gram husk (Saeed & Iqbal, 2003), Waste tea, Turkish coffee, Walnut shell(Orhan & Büyükgüngör, 1993) etc. Some more adsorbents like papaya wood (Saeed et al., 2005), maize leaf (Babarinde et al., 2006), teak leaf powder (King et al., 2006), *Coraindrum sativum*(Karunasagar et al., 2005), lalang (*Imperata cylindrica*) leaf powder (Hanafiah et al., 2007), peanut hull pellets (Johnson et al., 2002), sago waste (Quek et al., 1998), saltbush (*Atriplex canescens*) leaves

(Sawalhaet al., 1998; Sawalha et al., 2007), tree fern (Ho 2003; Ho& Wang , 2004; Ho et al., 2004), grape stalk wastes (Villaescusa et al., 2004) etc., are also studied in detail. The benefits of using agricultural wastes for wastewater treatment include easy technique, needs modest processing, superior adsorption ability, and selective adsorption of heavy metal ions, economical, easy availability and easy regeneration.

With increasing environmental awareness and legal constraints being imposed on the discharge of effluents, a need for cost-effective alternative technologies is essential. In this endeavor plant biomass can emerged as an option for developing economic and eco-friendly wastewater treatment through a process called biosorption. Biosorption can be defined as “a non-directed physicochemical interaction that may occur between metal/radionuclide species and microbial cells” (Shumate and Stranberg, 1985). It is a biological method of environmental control and can be an alternative to conventional contaminated water treatment facilities. It also offers several advantages over conventional treatment methods, including cost effectiveness, efficiency, minimization of chemical/biological sludge, the requirement of additional nutrients, and regeneration of bio sorbent with possibility of metal recovery.

Thus biosorption may be other alternative methods for removal of heavy metals. Biosorption is defined as the abilityof biological materials to accommodate heavy metalsfrom wastewaters through the metabolically mediatedphysico-chemical pathways of uptake. Algae, fungi, bacteria, parts of some higher plants and yeasts have provento be potential metal bio sorbents. So in present study bio sorption of Cd through water hyacinth,which grows naturally and can act as good biosorbents of heavy metal?

Biomass has been allotted numerous roles to play for sustainable development. In addition to being a food source and renewable raw material, it can be used for energy production, carbon sequestration and, as an essential element for the production of hydrochars and activated carbons. In the past few years, the use of hydrothermal carbonization for conversion of biomass waste into valuable carbon materials has received considerable attention due to its ability to produce hydrochars with attractive characteristics that promote efficient utilization for a variety of applications such as adsorption (Liu &. Zhang 2009; Liu et al., 2010), bio imaging (Selvi et al., 2008; Guo et al., 2008), catalysis (Titirici et al., 2006; Wang et al., 2011), activated carbon synthesis (Sevilla et al., 2011; Sevilla& Fuertes 2011;Sevilla et al., 2011) etc. Utilization of biomass waste for producing hydrochars is attractive because it offers solutions for solid waste management, reduces the cost of raw materials and the properties of the final product can be tailored for different temperature.

Various industrial wastes have also got adsorption capacity and can be used for adsorbing heavy metals from wastewater. These industrial wastes are produced as a by-product and are used rarely for any purpose. The by-product nature renders it to be easily available and very economical also. These industrial wastes are found to have good application as adsorbent. Adsorptive capacity of these wastes could be increased followed by slight processing. Industrial by-products such as fly ash (Bayat,2002; Wang et al., 2007), blast furnace sludge (Dimitrova, 1996; Srivastava et al., 1997), waste slurry, lignin-a black liquor waste of paper industry (Suhas and

Ribeiro, 1994; Srivastava et al., 2007; Demirbas, 2004), iron (III) hydroxide (Namasivayam and Ranganathan,1993; Namasivayam and Ranganathan K, 1998) and red mud (Altundogan et al., 2000; Gupta VK, Ali Imran 2002) have been explored for their technical feasibility to remove toxic heavy metals from contaminated water. Other industrial wastes, coffee husks (Oliveira et al., 2008), Areca waste (Zheng et al., 2008) tea factory waste (Malkoc and Nuhoglu, 2007), sugar beet pulp (Pehlivan et al., 2006), waste pumice of olive oil factory waste (Malkoc et al., 2006), battery industry waste, waste biogas residual slurry (Namasivayam and Yamuna , 1995), sea nodule residue(Agrawal et al., 2004) have been utilized as low-cost adsorbents for the removal of toxic heavy metals from wastewater. Several adsorbents have been used for adsorption of Zinc from waste water. Some of the highest adsorption capacities reported for Zn^{2+} are 168 mg/g powdered waste sludge, 128.8 mg/g dried marine green macro-algae, 73.2mg/g lignin, 55.82mg/g cassava waste, and 52.91mg/g bentonite (Zwain et al., 2014).

Use of water hyacinth (*Eichornia crassipes*) which is an aquatic plant (macrophyte) for removal heavy metal particularly cadmium from waste water. Understanding of these plants is important to the overall operation of the treatment system due to acceptability and availability of the local climate. Water Hyacinth systems are differentiated from oxidation ponds in that they use aquatic macrophytes for treatment. The macrophytes used are usually floating varieties, but some systems have been observed with submerged varieties. The aquatic plants in a system may act in a similar capacity to the algae in an oxidation technique by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by up taking them into plant tissues. The macrophytes used are usually floating varieties, but some systems have been investigated with submerged varieties. The macrophytes in a system may act in a similar capacity to the algae in am oxidation pond by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by incorporating them into the plant tissues. Treatment techniques which use vegetation are attractive to designers in part because the aquatic plants act as a natural nutrient sink. Some plants are capable of absorbing substantial amount of metals and some dissolved organics (Lakshman, 1989). The organics may be destroyed be the plant's metabolic activities or stored while metal are not degraded, but are usually stored within the plant tissue. Many of the plants used I these systems can be sold, either whole or in part, and if a market exists they offer a potential for some revenue to offset operating expenses (DeBusk and Ryther 1987).

Water hyacinth is the largest of the known floating aquatic macrophytes, reaching a height of as much as one hundred twenty centimeters. It is advantage of South America, India and subcontinent. At the time botanists believed the plant's range to be restricted to South America with possible excursions in to Central America too and the larger Islands in the Caribbean (Dinges, 1982). The plant moves readily in the wastewater but is intolerant of high salinity. This is probably the only reason that its range control of these plant's species is difficult since they are one of the world's most productive plants they have eighth fastest growth rate of the top ten weeds (Metcalf & Eddy, 1991). In nutrient rich waters such as wastewater, the rate can be even higher (Reed et al., 1988). These very characteristics that make the importance of water hyacinth a serious problems on natural water male it a good candidate for use in wastewater treatment. The range of this plant in the wild has expanded in to tropical and subtropical regions of the world. The thirty-second parallels are the approximate limits of the plant's geographic range (EPA, 1978). Water hyacinths can be growing outside this range, but they must be protected from the winter temperatures.

Water Hyacinth systems are differentiated from oxidation ponds in that they use aquatic macrophytes for treatment. The macrophytes used are usually floating varieties, but some systems have been observed with submerged varieties. The aquatic plants in a system may act in a similar capacity to the algae in an oxidation technique by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by up taking them into plant tissues. The macrophytes used are usually floating varieties, but some systems have been investigated with submerged varieties. The macrophytes in a system may act in a similar capacity to the algae in am oxidation pond by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by incorporating them into the plant tissues. Treatment techniques which use vegetation are attractive to designers in part because the aquatic plants act as a natural nutrient sink. Some plants are capable of absorbing substantial amount of metals and some dissolved organics (Lakshman, 1989). The organics may be destroyed be the plant's metabolic activities or stored while metal are not degraded, but are usually stored within the plant tissue. Many of the plants used I these systems can be sold, either whole or in part, and if a market exists they offer a potential for some revenue to offset operating expenses (DeBusk and Ryther 1987). Aquatic Plant (Water Hyacinth) has essentially the same nutritional requirements as terrestrial plants, but they have adapted their metabolisms to the aquatic environment. Water Hyacinth has high water contents compared to terrestrial plants. Aquatic Plant not only provide treatment by taking nutrients and dissolved constituents into their systems, But also by modifying the environmental conditions around them, or by providing a growing surface for the aerobic microorganisms which contribute to the treatment.

In present study, water hyacinth (*Eichornia crassipes*) was grown in waste water to study bio sorption of Cd through rhizofiltration. To study the adsorption, activated charcoal were developed as low cost absorbent to remove the Cd metal from aqueous solution. Iron Oxide(Fe_2O_3) was also used to study adsorption of Cd. Thus, adsorption processwas studied by removal of cadmium from activated charcoal and iron oxide as the adsorbent.The main scope of present study, the removal of cadmium using cheap and readily available adsorbents.The experiments were performed in the laboratory scale, and consist of batch and column tests. Batch experiment results will help to determine the sorption capacity and to understand sorption mechanism of the selected adsorbent. Column tests will perform with variable parameters to access optimum operating conditions in continuous mode. Introduction All Aquatic Plant systems rely upon the plant species employed to provide or facilitate the treatment desired.

1.2 AIMS AND OBJECTIVES:

The present work in Study bioaccumulation of heavy metal from sewage wastewater and development of adsorption based removal technique aim to remove cadmium from wastewater by activated charcoal prepared from water hyacinth. In this work biosorption of cadmium by water hyacinth directly.

The main objective of proposed research work

- Periodical analysis of chemical properties of sewage waste water.
- To study of biosorption and removal efficiency of heavy metal in water hyacinth (*Eichornia crassipes Mart.*).
- To develop activated carbon from different part of water hyacinth.
- To study and characterize surface morphology of activated charcoal.
- To study the metal removal efficiency of activated carbon developed from water hyacinth in different condition.

Chapter – 2

Chapter 2

Review and Literature

Industrial wastewater contains high levels of heavy metals that may pollute the water once it is discharged to the nature. These metals include arsenic, chromium, copper, zinc, aluminium, cadmium, lead, iron, nickel, mercury and silver. Heavy metals are elements that have more than five times the specific gravity than that of water. They are one of the most toxic types of water pollutants. At least 20 metals are considered to be toxic, and approximately half of these metals are emitted to the environment in quantities that are hazardous to the environment, in addition to the human health (Inthorn *et al.,* 2002).

2.1 Cadmium Pollution

This part of the literature survey has been made to understand this toxic metal, cadmium, in respect of its general properties, sources, production and uses, mechanism of water, air and soil pollution by it, the probable pathways of its exposure to human and its adverse effects on human, animals and vegetation.

2.2 Cadmium: Some General Information

Cadmium (Cd) was discovered by Fredrich Stromeyer in 1817. Cd is in the Group-12 or the Zinc Group of the periodic table (Table-2.1) along with Zinc (Zn) and Mercury (Hg). Atomic number and Atomic Weight of Cd are 48 and 112.41 respectively. Cadmium has the electronic structure of $[\mathrm{Kr}]^4 d^{10} 5s^2$ with major oxidation state of II. Typical to $d^{10}s^2$ electronic arrangement it forms Cd^{2+}ions. Table-2.1 summarizes some physical properties of Cadmium (Srivastava *et al.,* 2006).

Table 2.1: Some physical properties of Cadmium

Properties	**Values**
Covalent Radius (Å)	1.41
Ionic Radius Cd^{2+} (Å)	0.95
Melting Point (OC)	321
Boiling Point (OC)	765
Density (g/cc)	8.65
Pauling’s Electro-negativity	1.7
Isotopes	15
Standard Potential	-0.402V

Like any other metal solubility of cadmium varies with pH as can be seen from Figure-2.1. Cadmium forms an insoluble and highly stable hydroxide at an alkaline pH. Cadmium in solution is approximately 1 mg/L at p H 10 and 0.05 mg/L at pH 11.

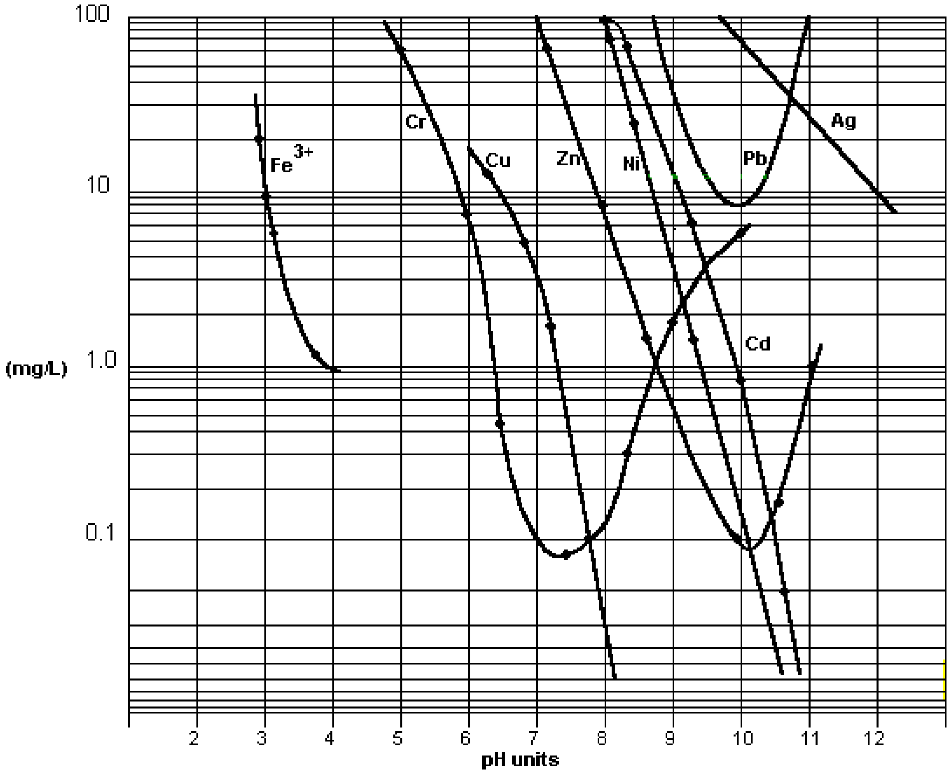


Fig. 2.1: Solubility of metal versus pH (Source: Suponik T, 2010)

2.3 Sources of Cadmium

Cadmium is a lustrous, silver-white, ductile, very malleable metal. Its surface has a bluish tinge and the metal is soft enough to be cut with a knife, but it tarnishes in air. It is soluble in acids but not in alkalis. It is similar in many respects to Zinc but it forms more complex compounds. Cd has both natural and anthropogenic sources. In spite of being rare in the earth's crust (0.16 ppm by weight), it is familiar because extraction and purification of cadmium are simple. Cadmium is obtained as a by-product of zinc refining. Greenockite (CdS), is the only cadmium mineral of importance. It is not possible to produce refined zinc metal without generating cadmium as a by-product. The percentage of cadmium in zinc concentrates varies from mine to mine, ranging from 0.07% to 0.83 % with an average of 0.23%. Since the average zinc content of these concentrates is 55 %, approximately 3 kg of cadmium will be produced for every tonne of refined zinc. The evolution of cadmium production in the western world between 1980 and 1993 is shown in Figure-2.2 (Lodeiro *et al.*, 2006).

2.4 Effects of Cadmium

Cadmium is very toxic heavy metal in nature which exerts toxic effects on the kidney, the skeletal system as well as the respiratory system and it is classified as a human carcinogen (IPCS, 2005–2007). It is normally present in the atmosphere at low levels; however, anthropogenic activity has greatly increased cadmium levels (IPCS, 1992). Cadmium can travel long distances from the source of emission by atmospheric transport (WHO, 2007).

It is generally accumulated in many organisms, notably mollusks and crustaceans. Lower concentrations are found in vegetables, cereals and starchy roots, which having the bio magnifications properties. Human exposure occur cadmium mainly from consumption of contaminated food, active and passive inhalation of tobacco, smoke and inhalation by workers in the non-ferrous metal industry (IPCS, 1992).

National and global actions are now necessary to impose the implemented to decrease global environmental cadmium releases and reduce occupational and environmental exposure with in limited time frame. The major part of cadmium metal is coming to human from diet of agricultural products. The pathway of human exposure from agricultural crops is susceptible to increases in soil cadmium due to excess use of fertilizer, pesticide and insecticide which as increase in soil cadmium contents result in an increase in the uptake of cadmium by plants.

Cadmium may be released to the our atmosphere in a different number of ways, including: Natural activities, such as volcanic activity, weathering and erosion of rocks, and river transport; Human activities, like tobacco smoking, mining, smelting and refining of nonferrous metals, fossil fuel combustion, incineration of municipal waste (especially cadmium-containing batteries and plastics), manufacture of phosphate fertilizers, and recycling of cadmium-plated steel scrap and electric and electronic waste. Remobilization of historic sources, such as the contamination of watercourses by drainage water from metal mines. Cadmium releases can be carried to and deposited on areas remote from the sources of emission by means of long-range atmospheric transport.

World Health Organization (WHO; 2003) cadmium guidelines Provisional tolerable monthly intake (PTMI) The Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) recently (in 2010) established a provisional tolerable monthly intake for cadmium of 25 µg/kg body weight according to WHO report (in preparation) and in Drinking-water the permissible limit should be 3 µg/l, and in ambient air, 5 ng/m^3(annual average).

Health effects:

High inhalation exposure to cadmium oxide fume may result in acute pneumonitis with pulmonary oedema, which may be cause of death in extreme cases. High ingestion exposure of soluble cadmium salts causes acute gastroenteritis. Long-term occupational exposure to cadmium has caused severe chronic effects, predominantly in the lungs and kidneys. Chronic renal effects have also been seen among the general population. Following high occupational exposure, lung changes are primarily characterized by chronic obstructive airway disease. Long-term inhalation exposure and intra tracheal administration causes chronic inflammatory changes in the lungs fibrosis (Eiland et al., 1994). Long-term parenteral or oral administration produces effects primarily on the kidneys, but also on the liver and the hematopoietic, immunity, skeletal, and cardiovascular systems. Under defined condition skeletal effects and hypertension have been induced in with continued cadmium exposure, to respiratory insufficiency. An increased mortality rate from obstructive lung disease has been seen in workers with high exposure, as has occurred in the past. The kidney is the main targeted organ. Cadmium accumulates mainly in the kidneys, by which the physo-chemical properties and metabolism are changed in human being and its biological half-life in humans is 10–35 years. This accumulation may lead to renal tubular dysfunction, which results cancer and in increased excretion of low molecular weight proteins in the urine. This is generally irreversible. High intake of cadmium is leading to change in calcium metabolism and the formation of kidney stones. Softening of the bones and osteoporosis may occur in those exposed through living or working in cadmium-contaminated areas. In an area of Japan where soil has been contaminated with cadmium from zinc/lead mines, Itai-itai disease used to be widespread and is still seen in women over 50 years of age. It is characterized by osteomalacia, osteoporosis, painful bone fractures and kidney dysfunction. High inhalation exposure to cadmium and its oxide fume results in acute effect with pulmonary oedema, which may be lethal. LD_{50} and LC_{50}, Long-term, high-level occupational exposure is associated with lung changes, primarily characterized by chronic obstructive airway disease. There is limited technical proof that cadmium may cause cancers of the kidney and prostate. IARC has classified cadmium and cadmium compounds as carcinogenic to human (Group 1), meaning that there is sufficient evidence for their carcinogenicity in humans.

There are various mechanisms at work for entry of cadmium as a pollutant in water, air and soil. A summary of cadmium releases to the above mentioned principal components of environment is presented here.

2.5 Mechanism of Water Pollution by Cadmium

Based on the data from different countries, data compiled by industry, the major sources of water discharges (whose relative importance varies depending on the country) are:

- Production of non-ferrous metals (zinc, lead and copper);
- Production of iron and steel;
- Production of phosphate fertilizers and phosphoric acid, gypsum disposal;
- Municipal sewage treatment.

Cadmium is a natural, usually minor constituent of surface and groundwater. Generally, cadmium may exist in water as hydrated ion (Cd^{2+} $6H_2O$); as inorganic complexes with CO_3^{2-}, OH^-, Cl^-, or SO_4^{2-}, or as organic complexes with humic acids. Cadmium can enter aquatic systems through weathering and erosion of soils and bedrock, atmospheric fall-out, direct discharge from industrial operations, leakage from landfills and contaminated sites, and the dispersive use of sludge and fertilizers in agriculture. Much of the cadmium entering fresh waters from industrial sources are rapidly adsorbed by particulate matter, where it may settle out or remain suspended depending on local conditions. This can result in low concentrations of dissolved cadmium even in rivers that receive and transport large quantities of the metal. Sediment is a significant sink for cadmium emitted to the aquatic compartment. Depending on physico-chemical conditions (e.g. pH, suspended matter levels, redox potential, salinity and on man-made interventions such as dredging, cadmium may be re-circulated to the water column and hence become bio available. Acidification of lakes may result in enhanced mobilization of cadmium from sediments, and lead to increased levels in the overlying water.

2.6 Mechanism of Air Pollution by Cadmium

Based on the information of various countries, data compiled by industry, it could be said that there exist four major sources of atmospheric releases. These sources are:

- Production of non-ferrous metals (zinc, lead and copper);
- Production of iron and steel;
- Combustion of fossil fuels;
- Waste incineration.

Emissions of cadmium to the atmosphere represent an important transport pathway, leading to its precipitation and the deposition onto soil, vegetation and surface waters (Ajmal *et al.,* 1998). The atmosphere receives direct input from industrial processes such as the production of non-ferrous metals, production of iron and steel, fossil fuel combustion and waste incineration, and also from natural sources such as forest fires and volcanism. Deposited cadmium can be re-entrained into air with windblown dust. Emissions give rise to both local contamination and deposition of cadmium in areas remote from the sources.

Cadmium released to the atmosphere is predominantly in particulate form and can be transferred to other environmental compartments via wet or dry deposition. Cadmium compounds commonly found in the atmosphere (e.g. oxide, sulphide, sulphate and chloride) are stable, do not undergo chemical reactions quickly, and have relatively short tropospheric residence times (one to four weeks). Nearly all-airborne cadmium originating from combustion sources is associated with aerosols and fine particles (Srivastava *et al.*, 1997).

2.7 Mechanism of Soil Pollution by Cadmium

Soil may also get polluted by Cadmium due to its release on land from some sources. A few of the major sources discharging their Cd-bearing waste on to land are:

- Production of phosphate fertilizers and phosphoric acid (gypsum);
- Production of non-ferrous metals (zinc, lead and copper);
- Production of iron and steel;
- Combustion of fossil fuel;
- Disposal of household waste;
- Disposal of industrial waste.

Information on levels of cadmium in solid wastes is limited. Due to improved treatment of flue gas and wastewater (e.g. in the production of nonferrous metals, iron & steel, and in power plants) it is obvious that more cadmium is retained in ash and sludge, which can be recycled or sent to landfill. The commercial use of cadmium in products has steadily increased since 1980, although a small decrease has been observed since 1991. It can therefore be anticipated that increasing amounts of cadmium may arise in solid waste, unless mitigated by recycling. Cadmium in soils is derived from natural and anthropogenic sources. The cadmium, which occurs naturally in soils, is derived mainly from underlying bedrock or transported parent material (e.g. glacial till and alluvium). Phosphates can be particularly rich in cadmium. Anthropogenic input of cadmium to soils can occur via aerial deposition, sewage sludge, manure, and phosphate fertilizer application. In contrast to the water and air compartments, where it is very rapidly transported, cadmium is rather immobile in the soil. The major factors governing cadmium speciation, adsorption and distribution in soils are pH, soluble organic matter content, hydrous metal oxide content, clay content and type, presence of organic and inorganic ligands, and competition from other metal ions. Soil pH is the most important factor controlling the availability of cadmium; it affects the stability and solubility of cadmium complexes, as well as nearly all adsorption mechanisms. The more acid the soil is, the more mobile the cadmium becomes, thereby facilitating its uptake by plants or its more rapid leaching.

The major route of exposure to cadmium for the non-smoking segment of population is via food. Even in the absence of environmental contamination cadmium as a trace constituent is present in most food commodities. Plants play a central role in the transfer of cadmium from the environment to man, and cadmium accumulated in certain foods of animal origin, such as offal, also indirectly originates from cadmium in vegetable fodder. Tobacco is an important source of cadmium uptake in smokers. In exposed workers, lung absorption of cadmium following inhalation of workplace air is the major route of exposure. Plants absorb cadmium through two principal pathways: direct atmospheric deposition, especially in rural and industrial areas, (20%-60% of total plant cadmium may originate from direct deposition) on exposed plant parts such as leaves, cereals, and fruits, and absorption through root uptake and subsequent transport, especially to leaves and less so to fruits and seeds.

The two important sources of cadmium to agricultural soils are atmospheric deposition and direct inputs through, for example, the application of phosphate fertilizers. The contribution from other pathways to total uptake is small.

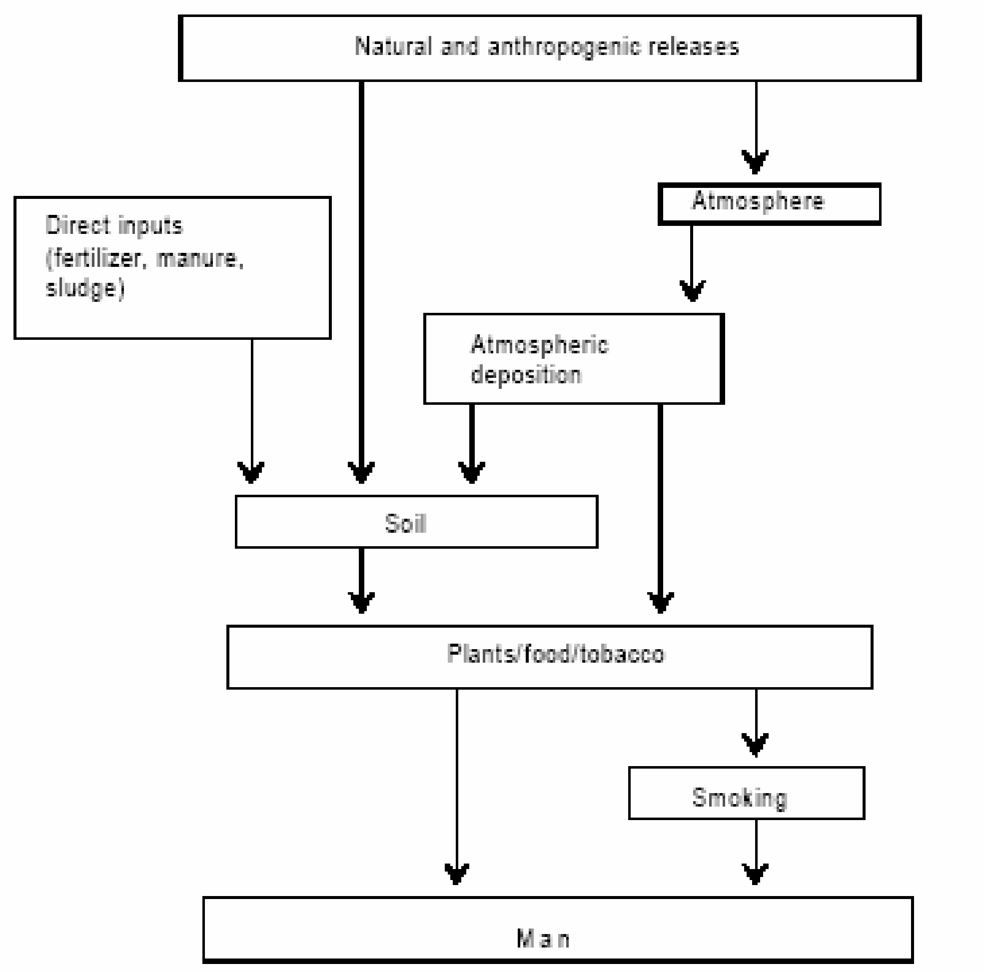


Fig.2.2 Sources of Cadmium (Chunhabundit R, 2016)

2.8 Environmental Effects

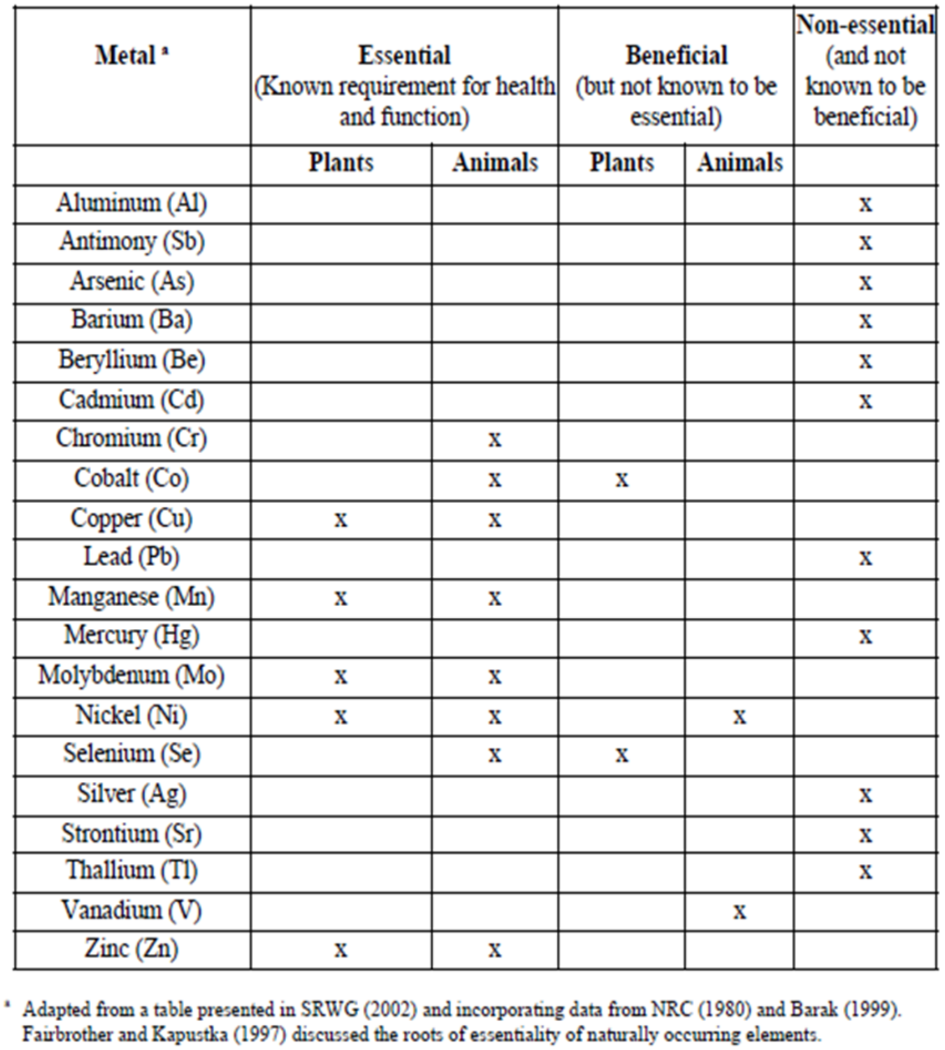
Cadmium and cadmium compounds are, compared to other heavy metals, relatively water soluble. Heavy metals are more mobile in e.g. soil and food cycle generally more bio-available and tend to bioaccumulation. Cadmium is readily accumulated by many organisms, particularly by microorganisms and molluscs where the bio-concentration factors are in the order of thousands which are known magnification. Soil invertebrates also concentrate cadmium markedly. In animals, cadmium concentrates in the internal organs rather than in muscle or fat. It is typically higher in kidney than in liver, and higher in liver than in Muscle. Cadmium levels usually increase with age due to its biomagnifications and accumulation properties with these properties cadmium become more carcinogenic, harmful to human being. Cadmium is not essential for plant or animal life. The following information has largely been extracted from the IPCS monographs /WHO 1992a; WHO 1992b/ unless otherwise indicated.

Birds and mammals

Large oral doses damage the gastric. The occurrence of teratogenic effects and placental damage depends on the stage of gestation at which exposure occurs. Acute inhalation of cadmium causes effects on the lung and the chronic effects on the kidney. It causes dysfunction of tubular & glomerular of kidney. Tubular cells get damaged also. Renal tubular dysfunction causes disturbance of calcium and vitamin D metabolism. Some studies show this has led to osteomalacia and/or osteoporosis. But some studies consider a direct effect of cadmium on bone mineralization. The toxic effects of cadmium in experimental animals are influenced by genetic and nutritional factors. This occurs due to interactions with other metals, particularly zinc, and pretreatment with cadmium. Chronic cadmium exposure produces a wide variety of acute and chronic effects in mammals similar to those seen in humans. Kidney damage and lung emphysema are the initial effects of high cadmium metal in the body. Some reports related to kidney damages have been identified in wild colonies of pelagic sea birds having cadmium level of 60-480 µg/g in the kidney (WHO 1992b).

Municipal waste may contain cadmium products, or materials in which cadmium is present as an impurity. The incineration of these wastes has potential for release of cadmium through stack emissions and land filling of ashes (Lodeiro et al., 2006). The leaching of cadmium from disposed solid waste is dependent on many factors, e.g. physico-chemical properties of the cadmium containing products, pH of the liquid phase of the landfill, rainwater, temperature changes. Results of laboratory experiments on leaching of cadmium from pigmented plastics have been interpreted as showing that these products would not contribute significantly to cadmium leachate from landfills. Cadmium assays of incinerator ash in the United States have suggested that land filled ash could pose a hazard to human health and the environment if cadmium were allowed to leach from landfills into groundwater. Domestic and industrial cadmium-containing waste can be brought to three sorts of landfills, industrial, municipal or mixed.

Table 2.2 Metal Classification by their known Essentialty



Metal [a]	Essential (Known requirement for health and function)		Beneficial (but not known to be essential)		Non-essential (and not known to be beneficial)
	Plants	Animals	Plants	Animals	
Aluminum (Al)					x
Antimony (Sb)					x
Arsenic (As)					x
Barium (Ba)					x
Beryllium (Be)					x
Cadmium (Cd)					x
Chromium (Cr)		x			
Cobalt (Co)		x	x		
Copper (Cu)	x	x			
Lead (Pb)					x
Manganese (Mn)	x	x			
Mercury (Hg)					x
Molybdenum (Mo)	x	x			
Nickel (Ni)	x	x		x	
Selenium (Se)		x	x		
Silver (Ag)					x
Strontium (Sr)					x
Thallium (Tl)					x
Vanadium (V)				x	
Zinc (Zn)	x	x			

[a] Adapted from a table presented in SRWG (2002) and incorporating data from NRC (1980) and Barak (1999). Fairbrother and Kapustka (1997) discussed the roots of essentiality of naturally occurring elements.

2.9 Absorption of heavy metals by water hyacinth

This chapter focused mainly on review of literature of current problem that touse of water hyacinth (*Eichornia crassipes*) which is an aquatic plant (macrophyte) for removal heavy metal particularly cadmium from waste water. Understanding of these plants is important to the overall operation of the treatment system due to acceptability and availability of the local climate. Water Hyacinth systems are differentiated from oxidation ponds in that they use aquatic macrophytes for treatment. The macrophytes used are usually floating varieties, but some systems have been observed with submerged varieties. The aquatic plants in a system may act in a similar capacity to the algae in an oxidation technique by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by up taking them into plant tissues. The macrophytes used are usually floating varieties, but some systems have been investigated with submerged varieties. The macrophytes in a system may act in a similar capacity to the algae in am oxidation pond by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by incorporating them into the plant tissues. Treatment techniques which use vegetation are attractive to designers in part because the aquatic plants act as a natural nutrient sink. Some plants are capable of absorbing substantial amount of metals and some dissolved organics. The organics may be destroyed be the plant's metabolic activities or stored while metal are not degraded, but are usually stored within the plant tissue. Many of the plants used I these systems can be sold, either whole or in part, and if a market exists they offer a potential for some revenue to offset operating expenses (DeBusk and Ryther, 1987).

Water hyacinth (*Eichhornia crassipes*) is the largest of the known floating aquatic macrophytes, reaching a height of as much as one hundred twenty centimeters. It is a advantage of South America, India and subcontinent. At the time botanists believed the plant's range to be restricted to South America with possible excursions in to Central America too and the larger Islands in the Caribbean (Dinges 1982). The plant moves readily in the wastewater but is intolerant of high salinity. This is probably the only reason that its range control of these plant's species is difficult since they are one of the world's most productive plants they have eighth fastest growth rate of the top ten weeds (Metcalf & Eddy, 1991). In nutrient rich waters such as wastewater, the rate can be even higher (Reed et al., 1988). These very characteristics that make the importance of water hyacinth a serious problems on natural water male it a good candidate for use in wastewater treatment. The range of this plant in the wild has expanded in to tropical and subtropical regions of the world. The thirty-second parallels are the approximate limits of the plant's geographic range (EPA, 1978). Water hyacinths can be growing outside this range, but they must be protected from the winter temperatures.

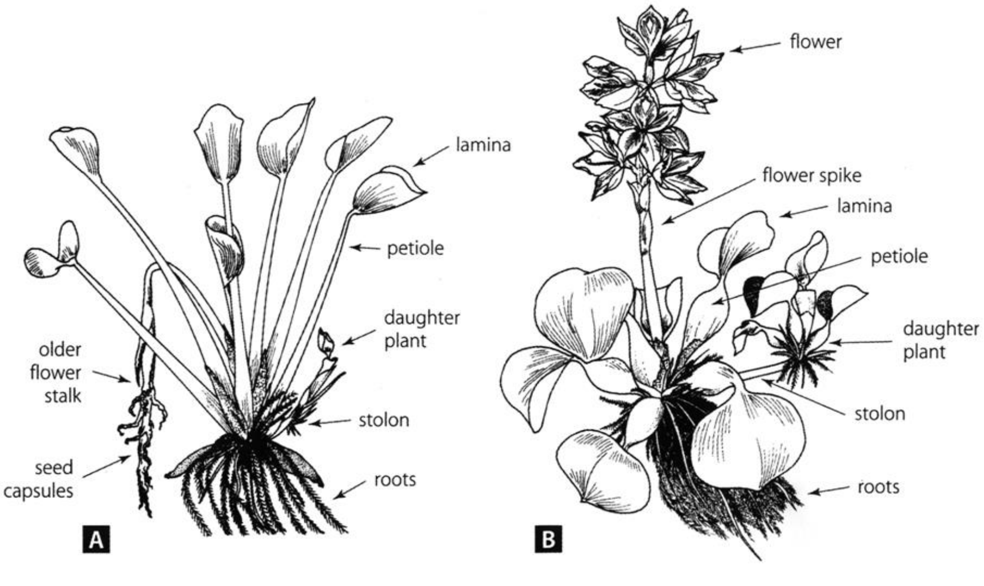


Figure (2.3) Part of Water Hyacinth (Source http://www.dpi.nsw.gov.au/agriculture/pestsweeds/weeds/profiles/water-hyacinth)

Water hyacinth is a perennial, vascular plant with larger leaf, rounded shape, shiny green leaves and a central stalk of violet flowers with very attractive look. Reproduction is generally vegetative. But seeds are also produced by the flowers to help ensure survival. When exhibiting vegetative reproduction, the plant extends a daughter plant forms at the terminal end and then each plant will continue the process. The roots of the water hyacinth plant are feather-like and are UN branched. They vary in length according to the growth conditions and the frequency of harvest, but they are not affected by crowding. In low nutrient natural waters, the water hyacinth plants tend to be only a few centimeters high, but the roots can extend up to a meter into the water. Under high nutrient conditions the roots will only extend about ten centimeter in to the water, but plants shoots will be over a meter in length since crowing is also likely (Dinges.1982).The morphology of the plant under crowded, high nutrient conditions is of the most interest of wastewater engineer since these represent the usual operating conditions of a water hyacinth treatment facility. The size and density of the root in waste body the plant are of interest because they provide the majority of the adsorption sites of roots for dissolved constituents and act as a living substrate for the attached aerobic microbial population that provides most of the degradation of organics in the treatment scheme (Metcalf & Eddy, 1991; EPA, 1988). The roots, stolons, petioles, and flower stalks all originate at the central rhizome which normally floats several centimeters below the water surface. This plant is considered a hardy species and can survive in a different variety of conditions, but if the tip of the rhizome is damaged, the entire plant will die.

Vegetation Algal systems have been investigated around for many years in the form of oxidation ponds. Emergent and floating varieties also tend to transport oxygen form their leaves to their root and the surrounding media, which allows to aquatic plants to grow in anaerobic environments.

Floating aquatic plants species are vascular plants that grow with their photosynthetic process at or above the wastewater surface and their roots extending down in to the water column. Usually these plants do not root into the soil substrate, but many ingrown in moist soil if the water becomes too shallow. Some plants, i: e pennywort or the water lily, are normally rooted into the substrate, Pennywort and alligator weed are plants which are normally found rooted in shallow water or marshy areas. The stolons and stems of these plants are buoyant, and when the water around them constrains sufficient nutrients, the new stolons being extended from the origin/ parent plant may remain at the surface on water and grow hydroponically.

Continued grow of the first free floating daughter plant eventually forms a floating mat of intertwined plants which may break free of the aquatic plants rooted into the substrate due to wind and sunlight and wave action in a natural body of water. When these plants are used for wastewater treatment, they can be placed in a situation where sufficient nutrients are present, and the only avenue for growth is on the surface of waste water. Free floating aquatic plant/Water Hyacinth draw the CO_2 and O_2 that they need from the air, but they depend upon the dissolved constituents of the wastewater for all of their nutrients. Under anaerobic condition, many of these types of plants transport oxygen to their roots for metabolic purpose. Excess oxygen is then available to the surrounding media. When the roots of plants are within the water, they act as a living substrate for attached growth of aerobic bacteria which then use the excess oxygen to degrade dissolved organic compounds in the water. Floating aquatic plants/Water Hyacinth tend to cover the wastewater surface and block out the passage of light to the depth in water reservoir, denying algae the energy needed to grow and reproduce.

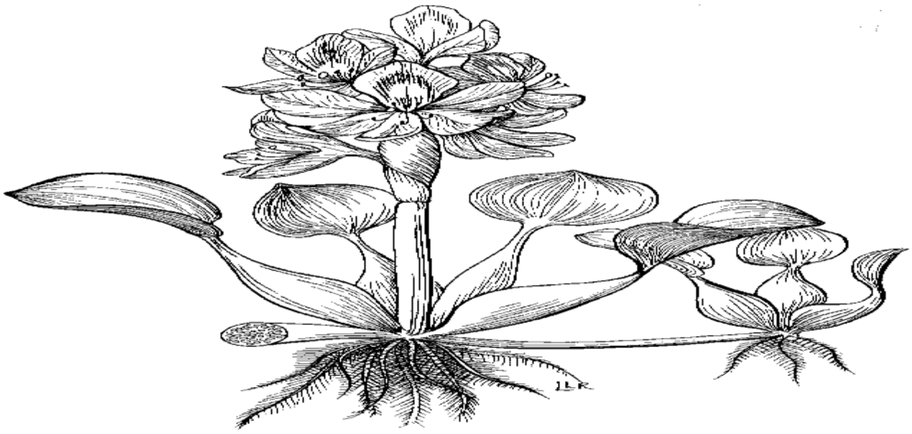


Figure (3.4) Water Hyacinth

Source (http://www.sfrc.ufl.edu/extension/4h/plants/Water_hyacinth/index.html)

Water Hyacinth systems are differentiated from oxidation ponds in that they use aquatic macrophytes for treatment. The macrophytes used are usually floating varieties, but some systems have been observed with submerged varieties. The aquatic plants in a system may act in a similar capacity to the algae in an oxidation technique by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by up taking them into plant tissues. The macrophytes used are usually floating varieties, but some systems have been investigated with submerged varieties. The macrophytes in a system may act in a similar capacity to the algae in am oxidation pond by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by incorporating them into the plant tissues. Aquatic plants have essentially the same nutritional requirements as terrestrial plants, but they have adapted their metabolisms to the aquatic environment. Water Hyacinth has high water contents compared to terrestrial plants. Aquatic Plant not only provide treatment by taking nutrients and dissolved constituents into their systems, But also by modifying the environmental conditions around them, or by providing a growing surface for the aerobic microorganisms which contribute to the treatment.

The mat of plants which usually develops on surface also causes the water tends to be unaffected by wind and remains relatively quiescent, and gas transfer is seriously hindered. When moderate to high organic loading are applied to floating aquatic plant (Water Hyacinth) system, the water tends to become anoxic anaerobic in spite of the capability of the plants to translocation oxygen. The quiescent conditions make these systems good at causing sedimentation of algae and suspended solids. Filtration of solids also contributes to removal when floating plants with extensive root systems are used (Dinges, 1982. EPA 1988; Metcalf & eddy, 1991). The development of aquatic plants roots up taking system depends upon the plant’s growth rate, and other atmospheric characteristics like temperature, nutrient content of the water, and operation by modifying the recycle ratio as well as nutrients present in wastewater which will help the harvest amount and frequency.

Some of the treatment processes that have been used to remove heavy metals from wastewater include precipitation with coagulation and flocculation, ion exchange, complication of dry biomass and adsorption. However, there are limitations: Precipitation produces large quantities of heavy metals rich waste sludge; ion exchange and biomass methods are costly and cannot be readily applied to large scale applications. Adsorption as a process, employed due to its low cost and applicability on large scales. Adsorption is commonly being done using activated carbon, which adsorbs dissolved organic substances in the water treatment (Lodeiro *et al.*, 2006). Although activated carbon has its advantageous, such as its effectiveness in removing colours and its applicability on wide variety of organic compounds, it has limitations that prevent it from treating highly soluble organics, and high concentrations or organic and inorganic compounds. In addition to these, cost of operation is high. Other adsorbents that have been used include synthetic polymers and silica-based substances. However, these materials are more costly compared to activated carbon. Hence, there is a perceived necessity and growing interest in finding adsorbents that are more cost-effective and produce fewer limitations including high temperatures and pressures. Therefore, finding suitable materials and operating conditions are essential to addressing the concerns of heavy metal pollution (Lodeiro *et al*., 2006).

Application of pond systems wastewater to aquatic must be free of unreasonable risks to public health. Pathogenic organisms are present in wastewaters reservoir or flowing wastewater with sludge and control is one of that constituent from wastewater is the fundamental reasons for waste management which cause the over burden on the water sources. The discussion of Aquatic plant (such as Water Hyacinth) systems concentrates on the results with water hyacinth systems. A few duckweed systems have been tried either alone or in conjunction with hyacinths. The projects discussed in this manual reflect this geographical distribution of project sites and of the plant species that have been studied extensively.

Originally from India, water hyacinth, *Eichhornia crassipes* (Mart.) Solms, is one of the world’s most useful invasive Water Hyacinth with respect to climatic conditions. Water hyacinth, a floating vascular plant which having high growth rate and photosynthesis. This is known to cause major ecological and socio-economic changes to the environment, and resource as a biomass. It commonly forms dense, interlocking mats due to its rapid reproductive rate and complex root structure. It is generally grow in wastewater which having high nitrates and nutrient in its. Water hyacinth reproduces both sexually and asexually. Ten to 100% of existing seeds are found to germinate within six months, with dry conditions promoting germination which is known as life cycle of water hyacinth. Nutrients and temperature are considered the strongest affecting factor for water hyacinth growth and reproduction.

Salinity constraints generally limit water hyacinth acce**p**tability in coastal areas and within estuaries. Low temperatures and winter ice cover currently limit water hyacinth from spreading into cooler latitudes however recent climate change models suggest that the distribution of aquatic invasive species is likely to expand in temperate regions. Water hyacinth may be invaded freshwater as well as wastewater systems in over 50 countries on five continents; it is especially pervasive throughout Southeast Asia, the southeastern United States, central and western Africa, and Central America.

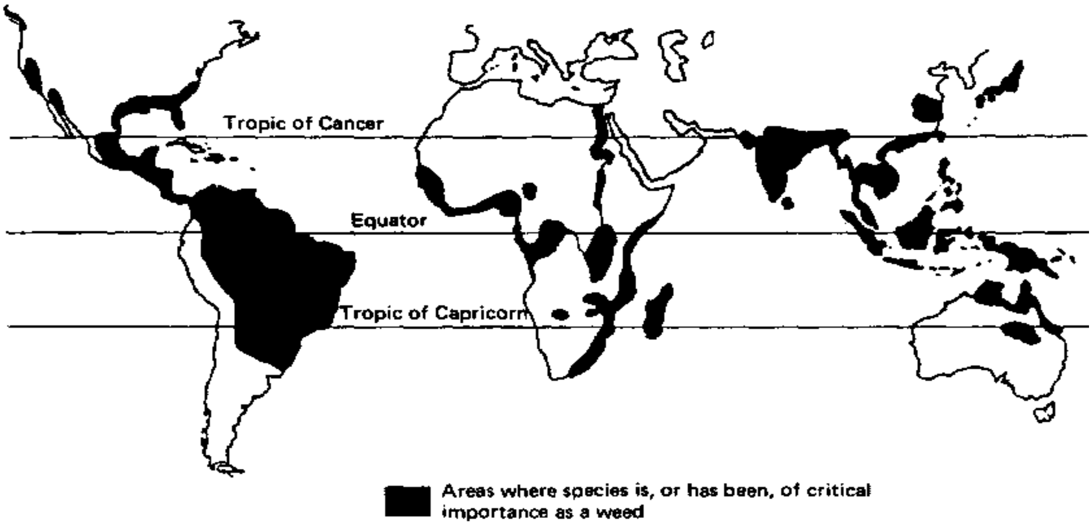


Fig. (2.5) Growth Area of water Hyacinth

Source (http://www.nzdl.org/cgi-bin/library.cg)

It is a best plant to treatment of wastewater in tropical and subtropical water bodies, where nutrient levels are high by following natural and human activities like agricultural runoff, deforestation, and insufficient wastewater treatment. There is good to see that no one know how, why, and when water hyacinth was introduced to wastewater bodies outside of its native range, but many populations are well established and persistent despite control efforts. Its success as research mis-attributed to its ability to outcompete its native vegetation and phytoplankton for light and its release from consumers. The ability to manipulate water levels is one of the single most important factors in Managing cattails (Beule, 1979). The ability to do this depends on several factors: availability of water, size and location of marsh basin, and the outlet structure. Beule states that "these abilities can be further modified by constructing sub-impoundments, pumping facilities another features within the marsh itself" (Beule 1979). According to Beule, "a highly marshy land would have a dependable, all-season water supply, such as a runoff of river with adequate volume, and is situated so that drainage is easy and quickly accomplished through discharge structure. A marsh with little management potential its surface water supply and whose only water release mechanism is percolation, evaporation and transpiration. Between these two extremes lie many available gradations of flooding and drainage of the water reservoir that ultimately determine the manageability of individual marshes" (Beule 1979). Changes to water hyacinth density have the potential to affect other ecological and human communities and up taking capacity of plants in areas where it is established; these changes may be perceived as positive or negative depending on the designated or beneficial uses of the water body. The trend over the past years in the construction of water pollution control facilities like technology and operating facility for metro city has been toward “concrete and steel” alternatives. With affecting factor in running condition of the treatment facility is higher energy prices and higher labour costs, now the challenge is that to maintain and develop these systems have become significant cost and ecofriendly items for the communities that operate them. For small city in particular, the operating cost is higher percentage of the city municipal’s budget than historically allocated to water pollution control and recycle of the water. Treatment processes that used in the system relatively more land and are lower in energy use and labour costs are therefore becoming sustainable development in an era is attractive alternatives for these communities. The high operating and installation cost of some conventional treatment processes has producing more economic pressures to the municipal community and has caused engineers to search for creative, cost-effective and environmentally sound ways to treatment of wastewater to control water pollution so that now the idea been taking place a technical approach is to construct artificial ecosystems which will work as a functional part of wastewater treatment.

Now wastewater has been treated and reused/recycle successfully used asa resource of water and nutrient resource in agriculture, gardening, silvi-culture, aquaculture, golf course and green belt irrigation as well as in construction of the building and recharge the ground water. The benefits of the aquatic wastewater treatment systems can be attributed to three basic factors:

- ❖ Recognition of the natural treatment functions with the efficient work of Aquatic Plants systems(such as Water Hyacinth) and wetlands, particularly as nutrient sinks and buffering zones without any use of alternative source of energy.

- In the case of wetlands, emerging or renewed application of aesthetic, wildlife, and other incidental environmental benefits associated with the preservation and enhancement of wetlands as well as ecology.
- Rapidly escalating costs of construction, operation and energy consumption associated with conventional treatment facilities.

A free floating water surface systems typically consists of large basins or channels, which may be natural or constructed subsurface barrier of clay or geo textile material to prevent seepage and prevent contamination in soil and ground water table with suitable medium to help life cycle of the emergent vegetation, and wastewater at a relatively shallow depth flowing over the soil surface. With respect to the water depth, low flow velocity of water, and presence of the plant stalks and microorganisms and litter regulate water flow and, especially in long pathway with narrow channels, ensure plug-flow conditions. There are limits to the technology of using artificial wetlands for high BOD treatment in wastewaters. Although limited data are available on the use of wetlands/ natural treatment system for treating primary effluent, constructed wetlands have been currently working in different a number of locations for treatment of secondary effluent. Treatment performance in constructed wetlands is a function of retention time, and among physical, chemical and biological factors. The slope of ground, depth of wastewater, vegetation condition, areal extent, and geometric shape control the flow velocity of water, thus, the retention time through play a major role in a wetlands treatment system. Where natural wetlands are located conveniently to municipalities, the major cost of operating is a discharge system is for pumping to treatment plant effluent to the site.

Wastewater treatment involve by the application of natural processes as well as conventional treatment process. In some cases, the wetland wastewater treatment system are performing as an alternative can be the least cost advanced wastewater treatment and disposal alternative. In many locations where drained land are unavailable and unsuitable for agriculture or other application is available, natural wetlands can be more often be constructed inexpensively with minimal. In considering the application of wastewaters, the relationship between hydrology and ecosystem and burden on water characteristics needs to be recognized. Affecting factors such as source of wastewater, velocity of wastewater, renewal rate, and frequency of inundation with adulteration have major bearing on the chemical, physical and biological properties of the wetland substrate. These properties of wastewater in turn influence the character and health of the ecosystem, life cycle and food cycle, as reflected by species composition and richness, primary productivity, organic deposition rate and flux, and nutrient cycling, In general, wastewater movement through Aquatic Plant ends to have a positive impact on the ecosystem, Rather than wasting water, upland swamps appear to save water and thus promote increased regional production indirectly. Aquatic plant systems are ponds with both types floating or submerged aquatic plants, which are playing a crucial role in ecosystem. The most studied systems are which used widely in treatment system due to the acceptability and resource as energy the plant is water hyacinth. These systems include two types based on the dominant plant types. The first type uses floating plants and is distinguished by the ability of these plants to derive their carbon-dioxide and oxygen needs from the atmosphere directly, another submerged which take all nutrients with oxygen and carbon dioxide from water. The plants receive their mineral nutrients from the water. Submerged plants are relatively easily inhibited by high turbidity in theater because their photosynthetic is done under the water, water are providing all essential parts are below the water.

2.10 Adsorption by activated carbon:

Activated carbon, also widely known as activated charcoal which is in the form of carbon which has been processed to developed it extremely porous medium and which have a very large surface area available for adsorption of chemical reactions. The word active is sometimes used in place of activated. with high degree of micro porosity, just 1 gram of activated carbon has surface area in more than of 500 m^2, a typically it can be determined by nitrogen gas adsorption on the pores of activated carbon. Sufficient activation/ charge of pores for useful applications may come from the high surface area, by which further chemical treatment generally enhances the adsorbing properties of the material. Activated carbon is most commonly derived from charcoal due to high availability of carbons in it.

Biomass has been allotted numerous roles to play for sustainable development. In addition to being a food source and renewable raw material, it can be used for energy production, carbon sequestration and, as an essential element for the production of hydrochars and activated carbons. In the past few years, the use of hydrothermal carbonization for conversion of biomass waste into valuable carbon materials has received considerable attention due to its ability to produce hydrochars with attractive characteristics that promote efficient utilization for a variety of applications such as adsorption (Liu &. Zhang 2009; Liu et al., 2010), bio-imaging (Selvi et al., 2008; Guo et al., 2008), catalysis (Titirici et al., 2006; Wang et al., 2011), activated carbon synthesis (Sevilla et al., 2011; Sevilla & Fuertes 2011; Sevilla et al., 2011) etc. Utilization of biomass waste for producing hydrochars is attractive because it offers solutions for solid waste management, reduces the cost of raw materials and the properties of the final product can be tailored for different temperature.

Basically, hydrothermal carbonization is a thermo-chemical conversion technique which uses subcritical water for the conversion of wet/dry biomass to carbonaceous products through fractionation of the feedstock. Carbonization temperature is dependent on the type of starting materials and its decomposition temperature; a range of 150–350 ^{o}C is typically employed (Berge et al., 2011; Titirici et al., 2012; Falco et al., 2012; Liu et al., 2013; Parshetti et al., 2013). Hydrothermal carbonization results in efficient hydrolysis and dehydration of biomass and bestows the hydrochar with high OFG (oxygenated functional group) content which makes it an effective precursor for the production of chemically activated carbon (Sevilla & Fuertes, 2009). Activation of suitable precursors such as lignocellulosic biomass results in formation of highly porous activated carbons whose large surface areas facilitate their performance as adsorbents (Gupta et al., 1997; Hamadi et al., 2001; Martin et al., 2004; Tan et al., 2007; Acharya et al., 2009; Demirbas et al.,2009; Gupta et al., 2012; Han et al., 2015). High porosity is extremely desirable for enhanced performance of adsorbents since it facilitates high mass transfer fluxes and catalyst/adsorbate loading. The tailored porosity and pore size distribution have widened the usefulness of activated carbons to more demanding applications, such as catalysis/electro-catalysis (Pham-Huu et al., 1999; Sevilla, & Fuertes, 2009; Jain et al., 2015), separation of multi- sized molecules, energy storage in capacitors (Simon

& Gogotsi, 2008; Biswal, 2013; Falco et al., 2013; Wang et al., 2013; Arvindan et al., 2014), electrodes and Li-ion batteries (Ulaganathan et al., 2015; Arun et al., 2015), CO_2 capture or H_2 storage (Lua & Guo,2001; Kockrick et al., 2010). Briefly, activation can be done in two ways (i) physical (or thermal) activation using CO_2 or steam at 800–900 ^oC; and (ii) chemical activation using KOH, $ZnCl_2$, H_3PO_4, etc. typically in the range of 450–650 ^oC. Extensive work is being done to enhance the porosity of activated carbons by the use of different chemical activating agents, optimization of the activation conditions such as temperature, ramp rate and gas flow rate and the usage of pre-treatment methods such as soaking or stirring. In addition, chemical characteristics of the lingo-cellulosic biomass are of significance and play a substantial role in creation of porosity in activated carbons. Therefore, it is of great importance to understand the role of these characteristics in development of porosity in carbons and thus optimize the process conditions by the use of appropriate pre-treatment processes.

Activated carbon is used for adsorption of organic substances and non-organic both and non-polar adsorbents, it is widely used for waste gas (and waste water) treatment process. It is the usually used as an adsorbent since most of its chemical (e.g. surface groups) and physical properties are good enough to remove contaminations, economical and best for ecological balance (e.g. pore size distribution and surface area) can be tuned according what the technology needed. It’s very usefulness and derives from its higher microspore volume and resulting high surface area for the adsorption process.

Mechanism of Adsorption Using Adsorbent:

Applications of adsorption: The principle of adsorption is employed, in heterogeneous process of catalysis which are used for separation of fluid from fluid with the help of solids (adsorbing media) in pours metals masks where activated charcoal adsorbs on pours. This process also used in the refining of petroleum and discoloring cane juice adsorption of gases and metals also form running fluids. In creating vacuum adsorption process by adsorbing gases on activated pours of charcoal/adsorbent. In chromatography technologies are also used to separate the constituents' from a mixture. To control humidity of any system and atmosphere is controlled by the adsorption of moisture on silica gel. The best example to control humidity is AC. In certain titrations to determinate the end point using an adsorbent as indicator (Example: Flouroscein). Municipal waste may contain cadmium products, or materials in which cadmium is present as an impurity. The incineration of these wastes has potential for release of cadmium through stack emissions and land filling of ashes (Lodeiro *et al.,* 2006). The leaching of cadmium from disposed solid waste is dependent on many factors, e.g. physico-chemical properties of the cadmium containing products, pH of the liquid phase of the landfill, rainwater, temperature changes. Results of laboratory experiments on leaching of cadmium from pigmented plastics have been interpreted as showing that these products would not contribute significantly to cadmium leach ate from landfills. Cadmium assays of incinerator ash in the United States have suggested that land filled ash could pose a hazard to human health and the environment if cadmium were allowed to leach from landfills into groundwater. Domestic and industrial cadmium-containing waste can be brought to three sorts of landfills, industrial, municipal or mixed.

The significant feature of sludge-based activated carbon that makes it a unique and a particularly economical adsorbent is that it can be produced from waste materials such as paper mill sludge or even the rice husk disposed of as waste from rice mills. A current problem faced by pulp mills is the generation of an excessive amount of sludge during the paper making process and secondary treatment of wastewater. For environmental and ecological reasons, the innocuous disposal of these sledges has become immensely important. Optimization of the processes involved with the conversion of paper mill sludge or rice husk to activated carbon provides an innovative, environmentally safe, and economically feasible solution to the problem of sludge management at paper mill facilities. Sludge to carbon conversion processes can significantly reduce the sludge volume produced in the paper mill industry or the rice mills, eliminate the need for further treatment of sludge, reduce the cost of hauling and land filling the sludge, and reduce transportation costs. The emphasis of this study is to optimize processes involved with the production of activated carbons with prescribed surface properties (micro- or meso porous structure) and specific endues from paper mill sludge. The higher purity (when compared to bio-solids), negative cost, high rate of production, and strong carbonaceous structure of paper mill sludge and rice husk makes them both useful as a precursor for carbon production.

2.11 Adsorption of heavy metals

Chen *et al.*, (1998) investigated the dynamic adsorption behaviour of Cr, Cu, Pb, and Cd on sorbents (silica sand with limestone) at different operating temperatures (600,700 & 800°C) and tried to find out the adsorption saturation point of the sorbents. The adsorption rate of Cr increased before 30min, decreased after 60 min at 600° C and after 30 min at 800°C, while at 700°C the rate increased at 90 min.The adsorption rate of Pb increased first and decreased after 60 min at 600 °C and 800 °C, while at 700 °C it decreased after 30 min and increased after 60 min, again decreased after 90 min.The adsorption rate of Cd decreased only at 90 mina 800 °C, while it gradually increased after 90min at 600 °C and 700 °C.

Christophil *et al.,* (2000) studied the competition of copper, lead, and cadmium adsorption on goethite and found it to be dependent on metal ion and oxide surface characteristics. Metal adsorption for copper, lead, and cadmium increased with increasing pH. As pH increased the net surface charge of goethite became more negative. This increase in negative charge resulted in an increase in cation adsorption and the typical ‘‘S’’ shaped adsorption edge was observed. The adsorption for the metals followed the order of Cu > Pb > Cd. The degree of affinity is a function of site capacity and the equilibrium constant, which often coincided with the electro negativity of the ion.

Huang (2003) using the adsorptive reaction kinetics equation and the mass conservation equation, deduced formulas for calculating the particulate heavy metal concentration and the dissolved heavy metal concentration. Furthermore, equations for calculating the equilibrium particulate heavy metal concentration and the equilibrium dissolved heavy metal concentration were formulated. The total desorption quantity of heavy metal pollutants from sediment particles was positively proportional to the suspended sediment concentration. It was found that adsorption and desorption of heavy metal pollutant on and off sediment particles was partly reversible. investigated the applicability of maghemite (Fe2O3) nanoparticles for the selective removal of toxic heavy metals from electroplating wastewater. The adsorption process was found to be highly pH dependent, which made the nanoparticles selectively adsorb these three metals from wastewater. The adsorption of heavy metals reached equilibrium rapidly within 10 min and the adsorption data were well fitted with the Langmuir isotherm. Regeneration studies indicated that the maghemite nanoparticles undergoing successive adsorption–desorption processes retained original metal removal capacity. Employed heat to coat crystalline goethite onto a quartz sand surface so that the adsorbent properties of the coating could be utilized, Adsorption experiments were conducted to demonstrate the adsorption of lead ions by goethite-coated medium under various temperatures and pH, respectively. The adsorption reaction between iron-coated medium and lead ions was simulated by a cation exchange model. Results indicated that the solution temperature and pH had a noticeable effect on the final adsorption capacity for lead ions. The pH-adsorption edges were shifted to lower pH values with increasing temperature. The adsorption reaction between lead ions and goethite-coated medium was an endothermic Process.

The chemical needs to be typically an acid, strong base, or a salt (phosphoric acid, potassium hydroxide, sodium hydroxide, zinc chloride, respectively). After impregnation, the raw material needs to be carbonized at lower temperatures (450–900 °C). It is believed that the carbonization/activation step proceeds simultaneously with the chemical activation. Chemical activation is preferred over physical activation owing to the lower temperatures and shorter time needed for activating material.

The significant feature of sludge-based activated carbon that makes it a unique and a particularly economical adsorbent is that it can be produced from waste materials such as paper mill sludge or even the rice husk disposed of as waste from rice mills. A current problem faced by pulp mills is the generation of an excessive amount of sludge during the paper making process and secondary treatment of wastewater. For environmental and ecological reasons, the innocuous disposal of these sledges has become immensely important. Optimization of the processes involved with the conversion of paper mill sludge or rice husk to activated carbon provides an innovative, environmentally safe, and economically feasible solution to the problem of sludge management at paper mill facilities. Sludge to carbon conversion processes can significantly reduce the sludge volume produced in the paper mill industry or the rice mills, eliminate the need for further treatment of sludge, reduce the cost of hauling and land filling the sludge, and reduce transportation costs. The emphasis of this study is to optimize processes involved with the production of activated carbons with prescribed surface properties (micro- or meso porous structure) and specific endues from paper mill sludge. The higher purity (when compared to bio-solids), negative cost, high rate of production, and strong carbonaceous structure of paper mill sludge and rice husk makes them both useful as a precursor for carbon production.

Krishnan *et al.,* (1987) used hair as adsorbent to remove Cadmium, Arsenic and Mercury. The process was found to be extremely effectively especially for mercury.

Gupta *et al.,* (1988) studied the removal of Cadmium by saw dust in the batch mode. The initial cadmium concentrations chosen were 1.0 mg/l, 5.0 mg/l, 10.0 mg/l, 25.0mg/l and 50.0mg/l. the contact time was 6 hours. 60%-88% removal was obtained depending on the initial concentrations.

Jha *et al.,* (1988) studied the removal of Cadmium using Chitosan in batch study. 80% removal was achieved at pH 8.3, and increased significantly beyond that.

Tee *et al.,* (1988) used waste tea leaves as adsorbent to remove Cadmium, Lead and Zinc. Waste tea leaves were found to be good sorbents for all three metals.

Yadav *et al.,* (1991) used wollastonite to remove Cadmium in batch studies. Equilibrium time was reported to be 140 minutes, and the adsorption followed Langmuir isotherm model. The sorption was founds to be independent of initial metal concentrations and pH.

Bhargava *et al.,* (1988) studied removal of Cadmium, Lead and Chromium using saw dust. The mode of study was batch using initial metal concentration ranging from 1mg/l to 5mg/l. Removal efficiency decreased with increasing metal concentration. Chromium was more efficiently adsorbed than lead, and cadmium showed least affinity for saw dust.

Varshney *et al.,* (1988) studied the removal of Cadmium in a moving media reactor using saw dust as the sorbent material. Increasing removal capacity was reported with increasing saw dust dose.

Shrivastava *et al.,* (1989) used montmorillonite and kaolinite (passing 250 mesh-280 mesh) to remove Cadmium and Lead by adsorption in batch mode. The experiment pH was varied between 2-4 and the initial metal concentrations were varied between $4X10^{-4}$M - $9X10^{-3}$M. Higher removal was observed in case of montmorillonite than kaolinite for both of the metals.

Gupta *et al.,* (1990) used wollastonite for removal of Cadmium in batch studies. Adsorbent dose was 50g/L, pH was 6.5 and the temperature was set at 30oC. Varying the initial cadmium concentrations from $2.0X10^{-4}$M to $0.5X10^{-4}$ the removal increased from 56% to 94%.

Manas (1991) used coconut coir dust as adsorbent in batch studies to remove Cadmium, Lead, Manganese, Zinc, Magnesium, Nickel and copper. The percentage removal obtained was 99% for cadmium, 95% for lead, manganese and magnesium, 98% for nickel, 97% for zinc and 87% for copper.

Okiment *et al.*, (1991) studied the removal of Cadmium and Lead using groundnut hull treated with EDTA as adsorbent in batch study carried out at a temperature of 29oC. The particle diffusion rate coefficient was found to be 10-2/minute.

Orhan et al. (1993) studied the removal of Cadmium and Chromium in batch mode using waste tea and coffee, exhausted coffee nuts and walnut shells as adsorbent. Respective percentage removals obtained were 98.5%, 99% and 99.8%. Freundlich isotherm model was followed. The reaction kinetics was found to be first order reversible type.

Gorai *et al.*, (1999) studied the adsorption of Cd, Pb, UO_2 and PO_4 by pond sediments. The soils were dried grinded and passed through a 2 mm mesh sieve. The adsorption experiment was carried out as follows: 5 g of soil was treated with each 50 ml 0.05 M $Cd(NO_3).24H_2O$, 0.05 M $Pb(NO_3)$2 solution. The suspension was shaken mechanically at a temperature of 30oC for different periods (1 hr-24 hr). At the end of the equilibration the suspension was filtered and 10 ml aliquot was taken for the determination of concentration of Cd^{2+} and Pb^{2+} by AAS. The metal ion Cd^{2+} was adsorbed by both the sediments and its adsorption increased with increase in the equilibrium time. Adsorption of Cd^{2+} by soil increases with increase in concentration of HCL and attains 80% at 10 M HCl. The plots of log D vs. log [HCl]/[HNO_3] are drawn. For Cd^{2+} adsorption is linear with slope 2. It indicates that adsorbed species is

$CdCl_2$.

Woolard *et al.,* (2000) studied the use of a modified Iron oxide as an adsorbent for Lead. The objective of the study was to investigate the conversion of Iron oxide in to zeolites. The X-Ray diffraction pattern for untreated and modified Iron oxide samples was studied. The crystalline phases that can be identified in the unmodified Iron oxide are quartz and mullite. These are also present in all the modified Iron oxide samples. A secondary phase comprising zeolite was formed during the modification process and can be seen in the 1M NaOH and 3M NaOH-treated samples. At higher NaOH concentrations the zeolite, hydroxysodalite, can be identified. Under the reaction conditions, it was found that this phase formed in greater quantities at higher NaOH concentrations. Studying the Scanning Electron Microscope (SEM) images it was seen that when the various treated Iron oxide samples are compared with the untreated ash, a marked change in surface morphology could be observed. The untreated Iron oxide comprises smooth spherical particles. During alkaline treatment the surface becomes progressively rougher and broken. Cracks can also be seen developing in the spheres. The variation in the elemental composition of the samples with alkaline treatment was studied. The variation in specific surface area of the treated Iron oxide samples is also studied. The adsorption experiments were carried out in a series of batch experiments. Firstly the adsorption of lead onto different modified Iron oxide was carried out at pH = 5. The concentration of lead in the solutions was then determined, using inductively coupled plasma (ICP) spectrophotometry. The study shows that the modified Iron oxide samples adsorb significantly more lead than the unmodified Iron oxide. It indicates that the 3M NaOH-modified Iron oxide has the greatest affinity for lead.

The shape of the isotherms suggested that the adsorption behaviour could be modelled using the Langmuir isotherm. The data indicate that the 3M NaOH-modified ash has the strongest affinity for lead. In all cases the affinity of the solid material has been enhanced relative to unmodified Iron oxide.

To study the effect of pH on adsorption, 0.3 g of Iron oxide sample (original, 1M, 5M and 6M NaOH-modified ash), adsorptions were carried out in the pH range 2 to 8. From the results it is apparent that in all cases the percentage of lead adsorbed increased as pH increased. Furthermore, the adsorption onto raw Iron powder increases over a wide pH range which indicates that there are a variety of exchange sites on the Iron surface with a range of acidities. This is to be expected since the Iron is not a pure compound but a mixture of different solids.

Rai *et al.,* (1998) made a detailed review about the use of non-conventional adsorbents to remove heavy metals. Brief descriptions of the reviewed studies where Iron powder has been used as the adsorbent material are listed below.

Bhargava *et al.,* (1974) studied removal of Cadmium, Lead and Chromium using Iron Powder Sample. The mode of study was batch using initial metal concentration ranging from 1mg/L to 5mg/L. Chromium was reported to be more efficiently adsorbed than the other two. At higher concentrations removal efficiency was reported to be decreased. Studied the removal of complex copper ammonia ions by Iron Powder in both batch and column study mode. 98% removal was observed by precipitation. 0.63%-3.13% removal was observed by adsorption.

Gupta *et al.*, (1988) studied the removal of Chrome dye (Metomega chrome orange) by Iron Powder (passing 80μ-300μ) in the batch mode. Initial concentration was varied between 5mg/l - 20mg/l. pH was varied between 3.0-11.8. Higher removal was obtained for lower pH, lower initial concentration and lower particle sizes. The rate controlling step was assessed to be intra-particle diffusion mainly.

Gupta *et al.*, (1988) studied the removal of Chrome dye (Omega red) by Iron Powder in t the batch mode. Initial concentration was 50mg/l, pH was 4.2, temperature was 30oC and adsorbent dose was 20g/l. Pronounced removal of 98.85% was obtained.

Haribabu *et al.*, (1992) studied the removal of Chromium by Iron Powder in the batch mode. The Iron Powder dose was 40g/l. 84% removal was achieved at a pH of 2.0 and temperature of 30^{o}C.

Kannanet *et al.*, (1991) studied the removal of Nickel using Iron Powder in batch study. The initial concentration of nickel was chosen to be 100mg/l. 46% removal as achieved at a pH of 3.

Mathur *et al.*, (1998) used Iron Powder as adsorbent in batch study to remove Lead. Higher removal was obtained by treatment with chelating agent at pH 5.

Freundlich isotherm was reported to be followed in both cases. For arsenic maximum adsorption was at a pH of 4 with an equilibrium time of 4 hours. Adsorption was reported to get decreased with increasing initial concentration of arsenic.

Fig. (2.6) Powdered Activated Carbon

A micrograph of activated charcoal under bright field illumination on a light microscope notices the fractal-like shape of the particles hinting at their enormous surface area. Each particle in this image, despite being only around 0.1 mm wide, has a surface area of several square meters. This image of activated charcoal in water is at a scale of 6.236 pixels/μm, the entire image covers region of approximately 1.1 by 0.7mm.

Traditionally, active carbons are made in particulate form as powders or fine granules less than 1.0 mm in size with an average diameter between .15and .25 mm. Thus they present a large surface to volume ratio with a small diffusion distance. PAC is made up of crushed or ground carbon particles, 95–100% of which will pass through designated mesh sieve or sieve. Granular activated carbon is defined as the activated carbon being retained on a 50-mesh sieve (0.297 mm) and PAC material as finer material, while ASTM classifies particle sizes corresponding to an 80-mesh sieve (0.177 mm) and smaller as PAC. PAC is not commonly used in a dedicated vessel, owing to the high head loss that would occur.

PAC is generally added directly to other process units, such as raw water intakes, rapid mix basins, clarifiers, and gravity filters. Adsorption phenomena Granular activated carbon (GAC) Granular activated carbon has a relatively larger particle size compared to powdered activated Carbon and consequently, presents a smaller external surface. Diffusion of the adsorbate is thus an important factor. These carbons are therefore preferred for all adsorption of gases and vapors as their rate of diffusion are faster. Granulated carbons are used for water treatment, deodorization and separation of components of flow system. GAC can be either in the granular form or extruded.

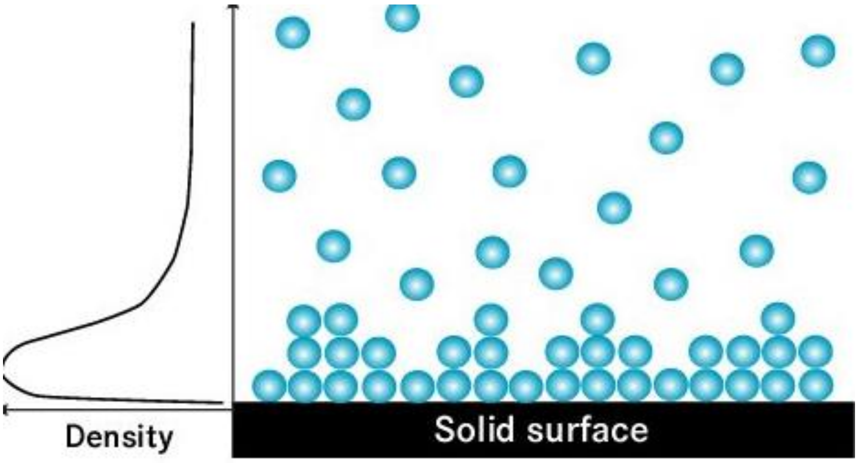


Fig. (2.7) Multilayer Adsorption Phenomena (Source: Online Google image source)

The most popular aqueous phase carbons are the 12×40 and 8×30 Sizes because they have a good balance of size, surface area, and head loss characteristics the molecules of gases or liquids or the solutes in solutions adhere to the surface of the solids. In adsorption process, two substances are involved. One is the solid or the liquid on which adsorption occurs and it is called adsorbent. The second is the adsorbate, which is the gas or liquid or the solute from a solution which gets adsorbed on the surface.

Adsorbent: The substance on whose surface the adsorption occurs is known as adsorbent.

Adsorbate: The substance whose molecules get adsorbed on the surface of the adsorbent (i.e. solid or liquid) is known as adsorbate.

Adsorption is different from absorption. In absorption, the molecules of a substance are uniformly distributed in the bulk of the other, where as in adsorption molecules of one substance are present in higher concentration on the surface of the other substance.

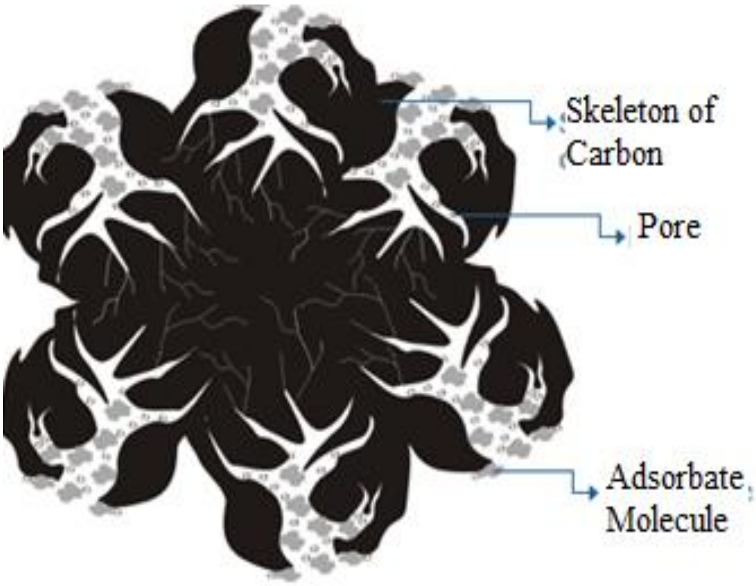


Fig. (2.8) Adsorption on Activated Carbons

Table (2.3) Comparison of Different type of Adsorption

Physisorption	Chemisorptions
1. Low heat of adsorption usually in the range of 20-40 kJ mol-1	1. High heat of adsorption in the range of 40-400 kJ mol-1
2. Force of attraction are Van der Waal's forces	2. Forces of attraction are chemical bond forces.
3. It usually take place at low temperature and decrease with increasing temperature.	3. It take place at high temperature
4. It is reversible process	4. It is irreversible process
5. It is related to the ease of	5. The extent of adsorption is

liquefaction of the gas.	generally not related to liquefaction of the gas
6. It is not very specific	6. It is highly specific
7. It forms multi-molecular layers	7. It forms monomolecular layers
8. It does not require any activation energy	8. It requires activation energy

Types of adsorption: Depending upon the nature of forces existing between adsorbate molecules and adsorbent, the adsorption can be classified into two types:

Physical adsorption (physisorption): If the force of attraction existing between adsorbate and adsorbent are Vander Waal’s forces, the adsorption is called physical adsorption. It is also known as Vander Waal’s adsorption. In physical adsorption the force of attraction between the adsorbate and adsorbent are very weak, therefore this type of adsorption can be easily reversed by heating or by decreasing the pressure.

Chemical adsorption (chemisorptions): If the force of attraction existing between adsorbate and adsorbent are almost same strength as chemical bonds, the adsorption is called chemical adsorption. It is also known as Langmuir adsorption. In chemisorption the force of attraction is very strong, therefore adsorption cannot be easily reversed.

Comparison of Different type of Adsorption Factors affecting adsorption: The extent of adsorption depends upon the following factors:

2.12 Factors affecting adsorption:

The extent of adsorption depends upon the following factors:

- Nature of adsorbate and adsorbent.

- The surface area of adsorbent.
- Activation of adsorbent.
- Experimental conditions. E.g., temperature, pressure, etc.

Adsorption Isotherm:

Adsorption process is usually studied through graphs known as adsorption isotherm.

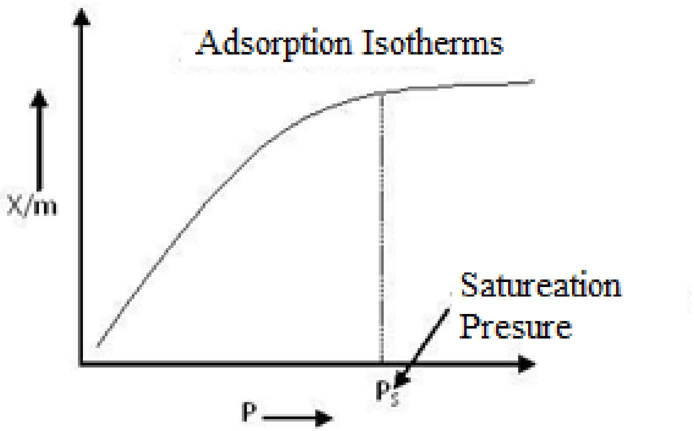


Fig. (2.9) Relations between Adsorption and Pressure

That is the amount of adsorbate on the adsorbent as a function if its pressure or concentration at constant temperature .The quantity adsorbed is nearly always normalized by the mass of the adsorbent to allow comparison of different materials.

Basic Adsorption Isotherm: From the above we can predict that after saturation pressure Ps, adsorption does not occur anymore, that is there are limited numbers of vacancies on the surface of the adsorbent. At high pressure a stage is reached when all the sites are occupied and further increase in pressure does not cause any difference in adsorption process.

At high pressure, Adsorption is independent of pressure.

Type of Adsorption Isotherm:

Five different types of adsorption isotherm and their characteristics are explained below.

Type I Adsorption Isotherm: The above graph depicts Monolayer adsorption.

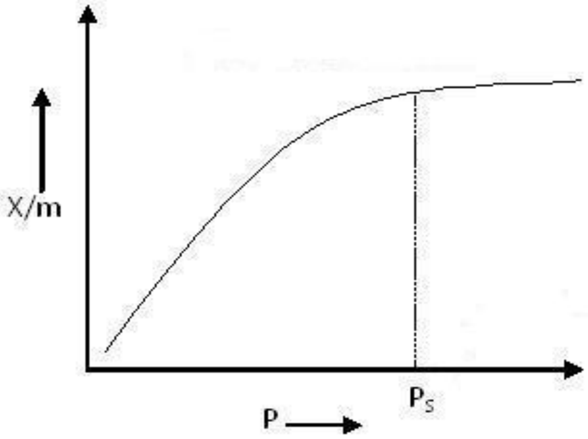


Fig. (2.10) Monolayer Adsorption

This graph can be easily explained using Langmuir Adsorption Isotherm.

- If BET equation, when P/P0<<1 and c>>1, then it leads to monolayer formation and
- Type I Adsorption Isotherm is obtained. Examples of Type-I adsorption are Adsorption of Nitrogen (N2) or Hydrogen (H) on charcoal at temperature near to -1800°C.

Type II Adsorption Isotherm Type II Adsorption Isotherm shows large deviation from Langmuir model of adsorption.

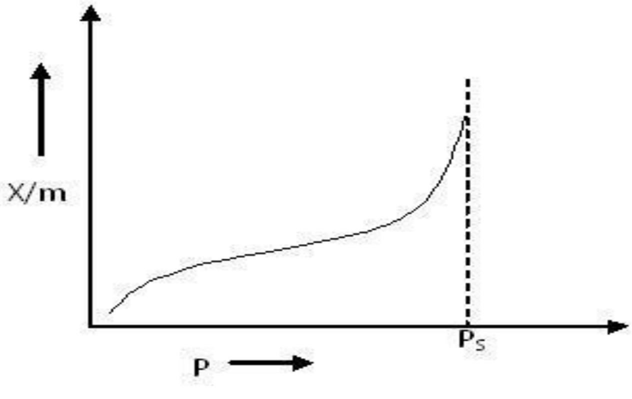


Fig. (2.11) Langmuir Isotherms I

- The intermediate flat region in the isotherm corresponds to monolayer formation.
- In BET equation, value of C has to be very large in comparison to 1.
- Examples of Type-II adsorption are Nitrogen (N2(g)) adsorbed at -1950°C on Iron (Fe) catalyst and Nitrogen (N2(g)) adsorbed at-1950°C on silica gel.

Type III Adsorption Isotherm:

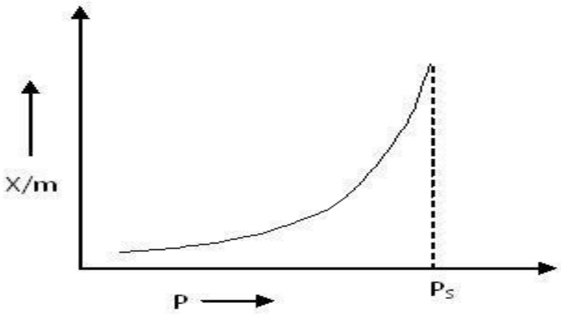


Fig. (2.12) Langmuir Isotherms II

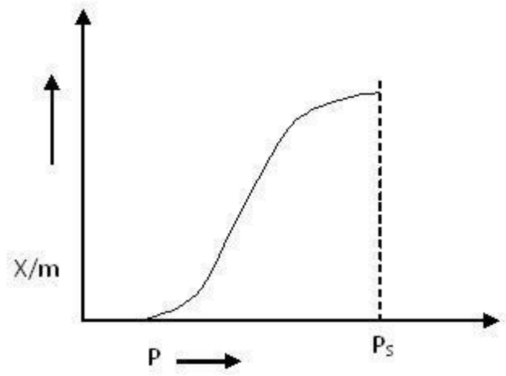
Type III Adsorption Isotherm also shows large deviation from Langmuir model

- In BET equation value if C <<< 1 Type III Adsorption Isotherm obtained.
- This isotherm explains the formation of multilayer.
- There is no flattish portion in the curve which indicates that monolayer formation is missing.
- Examples of Type III Adsorption Isotherm are Bromine (Br) at 790°C on silica gel or Iodine (I) at 790°C on silica gel.

Type IV Adsorption Isotherm: At lower pressure region of graph is quite similar to Type II. This explains formation of monolayer followed by multilayer. The intermediate flat region in the isotherm corresponds to monolayer formation.

The saturation level reaches at a pressure below the saturation vapor pressure. This can be explained on the basis of a possibility of gases getting condensed in the tiny capillary pores of adsorbent at pressure below the saturation pressure (PS) of the gas. Examples of Type IV Adsorption Isotherm are of adsorption of Benzene on Iron Oxide (Fe_2O_3) at 500°C and adsorption of Benzene on silica gel at 500°C.

Type V Adsorption Isotherm: Explanation of Type V graph is similar to Type IV.



Example of Type V Adsorption Isotherm is adsorption of Water (vapors) at 1000°C on charcoal. Type IV and V shows phenomenon of capillary condensation of gas. 3**.**

2.13 Freundlich Adsorption Isotherm

In 1909, Freundlich expressed an empirical equation for representing the isothermal variation of adsorption of a quantity of gas adsorbed by unit mass of solid adsorbent with pressure.

This equation is known as Freundlich Adsorption Isotherm or Freundlich Adsorption equation or simply Freundlich Isotherm.

$$\frac{x}{m} = kP^{1/n}$$

Where,

x/m = adsorption per gram of adsorbent which is obtained be dividing the amount of adsorbate (x) by the weight of the adsorbent (m). P is Pressure, k and n are constants whose values depend upon adsorbent and gas at particular temperature.

Though Freundlich Isotherm correctly established the relationship of adsorption with pressure at lower values, it failed to predict value of adsorption at higher pressure. This relation is called as the freundlich adsorption isotherm. As see the following diagram. The value of x/m is increasing with increase in p but as n>1 it does not increase suddenly. This curve is also called the freundlich isotherm curve.

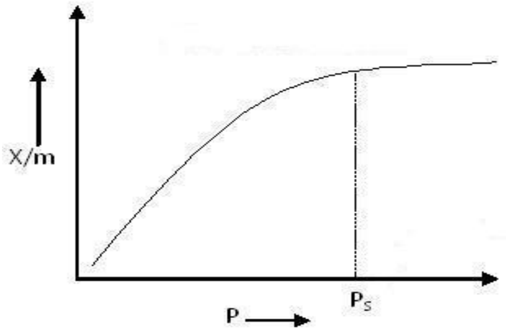
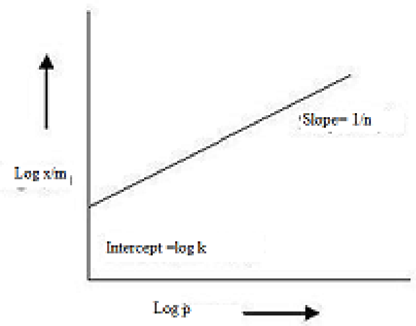


Fig. (2.13) Freundlich Isotherms

Taking the logarithms of a first equation.

$$\frac{\log(x)}{m} = logk + \frac{1}{n} logP$$



Hence, if a graph of log x/m is plotted against log p, it will be a straight line in the following diagram. From this the value of slope equal to 1/n and the value of intercept equal to log k can be obtained. Over and above, it the graph of log x/m against log p comes out to be a straight line, it can be assured that the freundlich adsorption isotherm is satisfied for this system. Langmuir Adsorption Isotherm: In 1916, Irving Langmuir published a new model isotherm for gases adsorbed to solids, which retained his name. It is a semi-empirical isotherm derived from a proposed kinetic mechanism. This isotherm was based on different assumptions one of which is that dynamic equilibrium exists between adsorbed gaseous molecules and the free gaseous molecules. It is based on four assumptions:

- The surface of the adsorbent is uniform, that is, all the adsorption sites are equivalent.
- Adsorbed molecules do not interact.
- All adsorption occurs through the same mechanism.
- At the maximum adsorption, only a monolayer is formed: molecules of adsorbate do not deposit on other, already adsorbed, molecules of adsorbate, only on the free surface of the adsorbent.

Langmuir suggested that adsorption takes place through this mechanism:

$$A\ (g) + B\ (s) \underset{\text{Desorption}}{\overset{\text{Adsorption}}{\rightleftharpoons}} AB$$

Where, A (g) = unabsorbed gaseous molecule

B(s) =unoccupied metal surface

AB = Adsorbed gaseous molecule.

The direct and inverse rate constants are k and k-1 Based on his theory, Langmuir derived an equation which explained the relationship between the number of active sites of the surface undergoing adsorption and pressure. This equation is called

Langmuir Equation.

$$\theta = \frac{KP}{1 + KP}$$

Equation 3.3

Where,

θ= the number of sites of the surface which are covered with gaseous molecule,

P= pressure

K =is the equilibrium constant for distribution of adsorbate between the surface and the gas phase.

The basic limitation of Langmuir adsorption equation is that it is valid at low pressure only.At lower pressure, KP is so small, that factor (1+KP) in denominator can almost be ignored.

The basic limitation of Langmuir adsorption equation is that it is valid at low pressure only.At lower pressure, KP is so small, that factor (1+KP) in denominator can almost be ignored. So Langmuir equation reduces to

$$\theta = KP$$

Equation 3.4

At high pressure KP is so large, that factor (1+KP) in denominator is nearly equal to KP. So Langmuir equation reduces to

$$\theta = \frac{KP}{KP} = 1$$

Equation 3.5

2.14 Adsorbents

- The material upon whose surface the adsorption takes place is called an adsorbent .Activated carbon is used as an adsorbent.

- Adsorbents are used usually in the form of spherical pellets, rods, moldings, or monoliths with hydrodynamic diameters between 0.5 and 10 mm.
- They must have high abrasion resistance, high thermal stability and small pore diameters, which results in higher exposed surface area and hence high surface capacity for adsorption.
- The adsorbents must also have a distinct pore structure which enables fast transport of the gaseous vapors.
- Oxygen-containing compounds - Are typically hydrophilic and polar, including materials such as silica gel and zeolites.
- Carbon-based compounds - Are typically hydrophobic and non-polar, including materials such as activated carbon and graphite.
- Polymer-based compounds - Are polar or non-polar functional groups in a porous polymer matrix.

2.15 Mechanism of Adsorption Using Adsorbent

Activated carbon is used for adsorption of organic substances and non-polar adsorbates and it is also usually used for waste gas (and waste water) treatment. It is the most widely used adsorbent since most of its chemical (e.g. surface groups) and physical properties (e.g. pore size distribution and surface area) can be tuned according to what is needed. Its usefulness also derives from its large micropore (and sometimes mesopore) volume and the resulting high surface area.

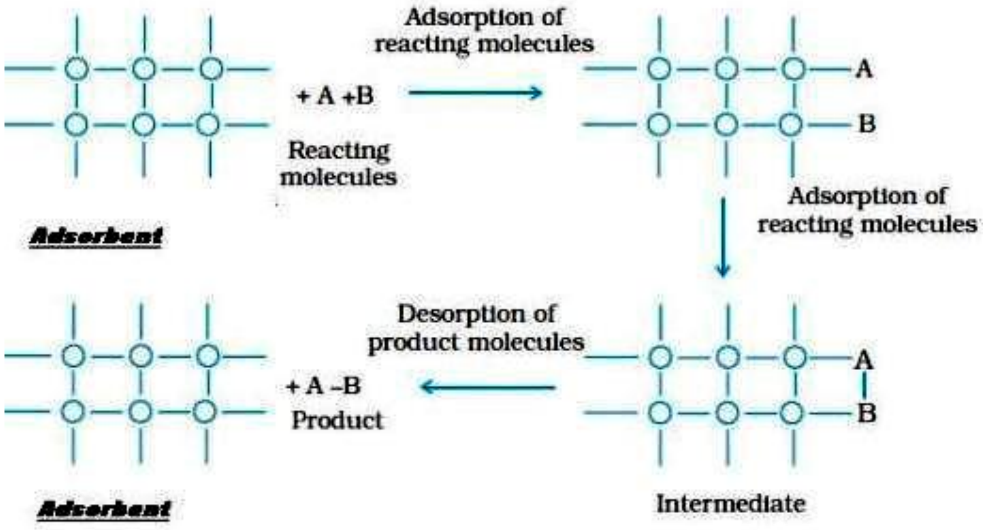


Fig. (2.14) Adsorption Mechanism

2.15.1 Applications of adsorption: The principle of adsorption is employed,

- In heterogeneous catalysis.
- In gas masks where activated charcoal adsorbs poisonous gases.
- In the refining of petroleum and decolouring cane juice.
- In creating vacuum by adsorbing gases on activated charcoal.
- In chromatography to separate the constituents' of a mixture.
- To control humidity by the adsorption of moisture on silica gel.
- In certain titrations to determinate the end point using an adsorbent as indicator (Example: Flouroscein).

Chapter – 3

CHAPTER 3

Material and Methods

3.1 Quality assurance

Reagents and calibration standards for physic-chemical analysis were prepared using milliqui distilled water. Chemicals were used throughout the study analytical grade (AR) chemicals (Merck, Germany) without any further purification or disturbance. The glass-wares were washed with dilute nitric acid (1.15 N) followed by several portions of distilled water. The quality assurance measures included meticulous infectivity control (stringent washing/cleaning procedures), a solvent for blank, equipment and other materials.

3.2 Chemicals

All chemicals used were of analytical reagent grade (AR) unless specified otherwise.High purity gases (Nitrogen, hydrogen ,zero air) were purchased from sigma gases, India. De-ionized water obtained from Milli-Q system (Milli-Q, Integral A-10 system,France) was used for all experimental purposes.BTEX standard mix (2000 µg/ml) was purchased from Supleco, USA for calibrationpurposes. Precursor chemicals (Purity > 99.5%) used for Solvents viz, Methanol,Ethanol, Acetone were purchased from Merck, Mumbai. Benzene anhydrous (99.8%), Toluene anhydrous (99.8%), Ethyl Benzene (99.8%) and ortho, para, meta-Xyleneanhydrous (99.5%) were purchased from Loba Chemicals, Mumbai. Dichloromethane (DCM) (Purity > 99.9%) was purchased from Sigma-Aldrich, USA. Labolene (Qualigens) was used for soap solution. All the glass-wares used were of borosilicate type.

3.3 Water hyacinth (*Eichhornia crassipes* (Mart.)

Originally from India, water hyacinth, *Eichhornia crassipes* (Mart.) Solms, is one of the world's most useful invasive Water Hyacinth with respect to climatic conditions. Water hyacinth, a floating vascular plant which having high growth rate and photosynthesis which was known to cause major ecological and socio-economic changes to the environment, and resource as a biomass. Water hyacinth was collected from the Greater Noida's drain of Greater Noida in present experiment.

Preparation of activated carbon and characterization:

Activated carbon was prepared by the water hyacinth. After the collection, the water hyacinth was washed properly to remove the mud and other organic matter. Different plant part like root, petiole and leaf were separated. Fresh weight of different plant parts was taken. The raw material was washed several times with tap water followed by distilled water and dried in oven at 60°C for 48-96 hours till constant weight was obtained. Dry weights were taken.

Activated carbon was made in the laboratory with the help of muffle furnace in temperature of 440 degree centigrade for four hours in the absence of oxygen. The carbon content of the material was activated and used after washing with the double distillate water. After washing with 0.2N hydrochloric acid and dry it with the help of oven at 95 degree centigrade. Now activated carbon is ready to use for activation process. Activated carbon was prepared by following steps:

Physical activation: In this process precursor was developed into activated carbons using gases. This was done by using one or a combination of the following processes:

Carbonization: Material was pyrolyzed at temperature ranging between 600–900

°C, in the absence of oxygen (usually in inert atmosphere with gases like argon or nitrogen).

Activation/Oxidation: Carbonized material was exposed to oxidizing atmospheres (carbon monoxide, oxygen, or steam) at temperatures above 250 °C, usually in the temperature range of 600–1200 °C)

3.4 Iron Oxide and Iron Powder:

Procedure of Iron Powder Preparation analysis of Iron powder as it is in its form Experiment will be conducted for the removal of Cadmium from aqueous solution by Oxidized Iron powder also. The samples were collected in air tight polythene bags to prevent the chemical changes. To conduct the experiments less than 2 mm particle size had been considered. Before conduct the experiments, sieve analysis of Iron Powder was carried out to prepare particle size distribution curve. The Iron Oxide samples were prepared by natural oxidation process. The powdered sample were moisturized and then allowed to oxidize naturally in the presence of air for approximate one month. There after the samples were crushed using rubber hammer and sieve analyses were carried out. Sieve analysis of the oxide particles has been carried out and the particle size has been restricted up to 2 mm for the experiment.Different surface analysis techniques like XRD and BET were applied to characterize the surface structure, particle size, pore space and other properties of activated carbon materials, iron oxide and iron powder.

3.5 X-ray diffraction analysis

The X-ray powder diffraction (XRD) is an analytical technique that is usually used to study crystallinity and structure of material (atoms packing in crystalline state, inter atomic distance and bond angles, size and shape of unit cells). It is one of the most significant characterization tool used in the field of solid state chemistry and material science. The atomic planes of a crystal cause an incident beam of X-rays to interfere with one another as they leave the crystal. The phenomenon is called X-ray diffraction. When a focused X-ray beam interacts with sample, some part of the beam is transmitted, some part is absorbed by the sample, some part is refracted and scattered, and some is diffracted. These diffracted beams can measure by applying Bragg's Law.

$$\text{Bragg's Law is} \quad \lambda = 2d\sin\theta$$

Where λ is the wavelength of the incident X-ray beam, d is the distance between adjacent planes of atoms, and θ is the angle of incidence of the X-ray beam. The X-ray diffraction (XRD) patterns of activated carbon and iron oxide powder were recorded at ambient temperature using Hecus X-Ray Systems GmbH, Graz (Austria) Model: S3 MICRO. The samples were irradiated with monochromatized Cu Kα Radiation (1.5406 A) X-ray source and analyzed between 5 to 80 $^{\circ}$C (2θ) in case of activated carbon. The operating voltage and current used were 45 kV and 40 mA, respectively. The time constant was maintained at 3.0 s and sweep at 5° min^{-1}. Average particle sizes were calculated using the Debye–Scherrer equation. JCPDS was used to interpretation of the peaks in the prepared material.

3.6 BET Surface area and total pore volume analysis

The technique was named BET after its inventor S. Brunauer, P. H. Emmet and E. Teller (BET). It is the first method developed to measure the specific surface area of porous solids. The BET method is based on the adsorption of gas on a surface. The amount of gas adsorbed at a given pressure allows for the determination of surface area. The method is applied in the analysis of pharmaceuticals, catalysts, projectile propellants, medical implants, filters, cements and adsorbents.

The surface area and the porosity of samples were determined by the Quantachome Autosorb-1 BET analyzer. The adsorption/desorption isotherms and pore volumes of the adsorbents were determined by nitrogen adsorption–desorption isotherms. The samples were kept at 200°C under vacuum before starting N_2 adsorption. Total surface area and pore volume were determined using the Brunauer–Emmet–Teller (BET) equation and the single point method, respectively. Microporosity was determined from t-plot method. Pore size distribution was obtained by Barret–Joyner–Halenda (BJH) method in the adsorption isotherm. Active metal surface area was measured by chemisorption using H_2 gas. 0.1 gm of each sample was loaded into a capillary glass tube and degassed of the samples was carried out at 25 °C for 6 h under nitrogen atmosphere. The nitrogen adsorption and desorption spectra were carried out at 77K using Quantachrome Autosorb-1 BET analyser.

3.7 Biosorption of Cd through water hyacinth

In aquatic systems, wastewater is treated principally by means of bacterial metabolism and physical sedimentation, as is the case in conventional activated sludge and trickling filter systems. The Aquatic plants(such as Water Hyacinth) themselves bring about little actual treatment of the wastewater. Their function is generally to support components of the aquatic environment that improve the wastewater treatment capability and/or reliability of that environment.

There are two Category of wastewater going to treat in the Experiment

1. Cannel wastewater in front of Gautam Budh University
2. Galgotias university wastewater

At the same time, population and production increases have increased water use, creating a corresponding rise in wastewater quantity. This increased water use and process wastewater generation requires more efficient removal of by-products and pollutants that allows for effluent discharge within established environmental regulatory limits. Although wastewater analytical tests are often separated into categories, it is important to understand that these tests are not independent of each other. In other words, a contaminant identified by one test in one category can also be identified in another test in a separate category. For most people a complete understanding of the standard methods required to accurately complete critical wastewater analytical tests is not necessary. However, a fundamental understanding of the theory behind and working knowledge of the basic procedures used for each test, and the answers to commonly asked questions about each test can be a valuable tool for anyone involved in generating, monitoring, treating or discharging process wastewater. We are focusing on the Turbidity, pH, Salinity, Electrical Conductivity, Total Dissolved Solids, and the most toxic metal removal of Cadmium and Iron by Water Hyacinth.

3.8 Experimental Setup

Four baskets of plastic material were used for the experiment. Each basket filled with the wastewater, two with Greater Noida’sDrain Wastewater. Separate baskets were used for water hyacinth and a control of each basket was used to observe difference in growth rates of among each plant due to uptake contaminants. We are providing sun shine for two hours per day for the respiration and growth of plants.Each types of wastewater having difference in growth rates among each plant due to differences in contaminant uptake.

First of all wastewater sample are collected in the plastic bottles after washing with distilled water. Afterwards, all samples have been centrifuge for four min. and it is preserved with the two drop of hydrochloric acid in the laboratory, so the metal does not attach to the wall of sampling bottles.

Fig.(3.1) Bioabsorption of Cadmium from Location #1 Wastewater

Fig. (3.2) Bioabsorption of Cadmium from Location #2 Wastewater

3.1 Dimension of the Baskets

Depth	**34 cm**
Upper Diameter	29.8 cm
Lower Diameter	27.0 cm
Capacity	25 Lit
Area	907.46 cm^2

Table (3.1) Dimension of the Basket

3.9 Adsorption of Cd through activated carbon, iron oxide and iron powder:

Batch Adsorption Experiments

Batch Adsorption Experiments were conducted at different adsorption time, initial adsorbate concentration, pH, temperature and agitation speed. Activated carbon, iron oxide and iron powder in different batch were used for the absorption of the Cadmium. Below following parameter were taken which affected adsorption process.

Fig. (3.3) Raw Water Hyacinth

Fig. (3.4) Segrigation of Water Hyacinth

Fig. (3.5) Dry Leaf of Water hyacinth

Fig. (3.6) Dry Petiole of Water Hyacinth

Fig.(3.7) Raw Activated carbon of Leaf

Fig. (3.8) Raw Activated carbon of Petiole

Fig. (3.09) Raw Activated carbon of Root

Fig. (3.10) Comparative Raw Activated Carbon of Water Hyacinth

Fig.(3.11) Effect of Agitation Speed on adsorption

Fig. (3.12) Adsorption process

Fig. (3.13) Centrifuge process the TDS from Sample

Preparation of Synthetic Cd^{2+} Solution

The stock Cadmium solution was prepared as per Standard Method (17th Edition)-1989. 2.7718g of $Cd(NO_3)_2.4H_2O$ salt was dissolved in 100 ml of distilled water and the volume was made up to 1000 ml to make 1000 ppm standard solution.

Removal Efficiency

The removal efficiency of Cadmium is measured in percentage which was removed from the wastewater and adsorbed at activated carbon which was made by different part of water hyacinth/ and also on iron powder and iron oxide powder.

$$\text{Removal Efficiency } \% = \frac{(W_1 - W_2)}{W_1} * 100$$

Where

W_1 = Initial Concentration of cadmium

W_2 =Final Concentration of cadmium

Table 3.2 Affecting Parameter of Adsorption

Parameters	**Variables**	**Constants**
Effect of Contact time Range (0.5-5 hours)	Contact time	Temperature Agitation speed, pH Dose of adsorbent Initial concentration
Effect of Agitation speed Range (25-60 RPM)	Agitation speed	Contact time pH Dose of adsorbent Temperature Initial concentration
Effect of Dose Range (1-5 g)	Dose	Temperature Agitation speed pH Contact time Initial concentration
Effect of pH	pH	Temperature Agitation speed Contact time Agitation speed Initial concentration
Effect of Initial concentration Constant	Concentration	Temperature Agitation speed Contact time Agitation speed pH

Isotherms

Isotherms of the adsorption process was calculated by the help of Freundlich Adsorption Isotherm the equations of following isotherms are

$$\frac{x}{m} = kP^{1/n}$$

Freundlich Adsorption Isotherm

taking the logarithms of a first equation.

$$\log(\frac{x}{m}) = logk + \frac{1}{n} logP$$

pH:

ThepH values from 0 to 7 are diminishing acidic, 7 to 14 increasingly alkaline and 7 is neutral. pH value is governed largely by carbon dioxide/ bicarbonate/carbonate equilibrium. Glass The basic principle of electronic pH measurement is the determination of activity of hydrogen ions by potentiometric measurement using a standard sensing electrode (glass electrode) and a reference electrode (calomel electrode).

The pH is determined by the measurement of the electromotive force (elf) of a cell compressing of an electrode (an electrode responsive to hydrogen ions such as glass electrode) immersed in the test solution and a reference electrode (usually a calomel electrode). Sensing electrode consists of a thin glass bulb containing a fixed concentration of HCl solution, into which an Ag-AgCl wire is inserted, serving as the electrode with a fixed voltage. Reference electrode consists of a half cell that provides a constant electrode potential. When glass electrode is immersed in a solution, a potential difference develops between the solution in the glass bulb and sample solution. The potential difference E is formulated by Nernst equation:

$$E=RT/nF\ \{\log (K/M)\}$$

Where,

E= half cell potential, T= Absolute temperature, F= Faraday constant, M= Activity of ions to be measured, R= Gas constant, n= Valence, K= Constant

Since the pH is defined operationally on a potential metric scale, the measuring instrument is also calibrated potentio-metrically with an indicating (glass) electrode and a reference electrode using standard buffers having assigned pH value so that

$$pH= -\log10\ [H+]$$

Where, pH = assigned pH of standard buffer.

Equipment and apparatus

pH meter, beaker.

Chemicals

pH Buffer 4, 7 and 9

Procedure

i. The electrode of the pH meter was rinsed with distilled water. It was wiped with a clean tissue paper.

ii. The electrode was dipped in standard solutions having pH values of 4.0, 7.0 and 9.0. This was done for the calibration of the pH meter.

iii. 10 ml sample was taken in a beaker, and the electrode was dipped into the sample in order to measure the pH. The meter reading was allowed to stabilize before noting it down.

iv. The electrode was washed with distilled water before measuring the pH level of another sample.

v. It was kept in mind that the temperatures of all the samples were in the same range.

Total Dissolved Solids

The TDS is combined contents or sum of organic and inorganic substances that are dissolve in water as an ionized (cations and anions), molecular, colloidal, and suspended form. The main source of total dissolved solid in groundwater is natural dissolution and weathering of minerals, rocks, and soil.

The gravimetric method is measuring the mass of residual or solid content that are dissolve in water by evaporation of liquid media. A well-mixed, measured portion of sample is filtered through a standard glass-fibre filter and the filtrate portion is evaporated to dryness at 180±2 ºC and that gives the amount of total dissolved solids. The reason for higher temperature used is to remove all mechanically occluded water. Where organic matter is generally very low in concentration, the losses due to higher drying temperature will be negligible.

Apparatus

Desiccators, Hot oven, Beaker, Evaporating disc.

Procedure

i. Take an evaporating dish or clean beaker and dry it completely. Store the dish/beaker in a desiccator until needed.

ii. Note the initial weight of the dish/beaker.

iii. Put 50 ml sample in the dish/beaker and keep it in a hot air oven at ~100ºC until the sample dries completely.

iv. Cool in a desiccator and note the final weight.

$$\text{TDS (Total dissolve solid) mg/l} = \frac{W2 - W1 \times 1000 \times 1000}{\text{Volume of sample}}$$

Where,

W2= final weight of evaporating dish

W1= initial weight of evaporating dish

V= volume of sample

Turbidity

Turbidity is caused by wide variety of suspended and colloidal materials. Run off from barren areas during rain is the most natural contributor of turbidity, particularly silt and clay. The discharge of untreated industrial and domestic effluents also adds great quantity of turbidity. Organic material reaching water bodies serves as food for bacteria, resulting the enhancements of bacteria and other microorganisms feed upon bacteria.

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Higher the intensity of scattered lights higher the turbidity. The standard method for the determination of turbidity has been based on the Jackson candle turbidity meter.

Apparatus: Turbidity meter or Nephelometer, weight balance.

Chemicals

Hydrazine sulphate solution

Dissolved 1.00 gm Hydrazine sulphate in 100 mL volumetric flask, then makeup up to mark with distilled water.

Hexamethylene tetramine solution

Dissolved 10.00 gm Hexamethylene tetramine in 100 mL volumetric flask, then makeup up to mark with distilled water.

Stock Solution (40 NTU)

5 ml of both solutions were taken in 100 mL volumetric flask, and stored at 25±3^{o}C

for 24 hours after that makeup up to mark with distilled water.

Procedure: Samples were store in room for some time at constant temperature, and then mixed the sample. Sample was poured into turbidity tube, and waited for disappearing of air bubble after that taken directly from reading from Nephelometer. If reading appear continues 40 or above needed for dilution of sample below 40 NTU.

Calculation: The concentration is calculated from calibration curve.

Electrical Conductivity

Conductivity is the capacity of water to carry an electrical current and varies both with number and types of ions in the solutions, which in turn is related to the concentration of ionized substances in the water. Most dissolved inorganic substances in water are in the ionized form and hence contribute to conductance. Conductivity measurement gives rapid and practical estimate of the variations in the dissolved mineral contents of a water body.

Conductivity is a numerical expression of the ability of a water sample to carry an electrical current and varies with the number and types of ions the solution contains. Most dissolved organic substances in water are in the ionized form and hence contribute to conductance.

Conductance G is defined as the reciprocal of resistance R.

$$G=1/R$$

Where, R is in Ohm and G is in Ohm-1(sometimes written as Mho).

Conductance of a solution is a measure between two spatially fixed chemically inert electrodes. To avoid polarization at the electrode surface the conductance measurement is made with an alternating current signal. The conductance (G) of a solution is directly proportional to the surface area (A, cm2) and inversely proportional to the distance between the electrodes (L, cm).The constant of proportionality (k) is such that

$$G= k\ A/L$$

k is called “conductivity” (also specific conductance). The unit of k is 1/ohm-cm or mho per centimeter. It can be defined as the conductance of a conductor 1 cm in length and 1cm2 in cross sectional area. The specific conductance depends on the nature of the conductor (the solution between the electrodes), the ion concentration and pressure.

Apparatus: Conductivity meter

Procedure:

i. The electrode of the conductivity meter was rinsed with distilled water. It was wiped dry with a clean tissue paper and rinsed again with the sample whose conductivity was to be measured.

ii. The electrode was dipped in a beaker containing the sample.

iii. The conductivity of the sample was noted from the screen of the meter.

iv. The electrode was washed again with distilled water and sample before measuring the conductivity of another sample.

v. It was kept in mind that the temperatures of all the samples were in the range of 25±1° C.

Determination of Moisture contents

The freshly collected vegetables and others plants samples 50 g were air dried for two days. After that dried at 70 ºC temperature in a hot air oven for 3 days then cooled in desiccator for 24 Hours. The moisture contents were calculated by following equation**.**

$$\text{Moisture contents } \% = \frac{(W_1 - W_2)}{W_1} * 100$$

W1 fresh weight of plants samples

W2 dry weight of plants samples

Instrument list

Table (3.3) List of instrument

Instrument Name	**Make**	**Model**
Atomic Absorption Spectrophotometer	Skyray	ASS 600
pH/Temperature Meter (Microprocessor Based)	Hach	LPV2550T97002
Conductivity/TDS Meter (Microprocessor Based)	Hach (Platinum material polycarbonate)	LPV356097002
Digital Nephelo Turbidity Meter	Hach (Silicon photovoltaic Detector)	2100Q01

Statistical analysis

Statistical data and graph have been plotted by sigma plot 10. XRD and BET was performed at IIT Kanpur.

Chapter – 4

Chapter 4

Results

4.1 Moisture content and percent production of activated carbon from water hyacinth:

Result indicated that maximum water content was observed in petiole (87.73%) and least in leaf (87.23%) while in root it was observed 87.56%. Activated carbon were prepared from different plant which indicated that maximum activated carbon was yield from leaf (42.82%) and least in root(32.55%) which may be due to lignin or pectin and cellulosic deposition on the surface leaf and petiole that increases carbon content in these part.

Table 4.1. Fresh weight, dry weight, water content and activated carbon yield of different plant parts of water hyacinth (*Eichorniacrassipes* Mart.)

Different plant parts	Fresh weight (g)	Dry weight (g)	Water/Moisture contents (%)	Activated Carbons (g)	Percent production (%)
Roots	2725.3	338.87	87.56	110.3	32.55
Petiole	4134.0	507.25	87.73	173.8	34.26
Leaf	949.1	121.18	87.23	51.9	42.82
Total Biomass	7808.4	967.3	87.62	336	34.73

4.2 Surface morphology of activated carbon, iron oxide and iron powder

BET analysis

The nitrogen adsorption-desorption isotherms of (activated carbon) is depicted in Fig. (4.01)

The pore size distribution was calculated using BJH theory. The surface area and total pore volume of (activated carbon) were found to be 88.2 m^2 /g and 0.214 cc/g, respectively. It is also evident from pore size distribution that the prepared (activated carbon) the high specific surface area and porous structure of the material facilitate the sorption ability, thereby, the prepared (activated carbon) have potential ability to remove contaminants from waste water.

Activated carbon was make by the leaf of water hyacinth which having the following properties.

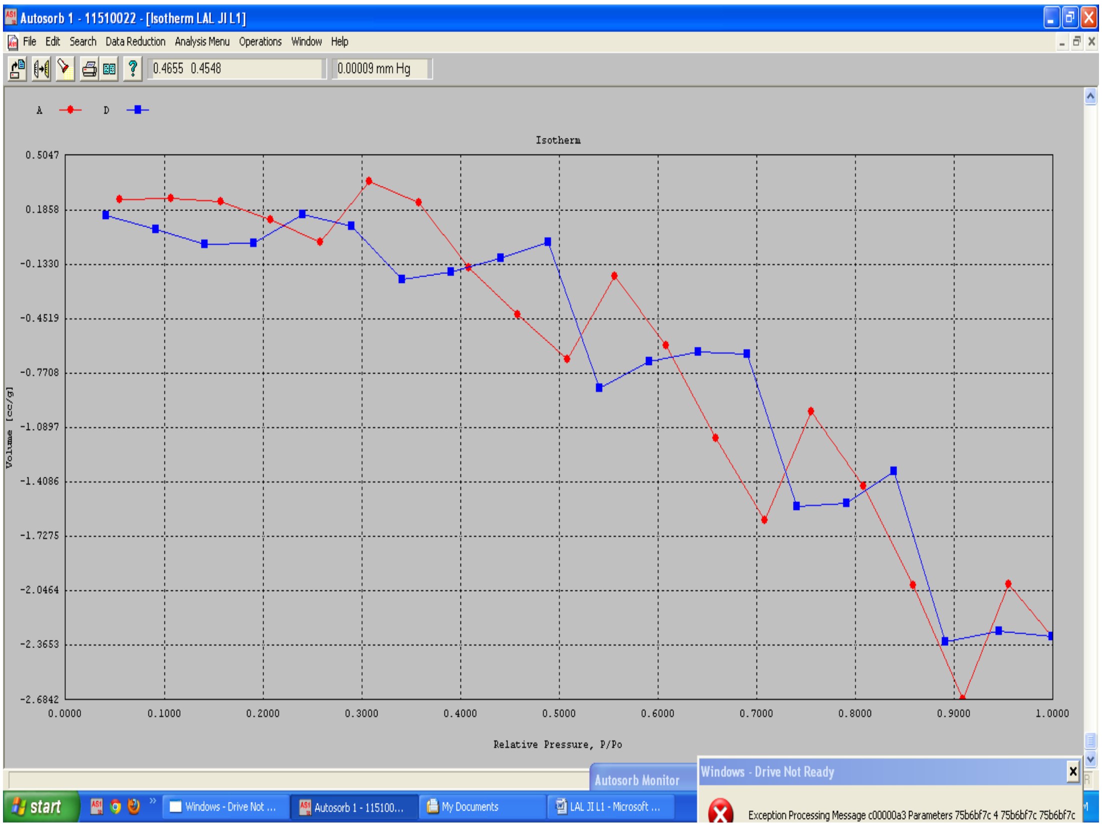


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Fig. (4.1) Adsorption and Desorption curve on activated carbon made by Leaf

SURFACE AREA DATA

Multipoint BET... 0.000E+00 m²/g

Langmuir Surface Area...................................... -4.141E-02 m²/g

BJH Method Cumulative Adsorption Surface Area............... 4.302E+00 m²/g

BJH Method Cumulative Desorption Surface Area.............. 2.527E+00 m²/g

DH Method Cumulative Adsorption Surface Area................ 7.212E+00 m²/g

DH Method Cumulative Desorption Surface Area................ 4.966E+00 m²/g

t-Method External Surface Area.............................. -3.238E+00 m²/g

t-Method Micro Pore Surface Area............................ 3.238E+00 m²/g

DR Method Micro Pore Area................................... 7.874E-01 m²/g

NLDFT Method Cumulative Surface Area........................ 5.887E-01 m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter

less than 31917.2 Å at P/Po = 0.99940....................... -3.584E-03 cc/g

BJH Method Cumulative Adsorption Pore Volume................ 5.565E-03 cc/g

BJH Method Cumulative Desorption Pore Volume................ 2.385E-03 cc/g

BJH Interpolated Cumulative Adsorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 5.565E-03 cc/g

BJH Interpolated Cumulative Desorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 2.385E-03 cc/g

DH Method Cumulative Adsorption Pore Volume................. 6.934E-03 cc/g

DH Method Cumulative Desorption Pore Volume................. 4.119E-03 cc/g

t-Method Micro Pore Volume................................. 1.420E-03 cc/g

DR Method Micro Pore Volume................................ 2.805E-04 cc/g

NLDFT Method Cumulative Pore Volume......................... 2.236E-04 cc/g

PORE SIZE DATA

BJH Method Adsorption Pore Diameter (Mode).................. 2.501E+01 Å

BJH Method Desorption Pore Diameter (Mode).................. 2.145E+01 Å

DH Method Adsorption Pore Diameter (Mode).................. 2.501E+01 Å

DH Method Desorption Pore Diameter (Mode).................. 2.145E+01 Å

DR Method Micro Pore Width .... 1.758E+01 Å

NLDFT method Pore Diameter (Mode)........................... 2.419E+01 Å

Activated carbon was make by the roots of water hyacinth which having the following properties.

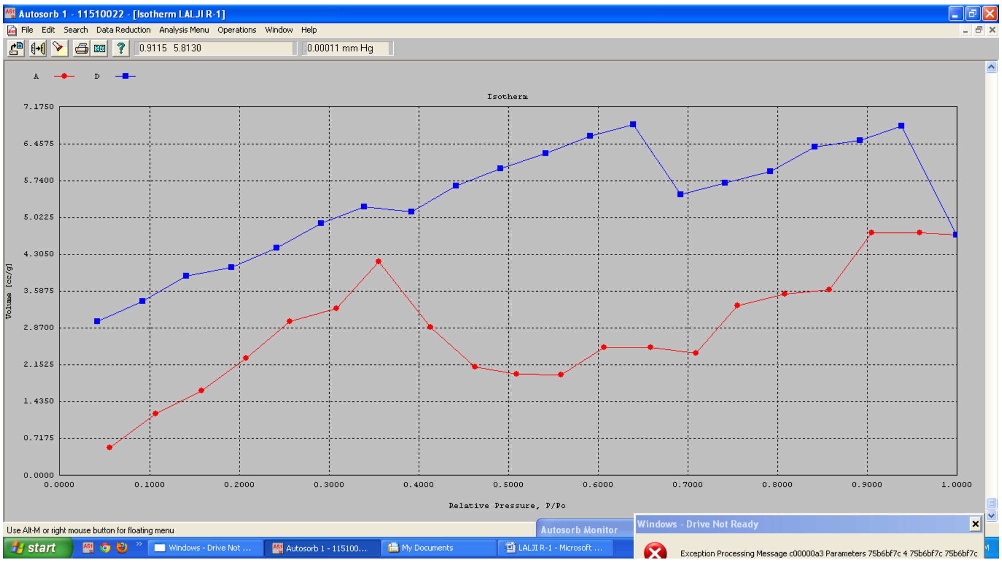

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Fig. (4.2) Adsorption and Desorption curve on activated carbon made by Roots

SURFACE AREA DATA

Multipoint BET... 2.201E+01 m²/g

Langmuir Surface Area...................................... -1.060E+02 m²/g

BJH Method Cumulative Adsorption Surface Area............... 2.295E+01 m²/g

BJH Method Cumulative Desorption Surface Area............... 1.591E+01 m²/g

DH Method Cumulative Adsorption Surface Area................ 3.156E+01 m²/g

DH Method Cumulative Desorption Surface Area................ 1.931E+01 m²/g

t-Method External Surface Area.............................. 2.888E+00 m²/g

t-Method Micro Pore Surface Area............................ 1.912E+01 m²/g

DR Method Micro Pore Area................................... 1.902E+01 m²/g

NLDFT Method Cumulative Surface Area........................ 1.050E+01 m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter

less than 31917.2 Å at P/Po = 0.99940....................... 7.268E-03 cc/g

BJH Method Cumulative Adsorption Pore Volume................ 1.717E-02 cc/g

BJH Method Cumulative Desorption Pore Volume................ 1.279E-02 cc/g

BJH Interpolated Cumulative Adsorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 1.717E-02 cc/g

BJH Interpolated Cumulative Desorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 1.279E-02 cc/g

DH Method Cumulative Adsorption Pore Volume................. 2.068E-02 cc/g

DH Method Cumulative Desorption Pore Volume................. 1.436E-02 cc/g

t-Method Micro Pore Volume.................................. 4.108E-03 cc/g

DR Method Micro Pore Volume................................. 6.777E-03 cc/g

NLDFT Method Cumulative Pore Volume......................... 9.805E-03 cc/g

PORE SIZE DATA

Average Pore Diameter...................................... 1.321E+01 Å

BJH Method Adsorption Pore Diameter (Mode).................. 2.788E+01 Å

BJH Method Desorption Pore Diameter (Mode).................. 1.652E+01 Å

DH Method Adsorption Pore Diameter (Mode).................. 2.788E+01 Å

DH Method Desorption Pore Diameter (Mode).................. 1.652E+01 Å

DR Method Micro Pore Width .... 5.644E+01 Å

NLDFT method Pore Diameter (Mode)........................... 2.769E+01 Å

Activated carbon was make by the Petiole of water hyacinth which having the following properties

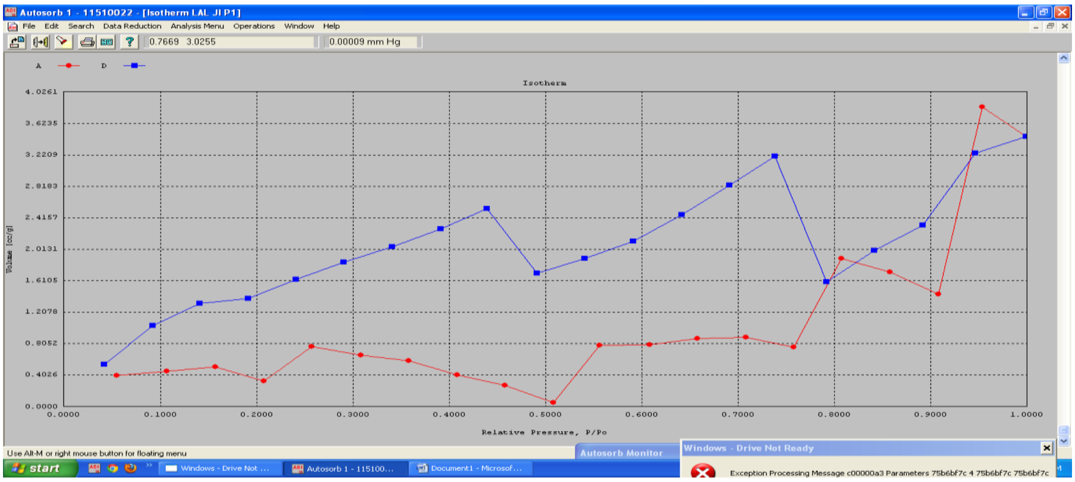

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Fig. (4.3) Adsorption and Desorption curve on activated carbon made by Petiole

SURFACE AREA DATA

Multipoint BET... 1.828E+00 m²/g

Langmuir Surface Area...................................... 3.242E+00 m²/g

BJH Method Cumulative Adsorption Surface Area............... 6.525E+00 m²/g

BJH Method Cumulative Desorption Surface Area............... 1.353E+01 m²/g

DH Method Cumulative Adsorption Surface Area................ 8.200E+00 m²/g

DH Method Cumulative Desorption Surface Area................ 1.856E+01 m²/g

t-Method External Surface Area.............................. 1.828E+00 m²/g

t-Method Micro Pore Surface Area............................ 0.000E+00 m²/g

DR Method Micro Pore Area................................... 6.010E+00 m²/g

NLDFT Method Cumulative Surface Area........................ 3.086E+00 m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter

less than 31917.2 Å at P/Po = 0.99940....................... 5.352E-03 cc/g

BJH Method Cumulative Adsorption Pore Volume................ 1.093E-02 cc/g

BJH Method Cumulative Desorption Pore Volume................ 1.219E-02 cc/g

BJH Interpolated Cumulative Adsorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 1.093E-02 cc/g

BJH Interpolated Cumulative Desorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 1.197E-02 cc/g

DH Method Cumulative Adsorption Pore Volume................. 1.146E-02 cc/g

DH Method Cumulative Desorption Pore Volume................. 1.467E-02 cc/g

t-Method Micro Pore Volume................................. 0.000E+00 cc/g

DR Method Micro Pore Volume................................. 2.141E-03 cc/g

NLDFT Method Cumulative Pore Volume......................... 4.778E-03 cc/g

PORE SIZE DATA

Average Pore Diameter...................................... 1.171E+02 Å

BJH Method Adsorption Pore Diameter (Mode)................. 2.233E+01 Å

BJH Method Desorption Pore Diameter (Mode)................. 1.382E+01 Å

DH Method Adsorption Pore Diameter (Mode)................. 2.233E+01 Å

DH Method Desorption Pore Diameter (Mode)................. 1.382E+01 Å

DR Method Micro Pore Width .... 5.795E+01 Å

NLDFT method Pore Diameter (Mode)........................... 1.847E+01 Å

Iron Powder having the following surface properties the parameter was analyzed by BET experiments.

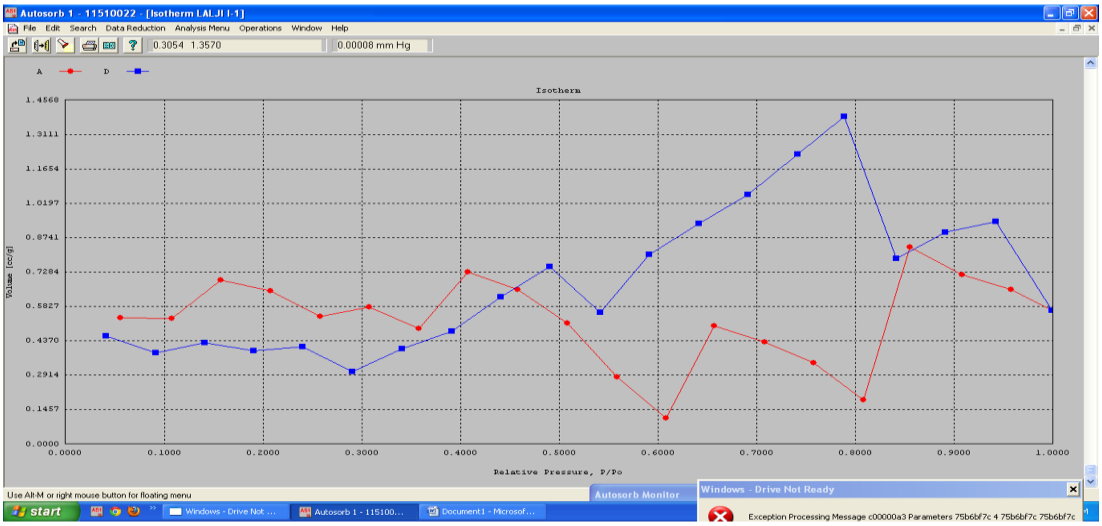

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Fig. (4.4) Adsorption and Desorption curve Iron Powder

SURFACE AREA DATA

Multipoint BET... 1.416E+00 m^2/g

Langmuir Surface Area...................................... 2.194E+00 m^2/g

BJH Method Cumulative Adsorption Surface Area............... 3.588E+00 m^2/g

BJH Method Cumulative Desorption Surface Area.............. 2.765E+00 m^2/g

DH Method Cumulative Adsorption Surface Area................ 4.985E+00 m^2/g

DH Method Cumulative Desorption Surface Area................ 3.623E+00 m^2/g

t-Method External Surface Area.............................. 3.524E-01 m^2/g

t-Method Micro Pore Surface Area............................ 1.064E+00 m^2/g

DR Method Micro Pore Area................................... 2.516E+00 m^2/g

NLDFT Method Cumulative Surface Area........................ 1.342E+00 m^2/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter

less than 31917.2 Å at P/Po = 0.99940....................... 8.794E-04 cc/g

BJH Method Cumulative Adsorption Pore Volume................ 3.897E-03 cc/g

BJH Method Cumulative Desorption Pore Volume................ 3.484E-03 cc/g

BJH Interpolated Cumulative Adsorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 3.897E-03 cc/g

BJH Interpolated Cumulative Desorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 3.484E-03 cc/g

DH Method Cumulative Adsorption Pore Volume................. 4.520E-03 cc/g

DH Method Cumulative Desorption Pore Volume................. 4.005E-03 cc/g

t-Method Micro Pore Volume................................. 6.741E-04 cc/g

DR Method Micro Pore Volume................................. 8.964E-04 cc/g

NLDFT Method Cumulative Pore Volume......................... 1.970E-03 cc/g

PORE SIZE DATA

Average Pore Diameter...................................... 2.484E+01 Å

BJH Method Adsorption Pore Diameter (Mode).................. 3.115E+01 Å

BJH Method Desorption Pore Diameter (Mode).................. 4.800E+01 Å

DH Method Adsorption Pore Diameter (Mode).................. 1.733E+01 Å

DH Method Desorption Pore Diameter (Mode).................. 3.354E+01 Å

DR Method Micro Pore Width .... 2.898E+01 Å

NLDFT method Pore Diameter (Mode)........................... 3.627E+01 Å

Iron Oxidized Powder having the following surface properties the parameter was analyzed by BET experiments.

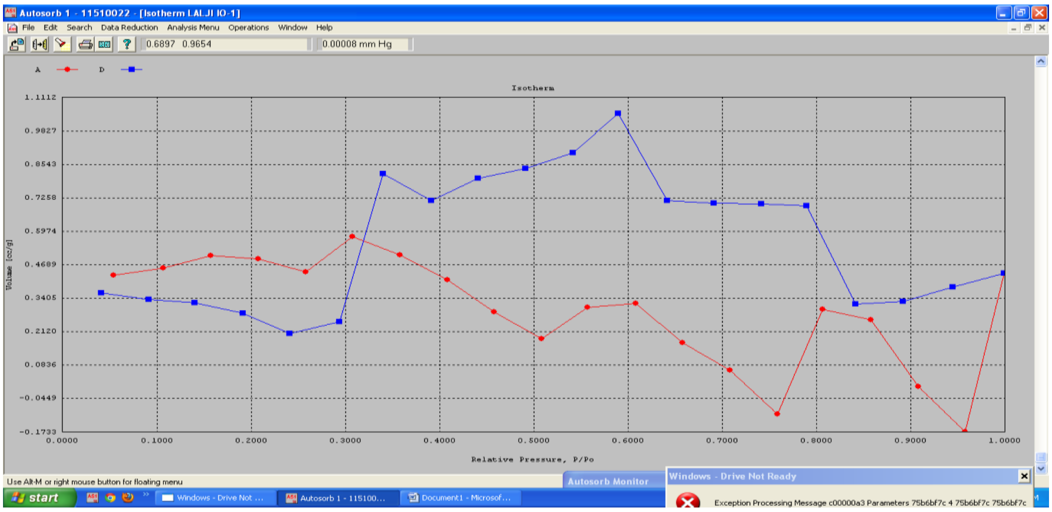

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Fig. (4.5) Adsorption and Desorption curve Iron Oxidize Powder

SURFACE AREA DATA

Multipoint BET... 1.450E+00 m²/g

Langmuir Surface Area...................................... 2.354E+00 m²/g

BJH Method Cumulative Adsorption Surface Area............... 1.738E+00 m²/g

BJH Method Cumulative Desorption Surface Area............... 4.162E+00 m²/g

DH Method Cumulative Adsorption Surface Area................ 3.248E+00 m²/g

DH Method Cumulative Desorption Surface Area................ 4.716E+00 m²/g

t-Method External Surface Area.............................. -2.965E-01 m²/g

t-Method Micro Pore Surface Area............................ 1.746E+00 m²/g

DR Method Micro Pore Area................................... 1.420E+00 m²/g

NLDFT Method Cumulative Surface Area........................ 1.373E+00 m²/g

PORE VOLUME DATA

Total Pore Volume for pores with Diameter

less than 31917.2 Å at P/Po = 0.99940....................... 6.752E-04 cc/g

BJH Method Cumulative Adsorption Pore Volume................ 2.861E-03 cc/g

BJH Method Cumulative Desorption Pore Volume................ 3.335E-03 cc/g

BJH Interpolated Cumulative Adsorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 2.191E-03 cc/g

BJH Interpolated Cumulative Desorption Pore Volume for pores

in the range of 5000.0 to 0.0 Å Diameter.................... 3.278E-03 cc/g

DH Method Cumulative Adsorption Pore Volume................. 3.501E-03 cc/g

DH Method Cumulative Desorption Pore Volume................. 3.668E-03 cc/g

t-Method Micro Pore Volume.................................. 8.876E-04 cc/g

DR Method Micro Pore Volume................................. 5.060E-04 cc/g

NLDFT Method Cumulative Pore Volume......................... 1.462E-03 cc/g

PORE SIZE DATA

Average Pore Diameter....................................... 1.863E+01 Å

BJH Method Adsorption Pore Diameter (Mode).................. 2.501E+01 Å

BJH Method Desorption Pore Diameter (Mode).................. 2.698E+01 Å

DH Method Adsorption Pore Diameter (Mode).................. 2.501E+01 Å

DH Method Desorption Pore Diameter (Mode).................. 2.698E+01 Å

DR Method Micro Pore Width .... 3.093E+01 Å

NLDFT method Pore Diameter (Mode)........................... 2.647E+01 Å

XRD Analysis

The XRD pattern analysis of the prepared activated carbon, shows the diffraction peaks approximately at 2ɵ and the diffraction peaks show change in intensity. Which is show figures.

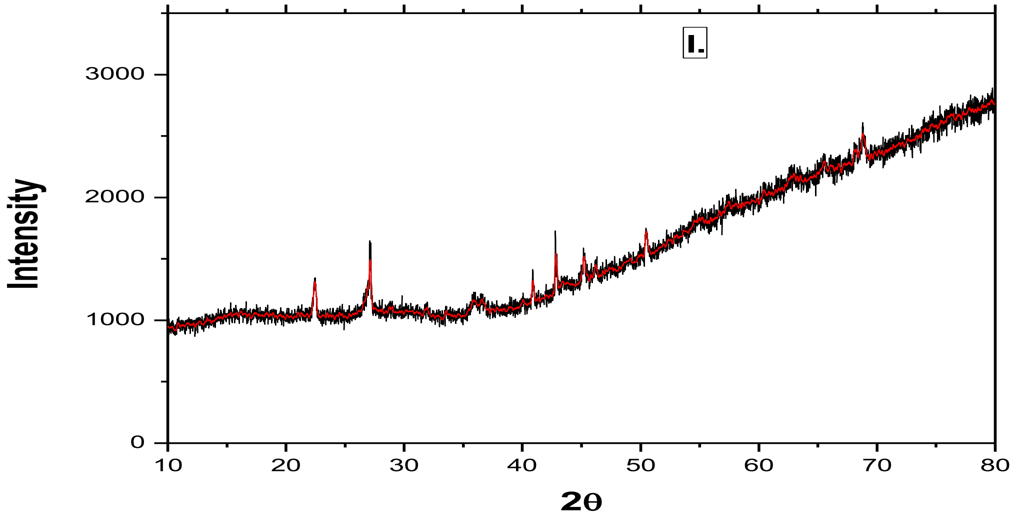

Fig. (4.6) Relation Between intensity and angle of Iron Powder

Most intense peak at $2\theta=28^0$ was observed in the diffraction spectra and less intense peak at $2\theta=22^0$

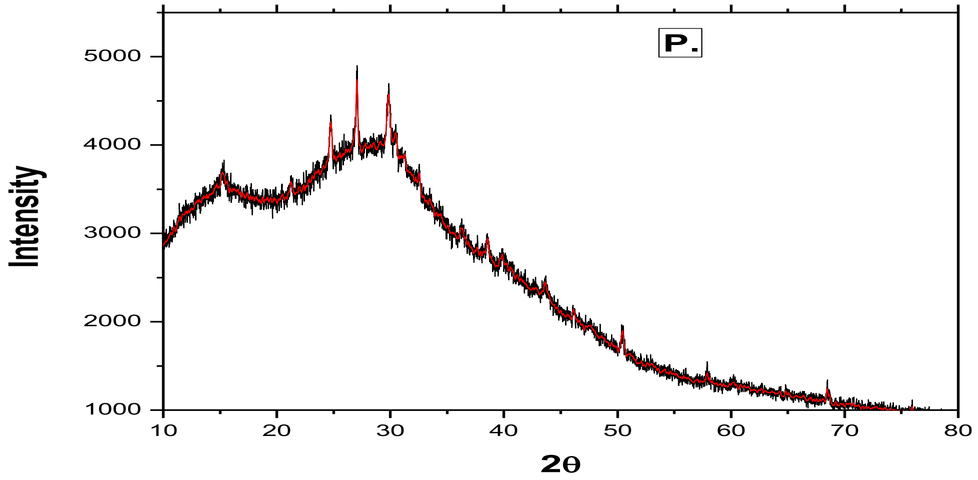

Fig. (4.7) Relation Between intensity and angle of Petiole

Most intense peak at $2\theta=26^0$ was observed in the diffraction spectra and less intense peak at $2\theta=24^0$

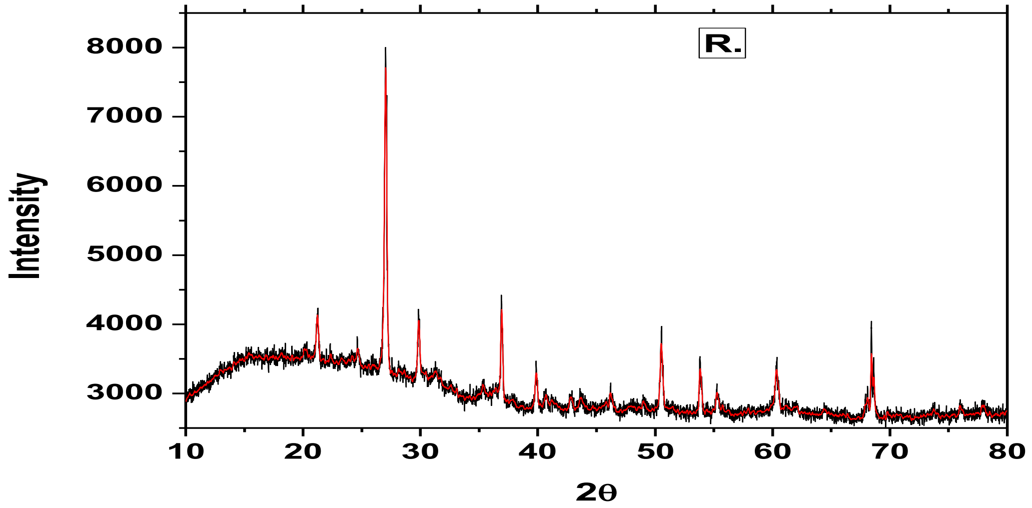

Fig.(4.8) Relation Between intensity and angle of Roots

Most intense peak at $2\theta=26^0$ was observed in the diffraction spectra and less intense peak at $2\theta=55^0$

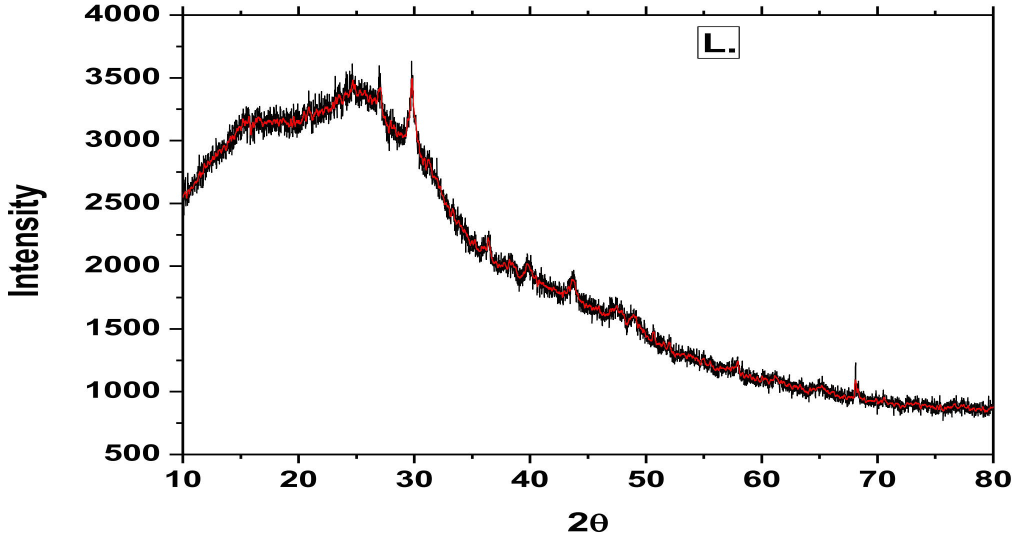

Fig. (4.9) Relation Between intensity and angle of Leaf

Most intense peak at 2θ=26^0 was observed in the diffraction spectra and less intense peak at 2θ=68^0

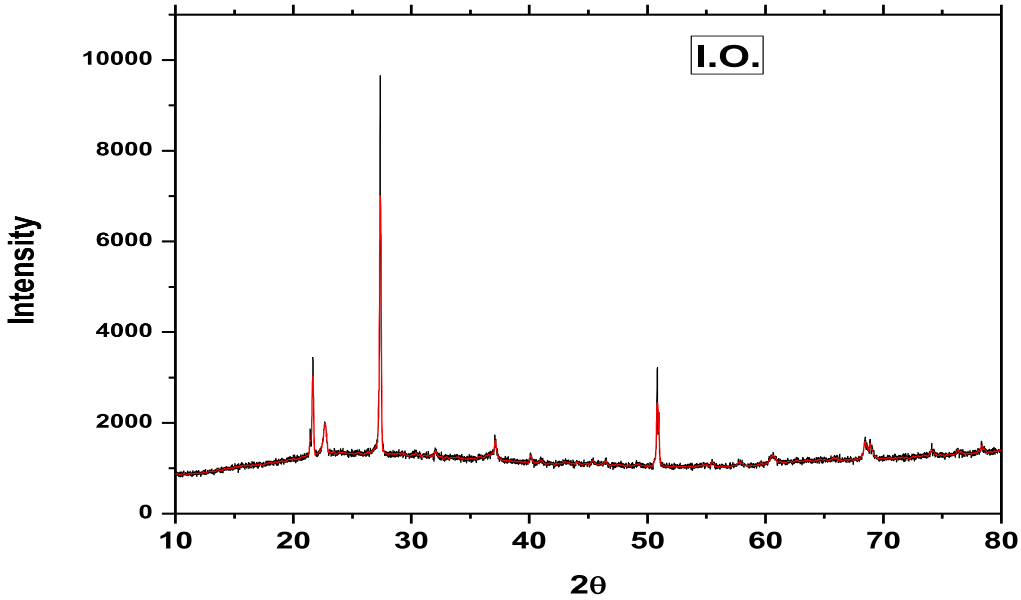

Fig. (4.10) Relation Between intensity and angle of Iron Oxidized Powder

Most intense peak at 2θ=27^0 was observed in the diffraction spectra and less intense peak at 2θ=68^0

4.3 Effect of biosorption by water hyacinth on concentration of Cd and other parameters of water

Biosorption experiment was conducted in four baskets of plastic material. Each basket filled with the wastewater collected from two different location of sewage drain i.e., L1 and L2 situated in Greater Noida. Properties of water were indicated in Table 2. Each basket used for growing water hyacinth, the control of each basket was used to observe difference in growth rates of among each plant due to uptake contaminants. Thus it was indicated that L1 sewage wastewater was more polluted than L2 sewage wastewater.

Table (4.2) Properties of waste water collected from two different location of sewage drain for experiment

Water Parameters	Location 1(L1)	Location2(L2)
Turbidity (NTU)	150.27	191
Water pH	7.58	8.23
EC (ms/cm)	1326	4.47
Salinity (mg/l)	6.53	2.32
TDS (g/l)	1847	2.86
Cd concentration(ppm)	1.27	0.907

Effect on pH

The pH of water is the most important factor for the growth of plant. Results indicated that pH of domestic waste water was decreased initially and it showed up to 7.40 at 16 days, time interval from 7.58 pH on growing water hyacinth (Fig. 4.11) but after some pH of water start to increase and it increases up to 8.06 after 24 days of time interval. Thus it was concluded that the pH of wastewater was slightly going down due to the acidic reaction in the wastewater but after certain days the completion of the acidic reaction the fermentation of the organic matter was started so that the pH of the wastewater is going to increase in this experiments. Similar trend was also observed in L2 sewage water.

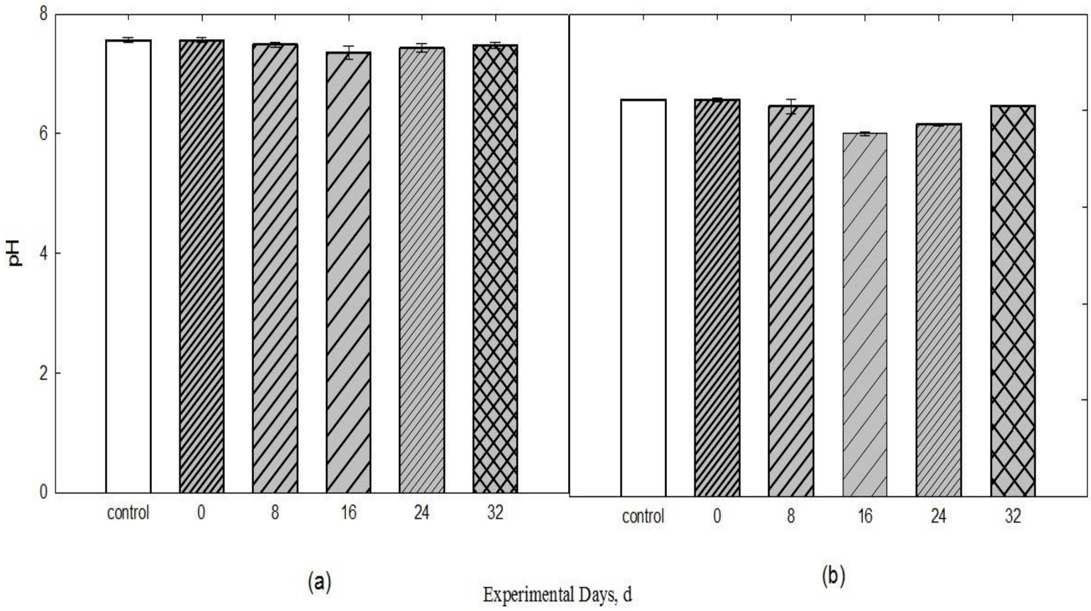

Fig.4.11: Effect on pH of water on the growth of water hyacinth in waste water.

Effect on TDS

TDS is also important factor for the wastewater which shows the presence of the solids in the wastewater which solids are going to effect the water quality as well as the flow rate due sedimentation of its solids in the way of the canal or rivers and also effect the life of the animals which are going to consume this water. Result indicated that initial TDS of L1 was very high in comparison of L2 (Table2) which was decreased on increasing time period in the proportionate. So, it was concluded that due to the some settle and some organic matter going to degrade that's why the graph are going down day by day (Fig. 4.12).

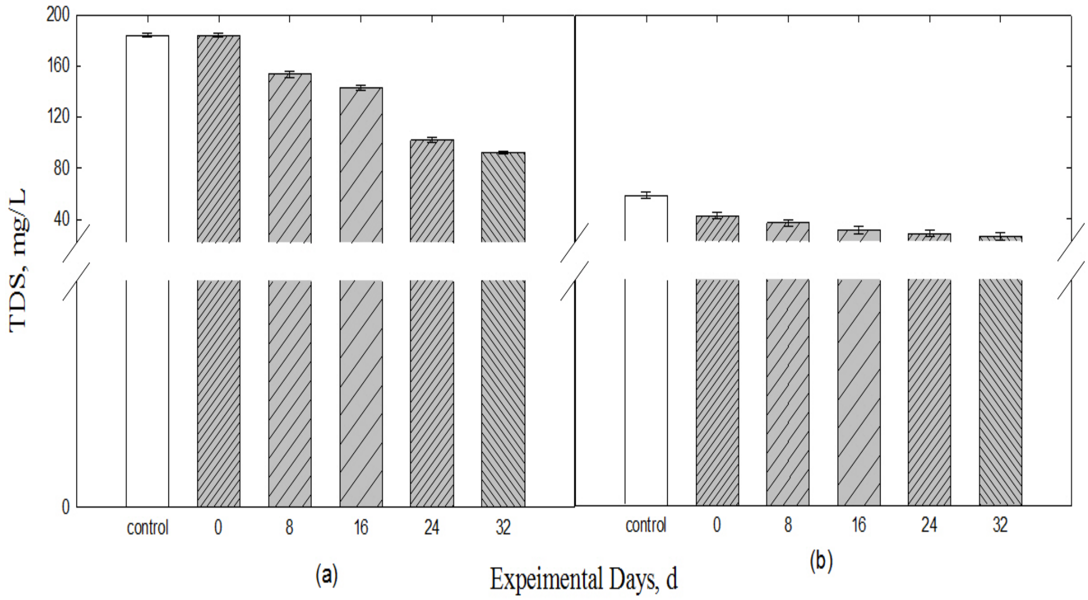

Fig. 4.12: Effect on TDS of water on the growth of water hyacinth in sewage wastewater collected from two different locations.

Effect on turbidity

Turbidity is shows the presence of the silica or mud particle of the soil by this compounds the water are showing like the milky color. Turbidity is not much more important for the wastewater because wastewater is flowing continuously so that the presence of the turbidity may increase this is depending on the types of the rocks by which the wastewater are flowing. Result indicated that the turbidity of the wastewater was decreased (Fig. 4.13) due to the settlement of the silica crystals because the water are in stationary conditions and some turbidity are settle on the organic matter which are present in the wastewater.

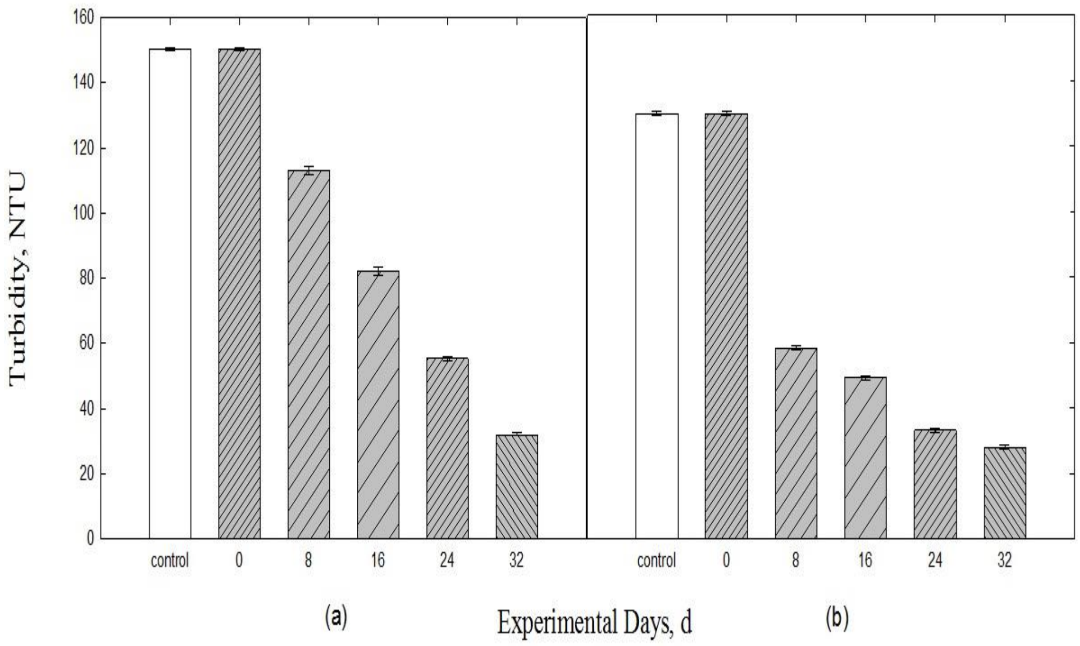

Fig. 4.13: Effect on turbidity of water on the growth of water hyacinth in sewage wastewater collected from two different locations.

Effect on salinity

Salinity indicated the presence of the soluble salts in the wastewater which are effecting the aquatic plant by alteration in growth and yields. In present experiment it was observed that there was no visible impact in between two different location of water in which L1 sewage water had high salinity while L2 sewage had very low salinity in comparison to L1.Figure 4.14 indicated that in L1 salinity was decreased very fast on increasing the time period while in L2 where was low salinity level increased on increasing the time periods.

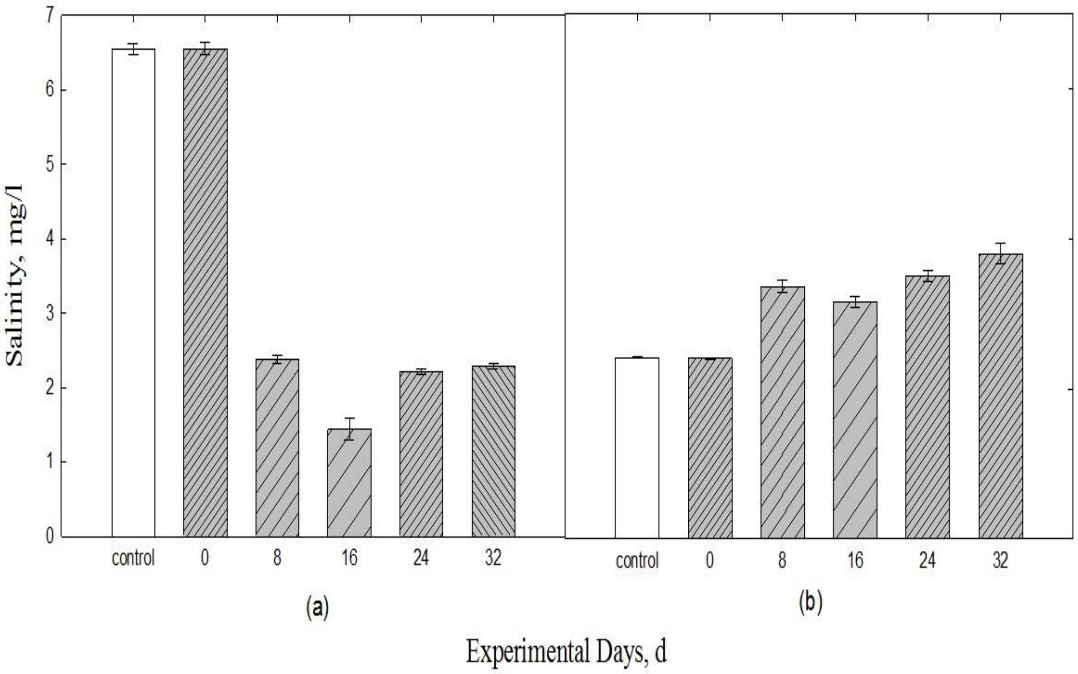

Fig. 4.14: Effect on turbidity of water on the growth of water hyacinth in sewage wastewater collected from two different locations.

Effect on cadmium concentration

Cadmium is the toxic metal which is very dangerous for the aquatic life in minimum concentration of the Cadmium will gives the maximum effect on the aquatic life as well as environment. Main target of present experiment to observed the removal of Cd from sewage waste water by absorption through water hyacinth. Result indicated that the concentration of the cadmium in wastewater was decreased and it was gradually decreases on increasing time periods (Fig. 4.15). Decreased in concentration of Cd in sewage waste water due to the bioaccumulation of Cd by the water hyacinth and the accumulation efficiency by the plants within the 16th days is approximately 58.4 % which is most efficient to removal of Cd naturally.

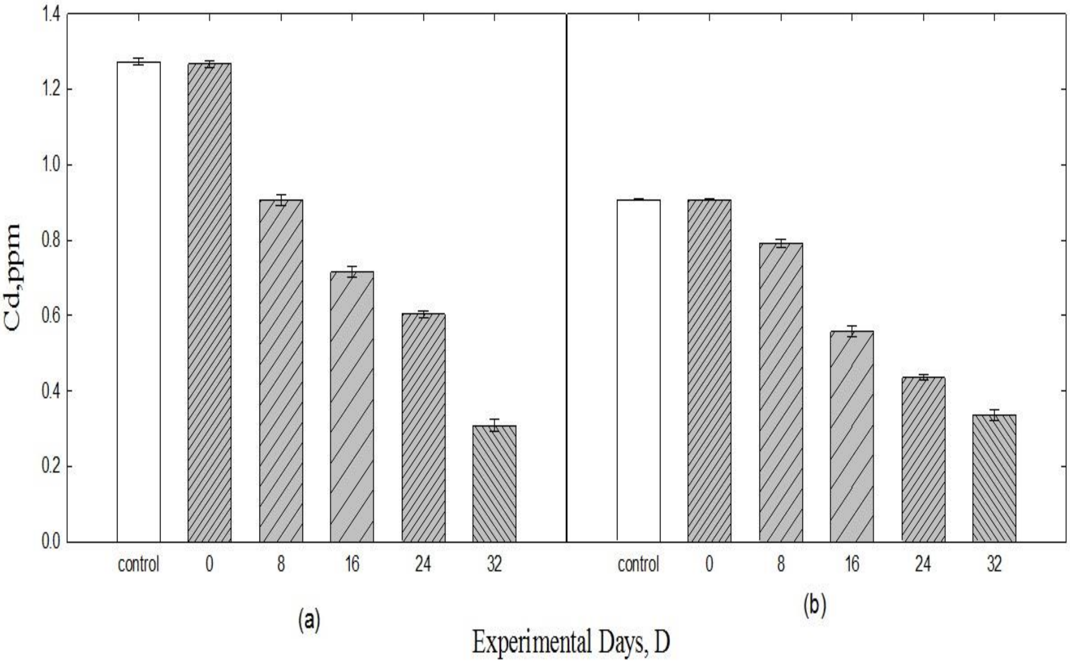

Fig. (4.15): Effect on concentration of cadmium due to growing water hyacinth in sewage wastewater collected from two different locations.

4.4 Adsorption of cadmium through activated carbon prepared from different plant parts of water hyacinth

4.4.1 Adsorption of Cd by activated carbon prepared by leaf of water hyacinth:

The adsorption efficiency of the activated carbon was studied on different condition like pH, dose of adsorbate, agitation speed and concentration of Cd. Activated carbon were prepared from different plant parts of water hyacinth which indicated that maximum activated carbon was developed from leaf (42.82%) and least in root (32.55%) which may be due to lignin or pectin and cellulosic deposition on the surface leaf and petiole that increases carbon content in these part(Table 1).

Effect of agitation speed: Different agitation speed was adjusted as 25, 30, 35, 40, 45, 50 and 55 rpm while other factors were constant. Result indicated that activated carbon developed from leaf showed best adsorption efficiency at 45 rpm which was 86.49 % removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Table 4.3 & Fig. 4.16).

Table 4.3: Effect of agitation speed on removal efficiency of Cd by activated carbon by leaf water hyacinth.

Agitation Speed (rpm)	Initial Concentration (ppm)	Final Concentration (ppm)	Removal Efficiency (%)
25	1.2769	0.9182	35.87
30	1.2769	0.8189	45.8
35	1.2769	0.6422	63.47
40	1.2769	0.4245	85.24
45	1.2769	0.412	86.49
50	1.2769	0.4621	81.48
55	1.2769	0.5173	75.96
60	1.2769	0.6221	65.48

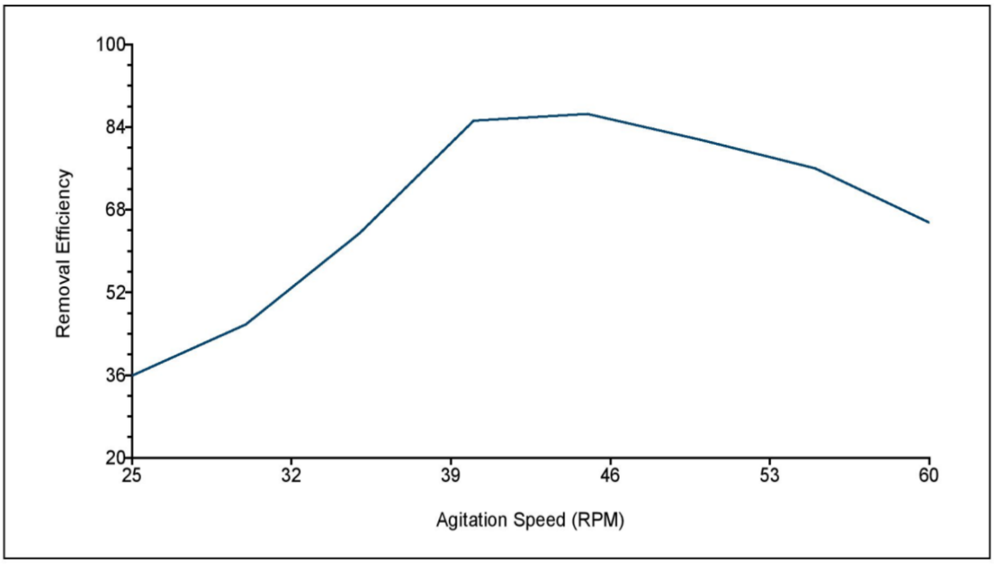

Fig. 4.16: Effect of agitation speed on removal efficiency of Cd by activated carbon by leaf water hyacinth.

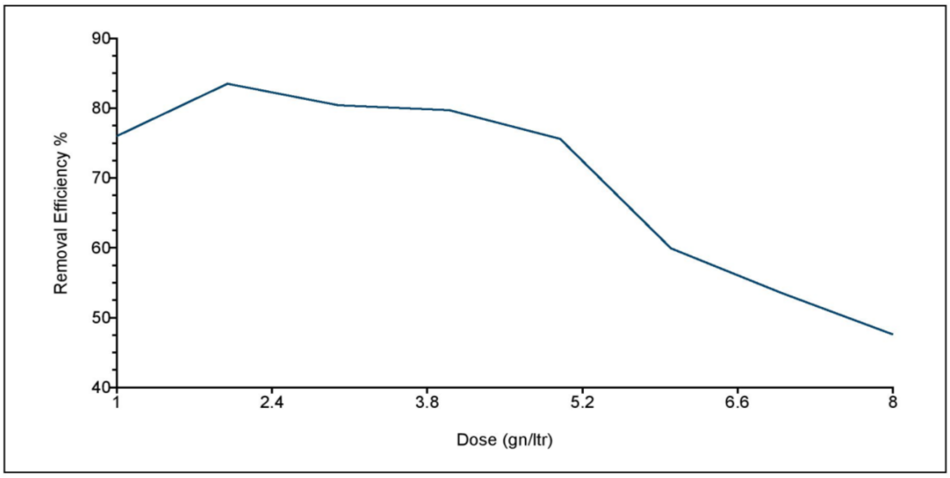

Fig. 4.17: Effect of dose of activated carbon on removal efficiency of Cd by activated carbon prepared from leaf of water hyacinth.

Effect of activated carbon dose: Variable dose of activated carbon was taken as 1, 2, 3, 4, 5, 6, 7 and 8 g/l while other factors were constant. Result indicated that activated carbon developed from leaf showed best adsorption efficiency at 2 g/l which was 83.49 % removal efficiency of Cd from sewage waste water while further increasing dose it was decreased (Table 4.4 & Fig. 4.18).

Table 4.4: Effect of dose of activated carbon on removal efficiency of Cd by activated carbon prepared from leaf of water hyacinth.

AC Dose (gm/L)	**Initial Concentration (ppm)**	**Final Concentration (ppm)**	**Removal Efficiency (%)**
1	1.2769	0.517	75.99
2	1.2769	0.442	83.49
3	1.2769	0.473	80.39
4	1.2769	0.48	79.69
5	1.2769	0.521	75.59
6	1.2769	0.678	59.89
7	1.2769	0.742	53.49
8	1.2769	0.801	47.59

Effect of contact time: Variable contact time was given as 180, 195, 210, 225, 240, 255, 270,285 and 300 minutes while other factors were constant. Result indicated that activated carbon developed from leaf showed best adsorption efficiency at 270 minute which was 86.68 % removal efficiency of Cd from sewage waste water while further increasing it was decreased (Table 4.5 & Fig. 4.19).

Table 4.5: Effect of contact time on removal efficiency of Cd by activated carbon prepared from leaf of water hyacinth

Contact Time (min)	Initial Concentration (ppm)	Final concentration (ppm)	Removal efficiency (%)
180	1.2769	0.5152	76.17
195	1.2769	0.4921	78.48
210	1.2769	0.4471	82.98
225	1.2769	0.4397	83.72
240	1.2769	0.4291	84.78
255	1.2769	0.4241	85.28
270	1.2769	0.4101	86.68
285	1.2769	0.4229	85.4
300	1.2769	0.4215	85.54

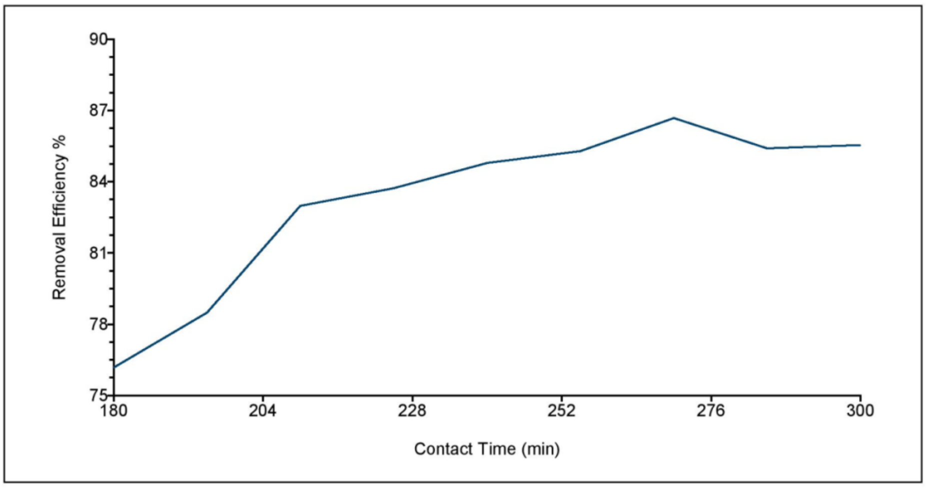

Fig. 4.18: Effect of contact time on removal efficiency of Cd by activated carbon prepared from leaf of water hyacinth.

Table 4.6: Effect of pH on removal efficiency of Cd by activated carbon prepared from leaf of water hyacinth.

pH	Initial Concentration (ppm)	Final Concentration (ppm)	Removal Efficiency (%)
1	1.2769	0.5211	75.58
2	1.2769	0.4941	78.28
3	1.2769	0.4312	84.57
4	1.2769	0.4001	87.68
5	1.2769	0.441	83.59
6	1.2769	0.4471	82.98
7	1.2769	0.4291	84.78
8	1.2769	0.4191	85.78

Effect of pH: Different pH was adjusted as 2, 3, 4, 5, 6, 7 and 8 while other factors were constant. Result indicated that activated carbon developed from leaf showed best adsorption efficiency at pH 4 which was 87.68% removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Table 4.6 & Fig. 4.20).

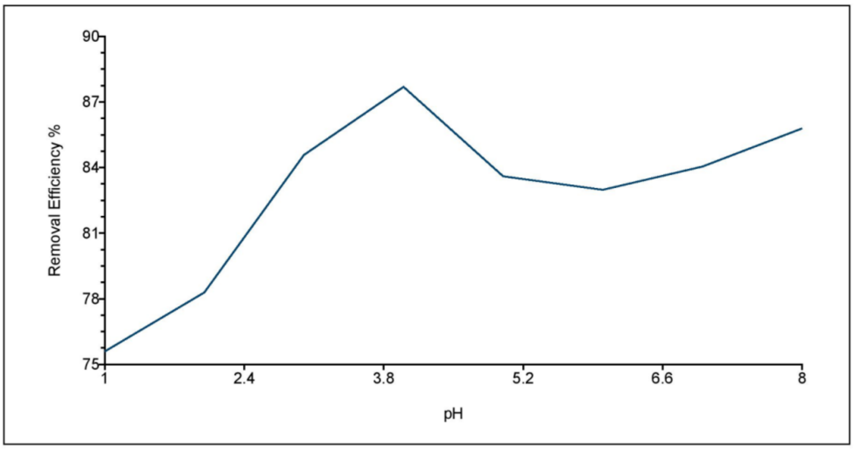

Fig. 4.19: Effect of pH on removal efficiency of Cd by activated carbon prepared from leaf of water hyacinth.

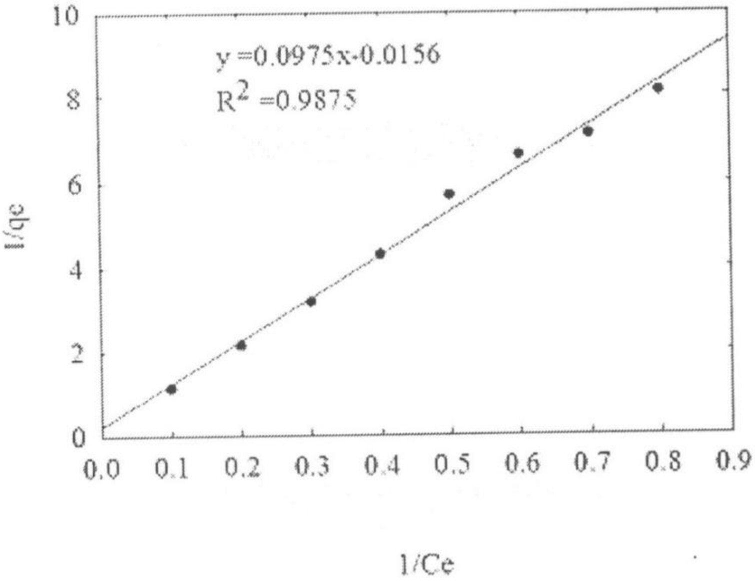

Fig. 4.11: Langmuir Isotherms of adsorption of Cd by activated carbon made by leaf

4.4.2 Adsorption of Cd by activated carbon prepared by root of water hyacinth:

Effect of agitation speed: Different agitation speed was adjusted as 25, 30, 35, 40, 45, 50 and 55 rpm while other factors were constant. Result indicated that activated carbon developed from root showed best adsorption efficiency at 45 rpm which was

85.59 % removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Fig. 4.21).

Table 4.7: Effect of dose of activated carbon on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

Agitation speed	Initial concentration (ppm)	Final concentration (ppm)	Removal Efficiency (%)
25	1.2769	0.9217	35.52
30	1.2769	0.8294	44.75
35	1.2769	0.6529	62.4
40	1.2769	0.435	84.19
45	1.2769	0.421	85.59
50	1.2769	0.4521	82.48
55	1.2769	0.5297	74.72
60	1.2769	0.6121	66.48

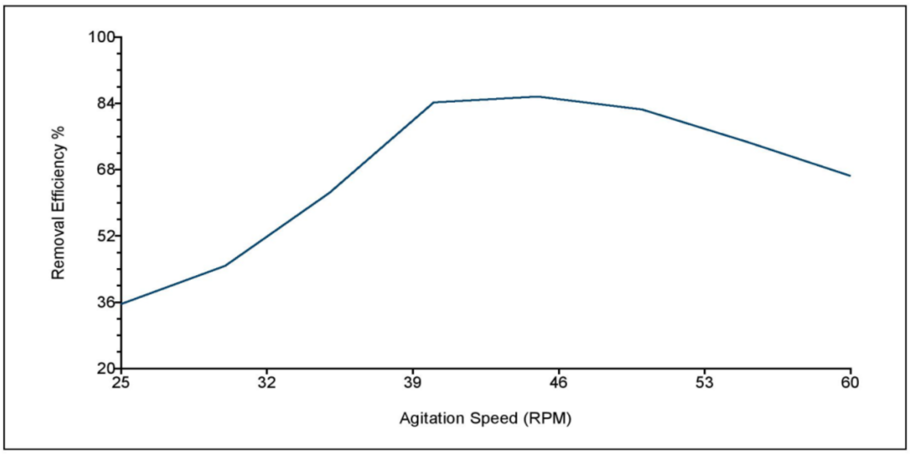

Fig. 4.21: Effect of Agitation Speed of activated carbon on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

Effect of activated carbon dose: Variable dose of activated carbon was taken as 1, 2, 3, 4, 5, 6, 7 and 8 g/l while other factors were constant. Result indicated that activated carbon developed from root showed best adsorption efficiency at 2 g/l which was 82.49 % removal efficiency of Cd from sewage waste water while further increasing dose it was decreased (Fig. 4.22).

Table 4.8: Effect of dose of activated carbon on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

Dose (g/L)	Initial Concentration (ppm)	Final Concentration (ppm)	Removal Efficiency (%)
1	1.2769	0.529	74.79
2	1.2769	0.452	82.49
3	1.2769	0.487	78.99
4	1.2769	0.492	78.49
5	1.2769	0.542	73.49
6	1.2769	0.697	57.99
7	1.2769	0.732	54.49
8	1.2769	0.827	44.99

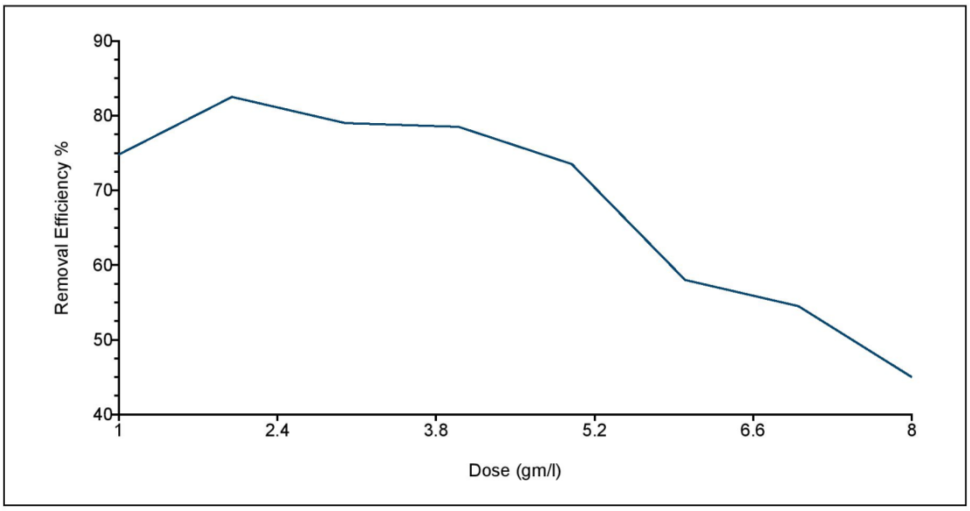

Fig. 4.22: Effect of dose of activated carbon on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

Effect of contact time: Variable contact time was given as 180, 195, 210, 225, 240, 255, 270,285 and 300 minutes while other factors were constant. Result indicated that activated carbon developed from root showed best adsorption efficiency at 270 minute which was 85.5 % removal efficiency of Cd from sewage waste water while further increasing it was decreased (Table 9 & Fig. 4.23).

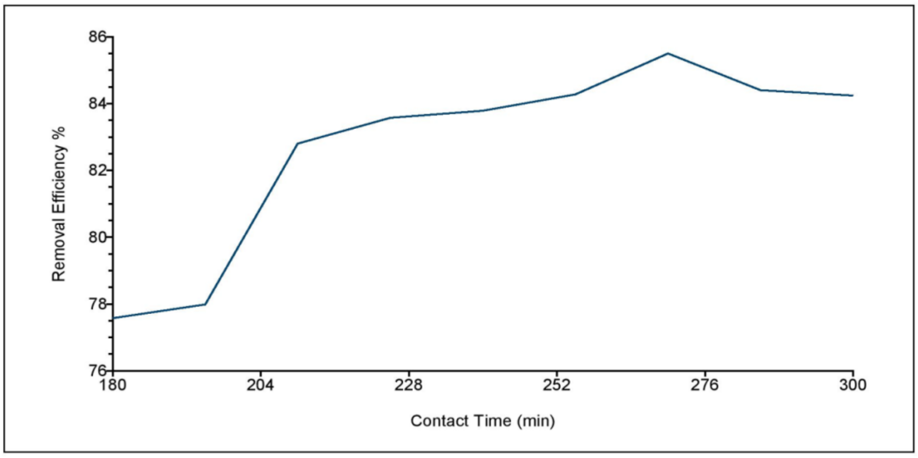

Fig. 4.23: Effect of contact time on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

Table 4.9: Effect of contact time on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

Contact time (minutes)	**Initial concentration (ppm)**	**Final Concentration (ppm)**	**Removal Efficiency (%)**
180	1.2769	0.5012	77.57
195	1.2769	0.4971	77.98
210	1.2769	0.4489	82.8
225	1.2769	0.4412	83.57
240	1.2769	0.4391	83.78
255	1.2769	0.4342	84.27
270	1.2769	0.4219	85.5
285	1.2769	0.4329	84.4
300	1.2769	0.4345	84.24

Effect of pH: Different pH was adjusted as 2, 3, 4, 5, 6, 7 and 8 while other factors were constant. Result indicated that activated carbon developed from root showed best adsorption efficiency at pH 4 which was 87.57 % removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Table 4.10 & Fig. 4.24).

Table 4.11: Effect of pH on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

pH	Initial concentration (ppm)	Final concentration (ppm)	Removal Efficiency (%)
1	1.2769	0.5214	75.55
2	1.2769	0.4971	77.98
3	1.2769	0.4329	84.4
4	1.2769	0.4012	87.57
5	1.2769	0.4421	83.48
6	1.2769	0.4481	82.88
7	1.2769	0.4311	84.58
8	1.2769	0.4292	84.77

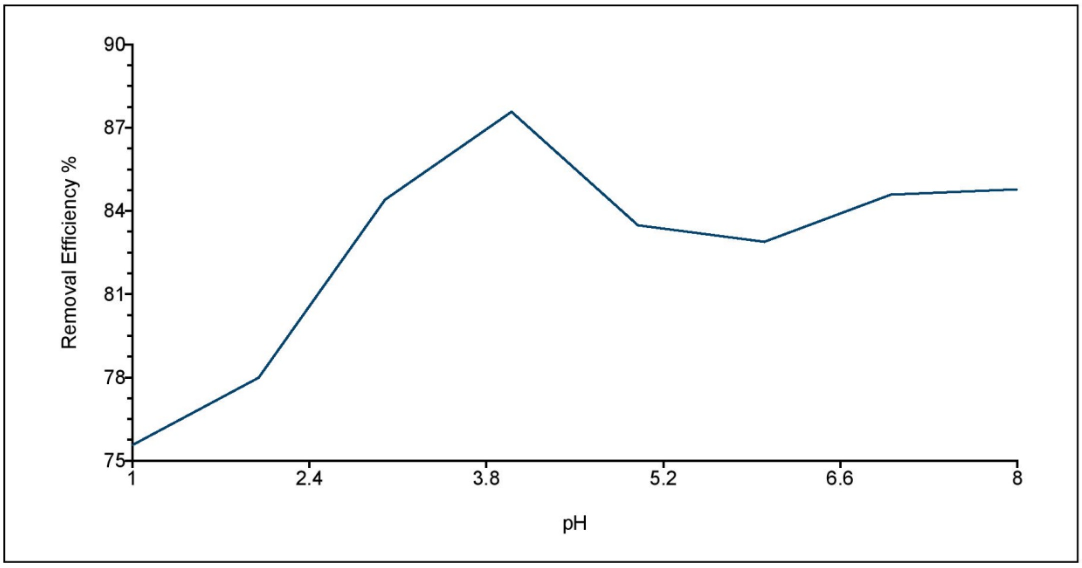

Fig. 4.24: Effect of pH on removal efficiency of Cd by activated carbon prepared from root of water hyacinth.

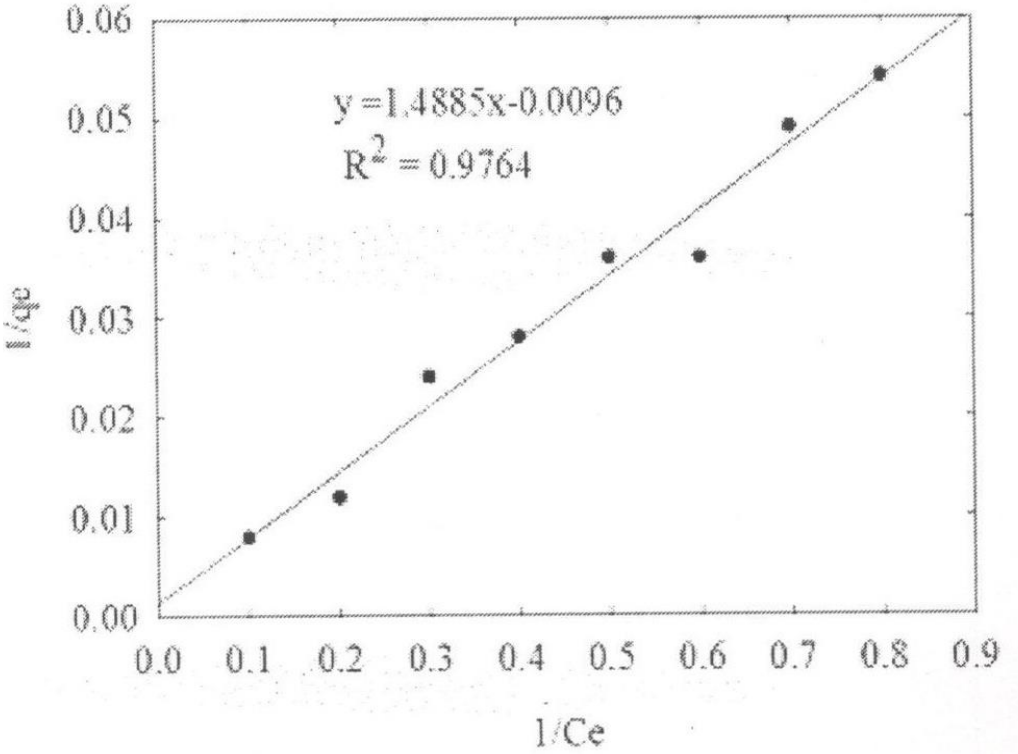

Fig. 4.25: Langmuir Isotherms of adsorption of Cd by activated carbon made by root

4.4.3 Adsorption of Cd by activated carbon prepared from petiole of water hyacinth:

Effect of agitation speed: Different agitation speed was adjusted as 25, 30, 35, 40, 45, 50 and 55 rpm while other factors were constant. Result indicated that activated carbon developed from petiole showed best adsorption efficiency at 45 rpm which was 88.27% removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Table 4.11 & Fig. 4.26).

Table 4.11: Effect of agitation speed on removal efficiency of Cd by activated carbon developed by petiole of water hyacinth.

Agitation Speed (rpm)	Initial Concentration (ppm)	Final concentration (ppm)	Removal Efficiency (%)
25	1.2769	0.9021	37.48
30	1.2769	0.8029	47.4
35	1.2769	0.6292	64.77
40	1.2769	0.4021	87.48
45	1.2769	0.3942	88.27
50	1.2769	0.4341	84.28
55	1.2769	0.5027	77.42
60	1.2769	0.6129	66.4

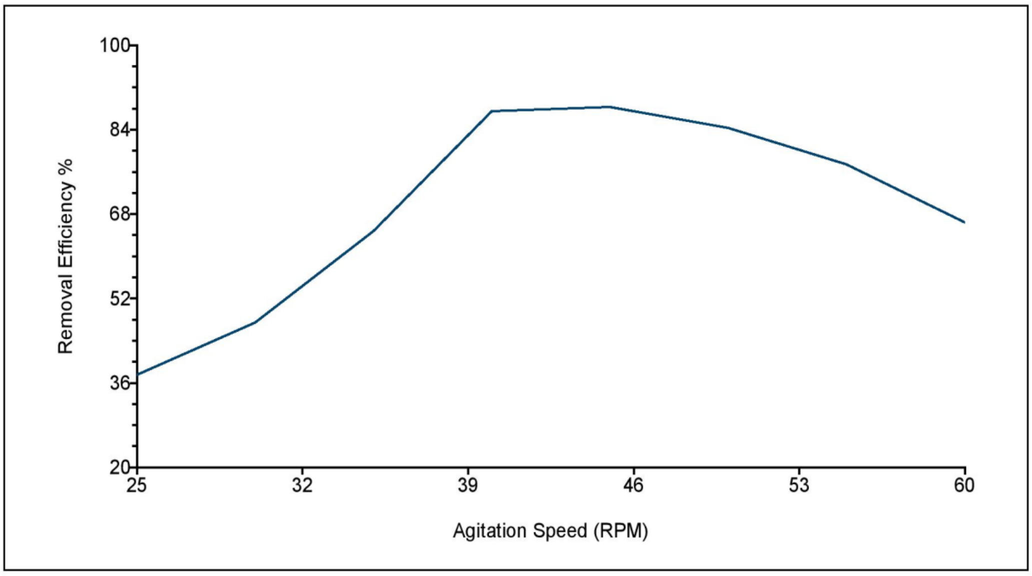

Fig. 4.26: Effect of agitation speed on removal efficiency of Cd by activated carbon developed by petiole of water hyacinth.

Effect of activated carbon dose : Variable dose of activated carbon was taken as 1, 2, 3, 4, 5, 6, 7 and 8 g/l while other factors were constant. Result indicated that activated carbon developed from petiole showed best adsorption efficiency at 2 g/l which was 83.59 % removal efficiency of Cd from sewage waste water while further increasing dose it was decreased (Fig. 4.27).

Table 4.12: Effect of dose of activated carbon on removal efficiency of Cd by activated carbon prepared from petiole of water hyacinth.

Dose (gm/L)	Initial Concentration (ppm)	Final Concentration (ppm)	Removal Efficiency (%)
1	1.2769	0.512	76.49
2	1.2769	0.441	83.59
3	1.2769	0.471	80.59
4	1.2769	0.482	79.49
5	1.2769	0.491	78.59
6	1.2769	0.531	74.59
7	1.2769	0.697	57.99
8	1.2769	0.721	55.59

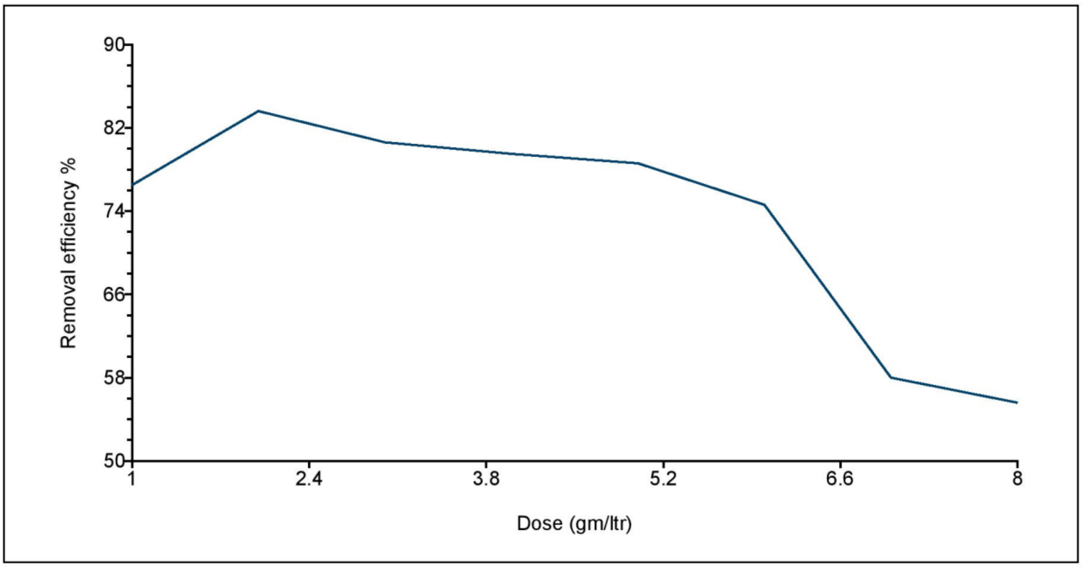

Fig. 4.27: Effect of dose of activated carbon on removal efficiency of Cd by activated carbon prepared from petiole of water hyacinth.

Effect of contact time: Variable contact time was given as 180, 195, 210, 225, 240, 255, 270, 285 and 300 minutes while other factors were constant. Result indicated that activated carbon developed from petiole showed best adsorption efficiency at 285 minute which was 87.68 % removal efficiency of Cd from sewage waste water while further increasing it was decreased (Table 4.13 & Fig. 4.28).

Table 4.13: Effect of contact time on removal efficiency of Cd by activated carbon prepared from petiole of water hyacinth.

Contact Time (min)	**Initial Concentration (ppm)**	**Final Concentration (ppm)**	**Removal Efficiency (%)**
180	1.2769	0.5237	75.32
195	1.2769	0.4821	79.48
210	1.2769	0.4471	82.98
225	1.2769	0.4397	83.72
240	1.2769	0.4297	84.72
255	1.2769	0.4129	86.4
270	1.2769	0.4147	86.22
285	1.2769	0.4001	87.68
300	1.2769	0.4121	86.48

Effect of pH: Different pH was adjusted as 2, 3, 4, 5, 6, 7 and 8 while other factors were constant. Result indicated that activated carbon developed from petiole showed best adsorption efficiency at pH 4 which was 87.66 % removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Fig. 4.29).

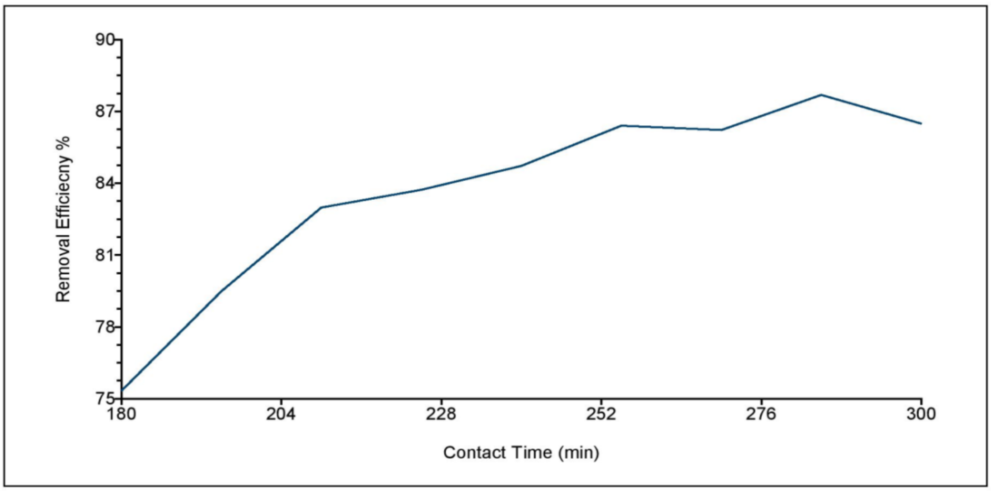

Fig. 4.28: Effect of contact time on removal efficiency of Cd by activated carbon prepared from petiole of water hyacinth.

Table 4.14: Effect of pH on removal efficiency of Cd by activated carbon prepared from petiole of water hyacinth.

pH	Initial Concentration (ppm)	Final Concentration (ppm)	Removal Efficiency (%)
1	1.2769	0.4921	78.48
2	1.2769	0.4841	79.28
3	1.2769	0.4291	84.78
4	1.2769	0.4001	87.68
5	1.2769	0.4321	84.48
6	1.2769	0.4497	82.72
7	1.2769	0.4392	83.77
8	1.2769	0.4921	78.48

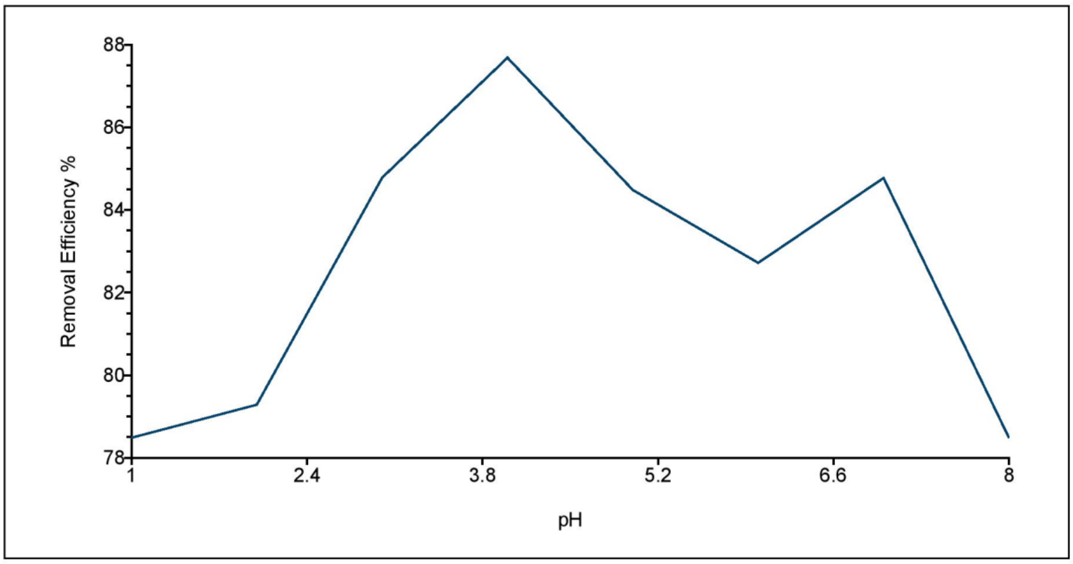

Fig. 4.29 : Effect of pH on removal efficiency of Cd by activated carbon prepared from petiole of water hyacinth

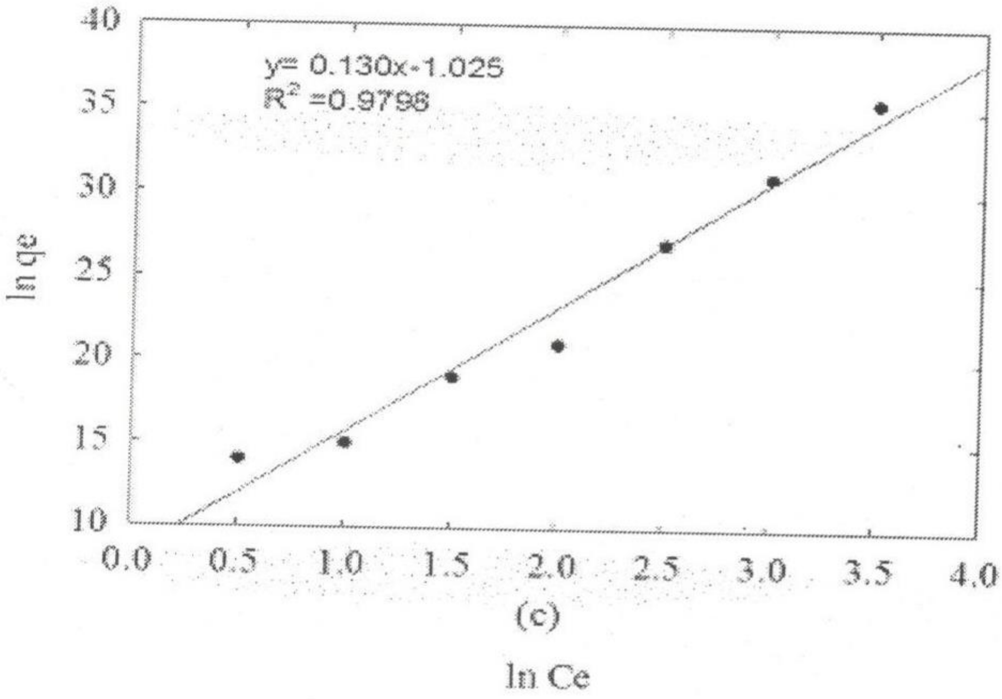

Fig. 4.30: Langmuir Isotherms of adsorption of Cd by activated carbon made by Petiole

4.5 Comparative study of adsorption of cadmium through activated carbon prepared from different plant parts of water hyacinth

Effect of agitation speed: Different agitation speed was adjusted as 25, 30, 35, 40, 45, 50 and 55 rpm while other factors were constant. Result indicated that activated carbon developed from root, petiole and leaf showed best adsorption efficiency at 45 rpm which was85.59,88.27, 86.49 % respectively removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Fig. 4.18).

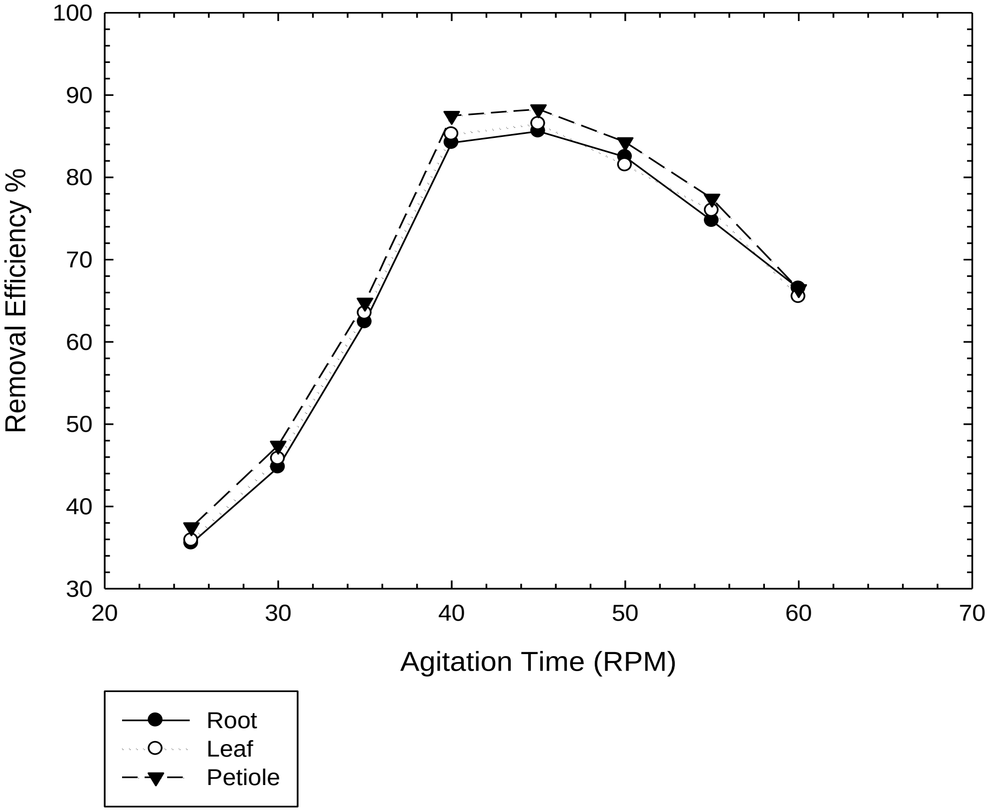

Fig. 4.31: Comparative effect of agitation on removal efficiency of Cd by activated carbon prepared from different plant parts of water hyacinth

Effect of activated carbon dose: Variable dose of activated carbon was taken as 1, 2, 3, 4, 5, 6, 7 and 8 g/l while other factors were constant. Result indicated that activated carbon developed from root, petiole and leaf showed best adsorption efficiency at 2 g/l which was 82.49, 83.59, 83.49 % respectively removal efficiency of Cd from sewage waste water while further increasing dose it was decreased (Fig. 4.19).

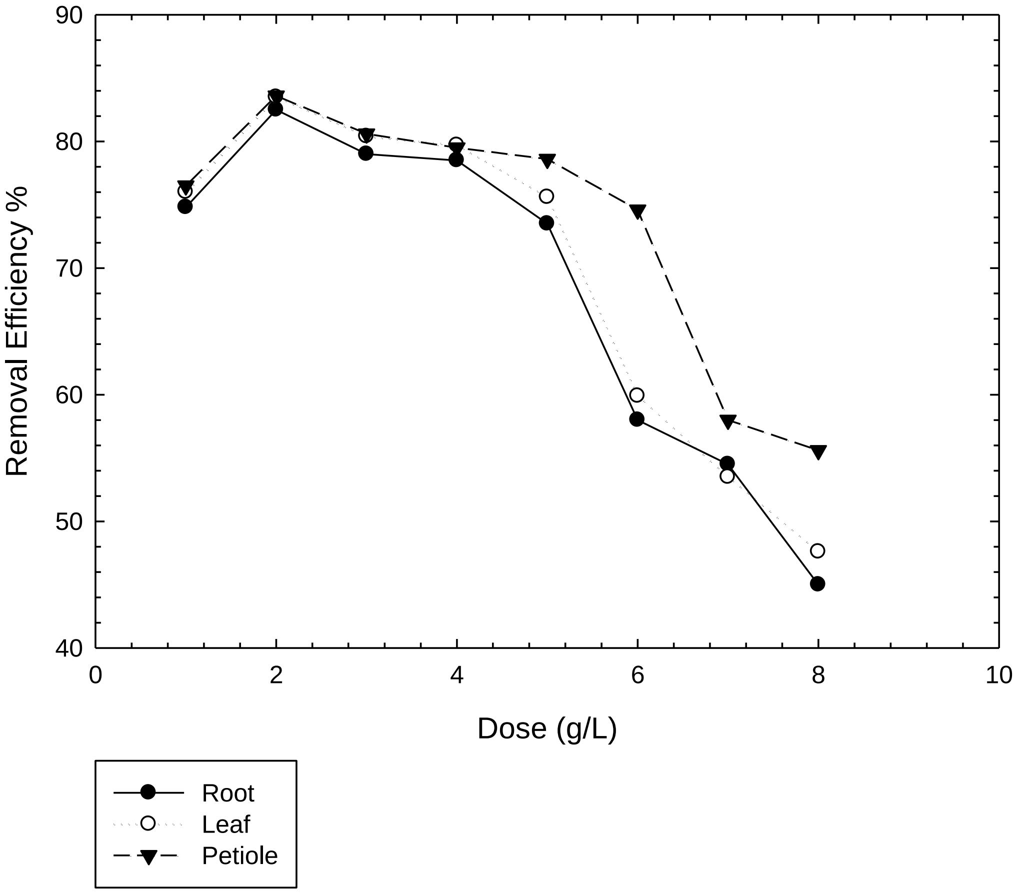

Fig. 4.32: Comparative effect of dose on removal efficiency of Cd by activated carbon prepared from different plant parts of water hyacinth

Effect of contact time: Variable contact time was given as 180, 195, 210, 225, 240, 255, 270,285 and 300 minutes while other factors were constant. Result indicated that activated carbon developed from root and leaf showed best adsorption efficiency at contact time 270 minutes85.5 and leaf 86.68% while in petiole at contact time 285 minuteshowed 87.68 % removal efficiency of Cd from sewage waste water while further increasing it was decreased (Fig. 4.20).

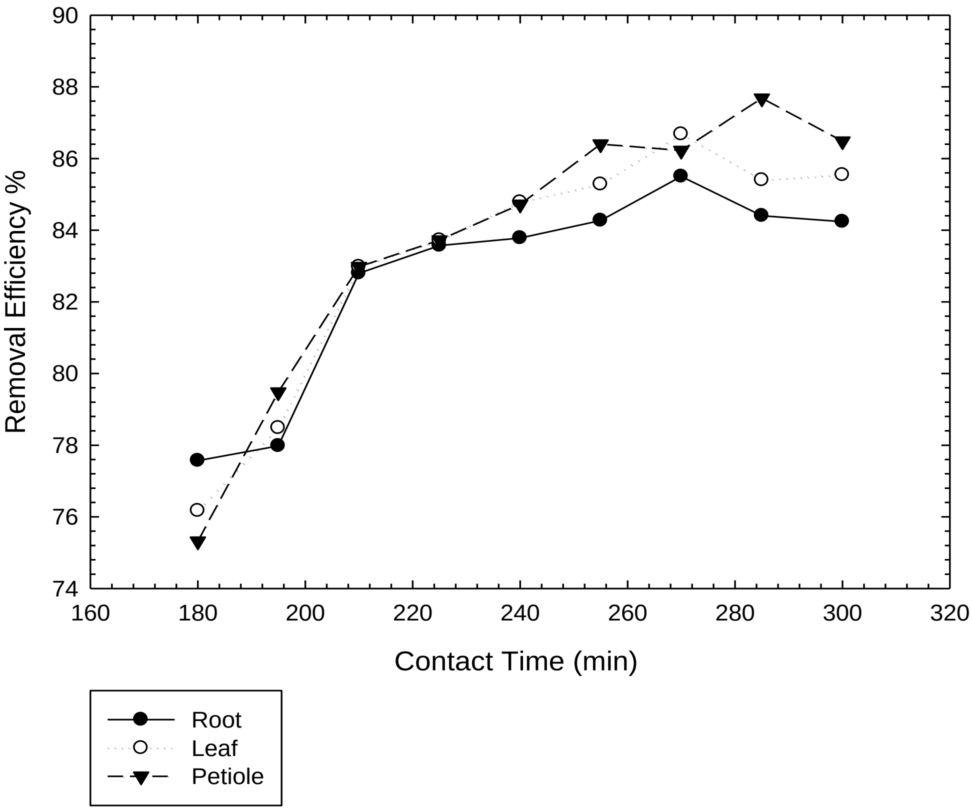

Fig. 4.33: Comparative effect of contact time on removal efficiency of Cd by activated carbon prepared from different plant parts of water hyacinth

Effect of pH: Different pH was adjusted as 2, 3, 4, 5, 6, 7 and 8 while other factors were constant. Result indicated that activated carbon developed from root, petiole and leaf showed best adsorption efficiency at pH 4 which was 87.57, 87.66 and 87.68 % respectively removal of Cd from sewage waste water while further increasing agitation speed it was decreases (Fig. 4.21).

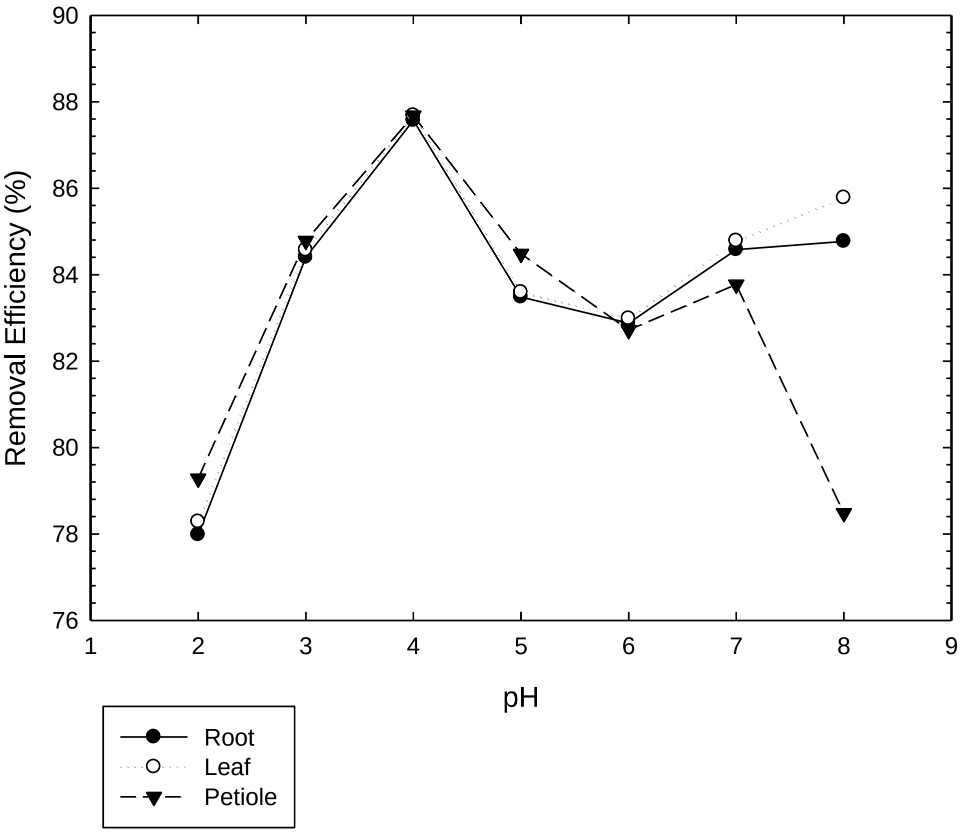

Fig. 4.34: Comparative effect of pH on removal efficiency of Cd by activated carbon prepared from different plant parts of water hyacinth

4.6 Comparative study of adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

In the batch adsorption study, experiment was conducted to determine the maximum adsorption efficiency of Iron & Iron Oxide Powder. The rate of adsorption is important for designing batch adsorption experiments; therefore, the effect of contact time on the adsorption of cadmium ions using Iron Oxide was investigated. The adsorption of Cd (II) ions increased considerably until the contact time reached 120 min. at room temperature. Further increase in contact time did not enhance the adsorption process; so, the optimum time was selected 120 min. for further

Table 4.15: Comparative study of effect of time on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

						Iron Oxide Powder		Iron Powder	
S. No.	Sample Description		Contact time (min.)	Agitation speed (rpm)	Dose (gm)	Final Concentr-ation (ppm)	Removal, %	Final Concentr-ation (ppm)	Removal, %
	Volume (ml)	Strength (ppm)							
1	0	0	0	0	0	0	0	0	
2	100	10	0.25	55	1	9.5566	4.434	9.2145	7.855
3	100	10	0.5	55	1	9.3764	6.236	9.1849	8.151
4	100	10	1	55	1	7.671	23.29	7.9942	20.058
5	100	10	1.5	55	1	7.1131	28.869	7.8833	21.167
6	100	10	2	55	1	6.4892	35.108	6.8718	31.282
7	100	10	3	55	1	6.3567	36.433	6.8543	31.457
8	100	10	5	55	1	6.2345	37.655	6.8049	31.951
9	100	10	10	55	1	6.2333	37.76	5.9157	40.843
10	100	10	15	55	1	6.2235	37.56	5.8831	41.169
11	100	10	20	55	1	6.2178	37.82	4.3698	56.302
12	100	10	30	55	1	5.1813	48.18	4.2589	57.411
13	100	10	45	55	1	5.0569	49.431	4.1015	58.985
14	100	10	60	55	1	3.5353	64.647	3.2255	67.74
15	100	10	90	55	1	3.4563	65.437	3.2187	67.81
16	100	10	120	55	1	2.8393	71.607	2.2144	77.856
17	100	10	180	55	1	2.8632	71.368	2.2111	77.889
18	100	10	240	55	1	2.8431	71.569	2.2011	77.989
19	100	10	300	55	1	2.8233	71.76	2.1952	78.048

Experiments. Kinetic experiments were carried out to assess the time needed for the adsorption process to attain equilibrium, the results of which have been shown in

Figs 4.22. It may be seen that the equilibrium is attained within 120 min. In all subsequent adsorption experiments, otherwise mentioned, 120 min. contact time was maintained.

Effect of retention time

The effect of retention times (from 0 min-280 min) on the cadmium ion removal, contact time was maintained for almost five houre to ensure that equilibriam was actualy achieved in study. The removal effcieny of the Cd(II) was increased sharpaly with respect to time and it constant or slite change after 120 min. there for the optimum removal efficicy of cdmium ion 72 and 76% with iron powder and iron oxide powder repectively at 120 min.

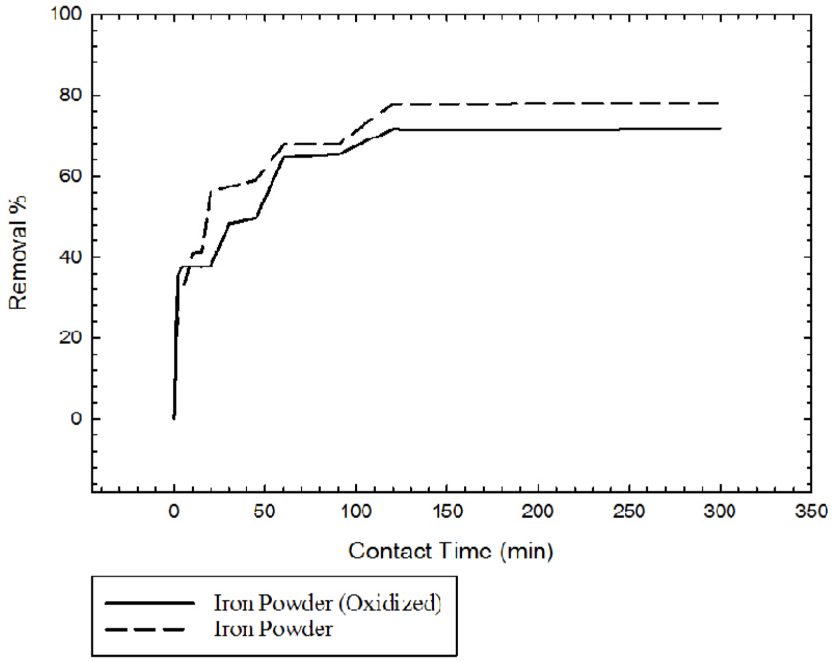

Fig. 4.35: Comparative study of effect of time on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

Effect of Adorbent dosage

Adsorbent play a critical role to affect the adsorption process, to achive the optimum adsorption efficiency, different amount of adsorbent dosesd on different batch experiments which were varrying from 1-10 gm per 100 ml of wastewater, the optimum dose of iron powder and iron powder oxidized is 75 & 83% respectively.

Table 4.16: Comparative study of effect of dose on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

						Iron Oxide Powder		**Iron Powder**	
S. No.	**Sample Description**		**Contact time (min.)**	**Agitation speed (rpm)**	**Dose (gm)**	**Final Concentrat-ion (ppm)**	**Removal %**	**Final Concentrat-ion (ppm)**	**Removal %**
	Volume (ml)	**Strength (ppm)**							
1	0	0	0	0	0	0	0	0	0
2	100	10	120	55	0.1	8.074	19.26	7.8526	18.65
3	100	10	120	55	0.2	6.8232	31.768	6.004	20.65
4	100	10	120	55	0.3	2.2377	44.56	3.5404	23.87
5	100	10	120	55	0.4	1.3694	60.67	3.3118	32.76
6	100	10	120	55	0.6	1.2978	70.67	2.8041	44.87
7	100	10	120	55	0.8	1.2601	87.39	2.7662	72.34
8	100	10	120	55	1	1.2256	87.74	2.6378	73.63
9	100	10	120	55	1.5	1.2241	87.76	2.5954	74.04
10	100	10	120	55	2	1.2233	87.82	2.4948	75.05
11	100	10	120	55	3	0.8178	91.82	2.1752	78.24
12	100	10	120	55	5	0.7142	92.58	2.0462	79.53
13	100	10	120	55	10	0.6125	93.38	2.0031	79.97

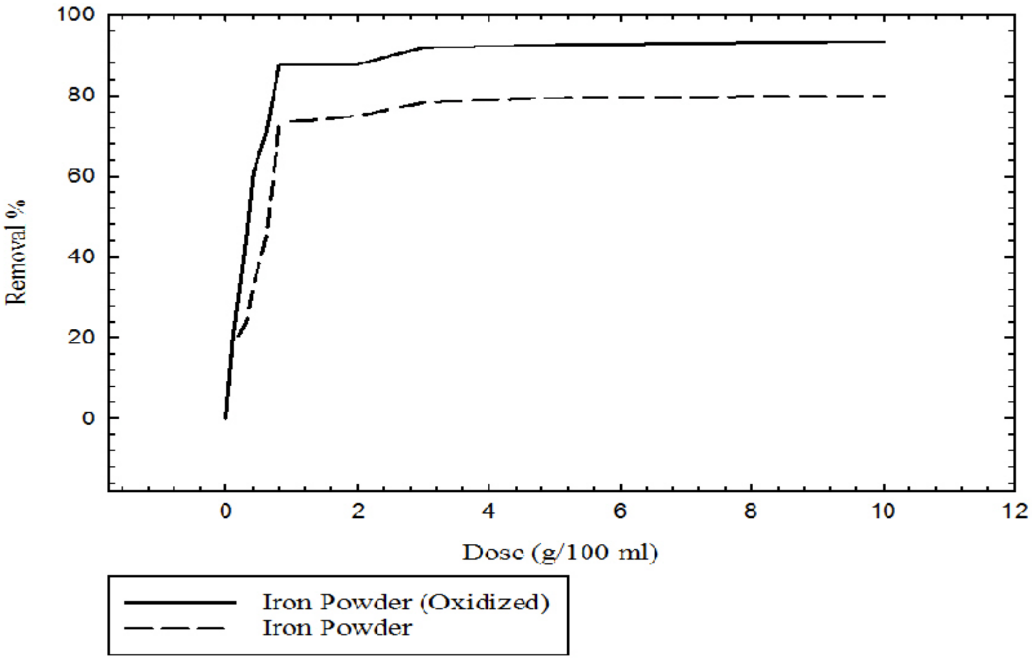

Fig. 4.36: Comparative study of effect of dose on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

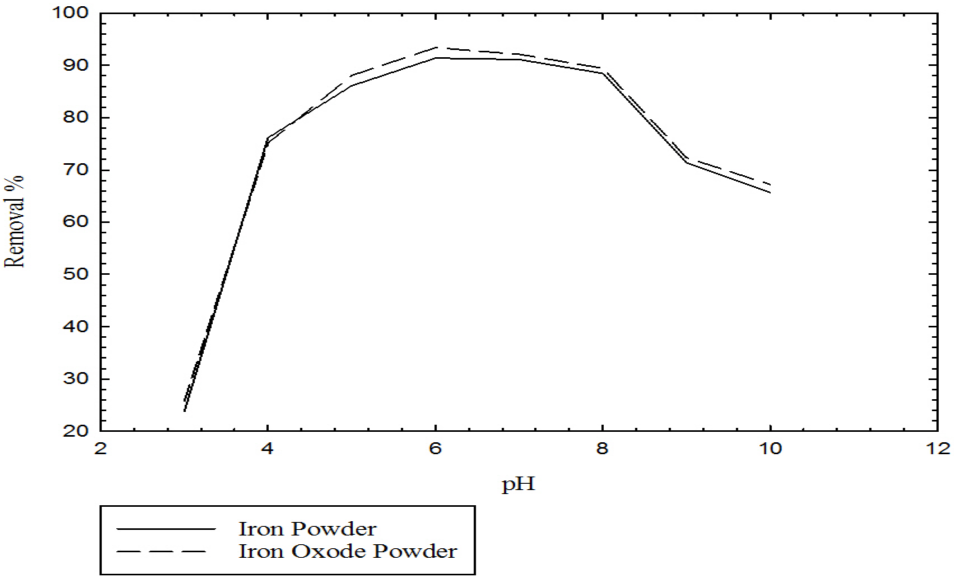

Fig. 4.37: Comparative study of effect of pH on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

Effect of pH for Cd(II) Removal

pH is one of the most important and influancing adsorption factor,which reflect the metal ion solubility in aqueous solutions. The intial pH concentration of solution affect the adsorption capacity of an adsorbent. The the maximum adsorption efficieny of iron powder and iron oxide power were 90 and 93 % respectively at 6 pH .

Table 4.17: Comparative study of effect of pH on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

S. No.	**Sample Description**					**Iron Oxide Powder**		**Iron Powder**	
	Volume (ml)	**Strength (ppm)**	**pH**	**Agitation speed (rpm)**	**Dose (gm)**	**Final Concentrat-ion (ppm)**	**Removal %**	**Final Concentrat-ion (ppm)**	**Removal %**
1	0	0	0	0	0	0	0	0	0
2	100	10	3	55	1	0.5712	12.88	0.7625	23.75
3	100	10	4	55	1	0.5438	81.87	0.7147	76.176
4	100	10	5	55	1	2.311	7.689	2.131	7.869
5	100	10	6	55	1	0.999	90.01	0.6862	91.425
6	100	10	7	55	1	1.002	89.98	0.8853	91.147
7	100	10	8	55	1	6.012	70.12	2.3029	88.485
8	100	10	9	55	1	3.733	62.67	2.862	71.388
9	100	10	10	55	1	3.214	68.76	3.098	69.02

Effect of intial concentration

As the concentration is increase of the metal ion the removal efficieny is increaseing at sudden concentartion and then decrease repiddely. This behavior can be explained due to limitation of active site on the adsorbent surface.

Table 4.18: Comparative study of effect of initial concentration on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

						Iron Oxide Powder		Iron Powder	
S. No.	**Sample Description**		**Contact time (min.)**	**Agitation speed (rpm)**	**Dose (gm)**	**Final Concentrat-ion (ppm)**	**Removal %**	**Final Concentrat-ion (ppm)**	**Removal %**
	Volume (ml)	**Strength (ppm)**							
1	0	0	0	0	0	0	0	0	0
2	100	10	120	55	1	0.5712	12.88	0.7625	23.75
3	100	3	120	55	1	0.5438	81.87	0.7147	76.176
4	100	5	120	55	1	1.3037	73.926	0.6945	86.11
5	100	8	120	55	1	2.1091	73.636	0.6862	91.425
6	100	10	120	55	1	1.1443	88.56	0.8853	91.147
7	100	20	120	55	1	5.9744	70.12	2.3029	88.485
8	100	50	120	55	1	18.664	62.67	14.3056	71.388

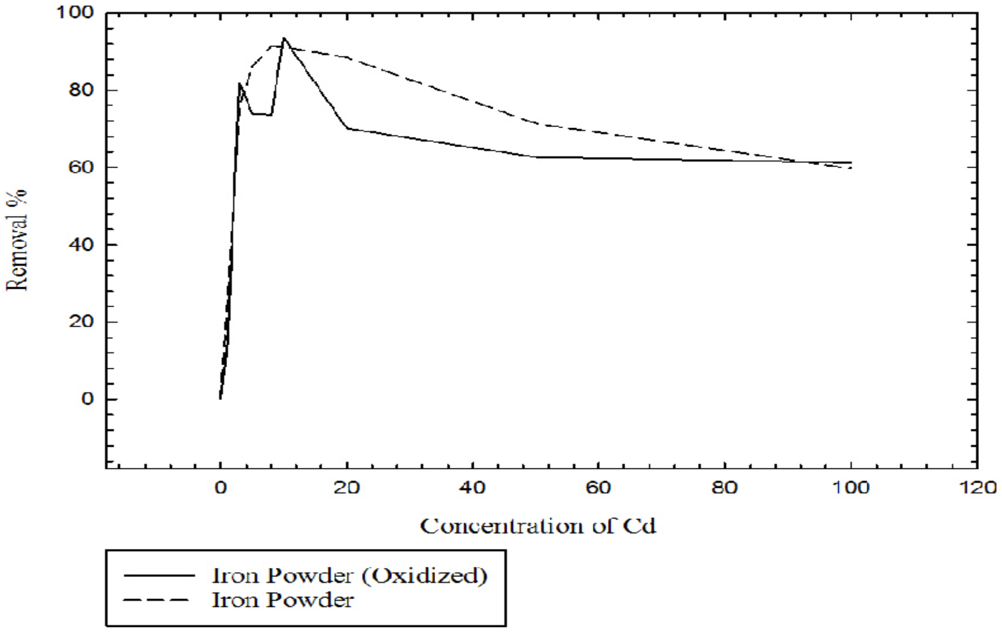

Fig. 4.38: Comparative study of effect of initial concentration on adsorption efficiency of Iron oxide and Iron powder for Cd from waste water

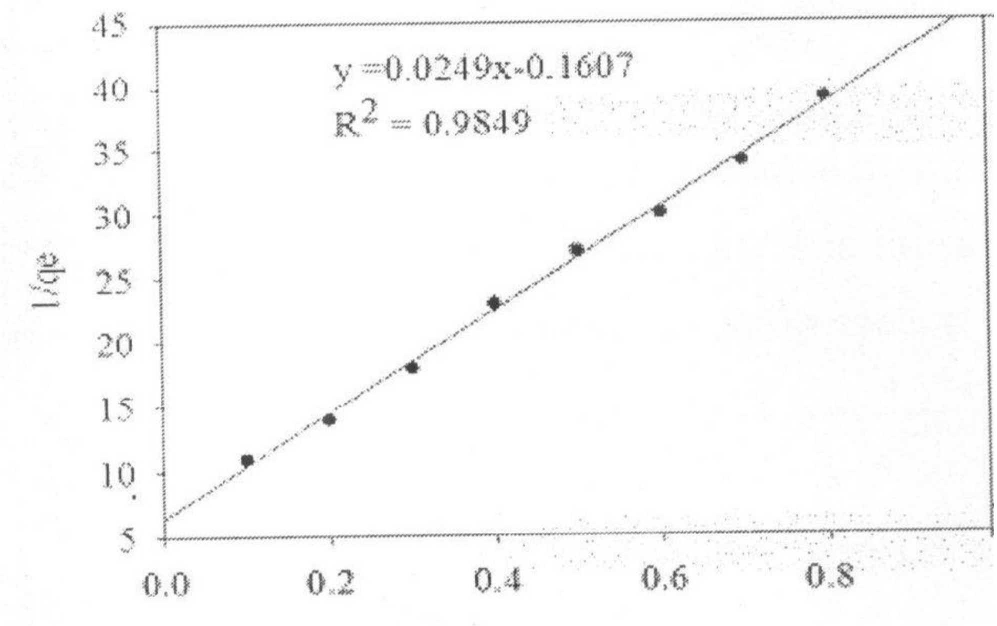

Fig. 4.39: Isothermas of Iron Oxide Powder

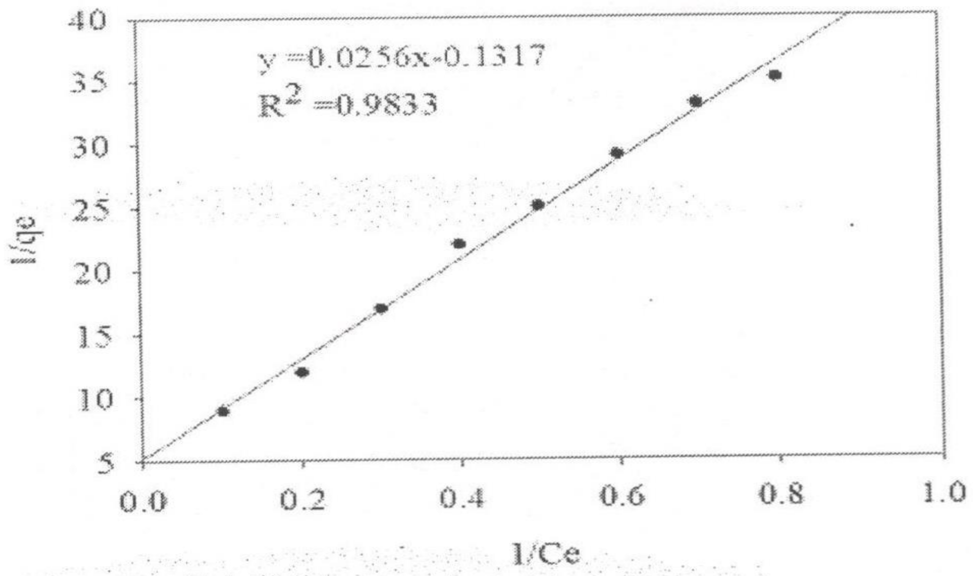

Fig. 4.40: Isothermas of Iron Powder

Chapter – 5

Chapter-5

Discussion

In present study, water hyacinth (*Eichhornia crassipes*) were used as bio-sorbet of cadmium from sewage waste water due to it has attracted significant attention as the world's worst invasive aquatic plant and extremely rapid proliferation and congest growth, presenting serious challenges in navigation, irrigation, and power generation. Attempts to control the weed have proved to be costly with minimum results. However, the same plant has demonstrated an amazing ability to absorb and concentrate many toxic metals from aquatic environments.Water hyacinth enhanced the removal of cadmium by accumulation in the tissues of plant parts. The aquatic plants cultured in such treatment system perform several functions, including assimilation and storing contaminates, transporting O_2 to root zone, and providing a substrate for microbial activity. The aquatic plants system offers an environment friendly and cost effective technology, which have been used for removing Cadmium, Iron and Copper from wastewater.

Water Hyacinth systems are differentiated from oxidation ponds in that they used aquatic macrophytes for treatment. The macrophytes used are usually floating varieties, but some systems have been observed with submerged varieties. The aquatic plants in a system may act in a similar capacity to the algae in an oxidation technique by transferring oxygen to the bacteria performing the degradation, or they may also provide removal of the contaminants of concern by up taking them into plant tissues. Treatment techniques which use vegetation are attractive to designers in part because the aquatic plants act as a natural nutrient sink. Some plants are capable of absorbing substantial amount of metals and some dissolved organics.

Present work indicated that due to water hyacinth different parameters of water were affected like pH, turbidity, TDS, salinity and concentration of cadmium. The pH of domestic waste water was decreased initially and it showed up to 7.40 at 16 days, time interval from 7.58 pH on growing water hyacinth but after some time interval pH of water start to increase and it increases up to 8.06 after 24 days of time interval. Thus it was concluded that the pH of wastewater was slightly going down due to the acidic reaction in the wastewater but after certain days the completion of the acidic reaction the fermentation of the organic matter was started so that the pH of the wastewater is going to increases in this experiments. TDS were also decreased after time interval which may be due to sedimentation in the bottom. Water hyacinth further can be used as sources of energy like biomass. It is also helpful to environment, ecological and very effective at low concentration of heavy metals.

Water hyacinth, among other aquatic macrophytes, has been shown to possess a great potential to remove pollutants when being used as a biological filtration system (Muramoto et al., 1991). It contains many polyfunctional metal-binding sites for both cationic and anionic metal complexes. Potential metal cation-binding sites of algal cell components include carboxyl, amine, imidazole, phosphate, sulphate, sulfhydryl, hydroxyl and chemical functional groups contained in cell proteins and sugars. The weed could remove several heavy metals and other pollutants. Recorded achievements triggered efforts directed towards the utilization of water hyacinth in phytoremediation.

Some of the treatment processes that have been used to remove heavy metals from wastewater include precipitation with coagulation and flocculation, ion exchange, complication of dry biomass and adsorption. However, there are limitations: Precipitation produces large quantities of heavy metals rich waste sludge; ion exchange and biomass methods are costly and cannot be readily applied to large scale applications. Adsorption as a process, employed due to its low cost and applicability on large scales. Adsorption is commonly being done using activated carbon, which adsorbs dissolved organic substances in the water treatment (Lodeiro *et al*., 2006). Although activated carbon has its advantageous, such as its effectiveness in removing colours and its applicability on wide variety of organic compounds, it has limitations that prevent it from treating highly soluble organics, and high concentrations or organic and inorganic compounds. In addition to these, cost of operation is high. Other adsorbents that have been used include synthetic polymers and silica-based substances. However, these materials are more costly compared to activated carbon. Hence, there is a perceived necessity and growing interest in finding adsorbents that are more cost-effective and produce fewer limitations including high temperatures and pressures. Therefore, finding suitable materials and operating conditions are essential to addressing the concerns of heavy metal pollution (Lodeiro *et al*., 2006).

Batch experiments verified that the plants are capable of decreasing all tested indicators for water quality to levels that permit the use of purified water for irrigation, which poses serious problems in various locations throughout the country. The removal efficiency of the Cadmium is 74.52%, in greater Noida's drain.

Activated carbon absorption process is also the best process of the removing the heavy metal from the wastewater. Bio-sorbent are the most efficient cost effective and environment friendly because of not enough use of aquatic plant we can use to make the activated carbon which are giving the absorption result. In this Experiment we have made the activated carbon from the different part of the water hyacinth like roots, petiole and leaf which are giving the best result for the absorption in all type of activated carbon the petiole gives the best result and then leaf. The removal of cadmium ion form Actgivated carbon made by different parts of water hycinth (Leaf, Roots and Petiole) by the these actvated carbon petiole are more efficient then leaf and roots0 and both are relevent ecofriendly and economical, the optimum removal charactersitics have been found for both the adsorbent which validate the Langmuir Isotherms, the adsorption of both adsobent reach equilibrium at 270 min at 4 pH and optimum dose is 2gram per 1000 ml wastewater.

Chapter – 6

Chapter-6

Summery and Conclusion

6.1. Summery

From the current study the conclusion of that work is removal of cadmium ion form wastewater by the iron oxide powder is more efficient then iron powder and both are relevent ecofriendly and economical, the optimum removal charactersitics have been found for both the adsorbent which validate the Langmuir Isotherms, the adsorption of both adsobent reach equilibrium at 120 min at 6 pH and optimum dose is 1gram per 100 ml wastewater. It could be used as a alternative adsorbent for the removal of cadmium ion.

6.2. Conclusion

The use of water hyacinth for metal biosorption was observed most suitable due to excellent removal capabilities of the biomass for several metals of environmental concern at low concentration. It is economic and environmental fisible. Factors, such as pH, temperature, adsorbent dose, etc significantly affect the biosorption capacities. On considering the invasive nature of the weed and environmental problems associated with its control, biosorption offers an attractive application of the plant. However, utilization of the biomass in industrial scale applications is still far from being realized. More investigation is still required on structural properties of the biosorbent, multi-metal studies, chanistic modeling, possible metal recovery, biosorbent modification and adaptation to continuous flow utilization. Water hyacinth can be used as bio mass after the bio accumulation of heavy metals. Water hyacinth further can be used as sources of energy like biomass. It is also helpful to environment, ecological and very effective at low concentration of heavy metals.

From the current study the conclusion of that work is removal of cadmium ion form Actgivated carbon made by different parts of water hycinth (Leaf, Roots and Petiole) by the these actvated carbon petiole are more efficient then leaf and roots0 and both are relevent ecofriendly and economical, the optimum removal charactersitics have been found for both the adsorbent which validate the Langmuir Isotherms, the adsorption of both adsobent reach equilibrium at 270 min at 4 pH and optimum dose is 2 gram per 1000 ml wastewater.

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List of Publication

1. Adsorption characteristics of Cadmium [Cd (II)] ION by Iron Powder and Oxidized Iron Powder (IJSRD- Vol-06 Issue-08, 2018 ISSN: (online :2321-0613)
2. Removal of Cadmium [Cd (II)] ion by Activated Carbon Prepared from Eichhornia Crassipes Mart (ACECM) (samriddhi, 2010-2017 S-JPSET : Vol. 9, Issue 2, ISSN : 2229-7111 (Print) & ISSN : 2454-5767 (Online)
3. Heavy Metal Removal from Domestic Wastewater Employing Live Eichhornia Crassipes. (samriddhi, 2010-2017 S-JPSET : Vol. 9, Issue 1, ISSN : 2229-7111)

List of International Conference

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