Chapter I: Biosorbents; A Literature Review

Chapter one deals with the available literature pertaining to the work on the efficient biosorbent in recent years. Increased anthropogenic activities have led to release of toxic substance in the environment. Which has resulted in deterioration of the natural environment. A major group of the toxic substances is heavy metals. Heavy metals are the metals which have density greater than 5 mg/cm^2. Toxic effects of these metals are hypertensions nephritis, renal dysfunction, gastrointestinal tract related diseases. Itai- itai disease caused by toxicity of cadmium and minimata caused by mercury toxicity are well documented. Heavy metals are non – biodegradable and are persistent in nature they gets accumulated in the biological systems.

Agricultural, industrial and natural causes are important factors in released of heavy Metals in the environment such as Metals Processing, lather tanning power stations, metal containing agrochemicals, paint industry, volcanic eruptions.

Due to toxic nature and other harmful effects, heavy metals require removal from the waste water. Methods available are chemical precipitation, ion-exchange, electro-chemical method, oxidation-reduction process, chemical coagulation, reverse osmosis, solvent extraction, adsorption by activated carbon and membrane process and ultra filtration.

These methods have drawback of either toxic sludge production or high cost or either toxic sludge production or high cost or chemical composition or technical constraints. so recent trend has been focused on newer methods like removal of heavy metal using biosorbents. Which has characteristic adsorbent properties. Biosorbents possess functional group like, carboxyl (COOH), Amide (NH_2), Thiol (SH), Phosphate

(PO_4^{3-}) and hydroxyl (OH) on the surface. There functional groups are involved in heavy metal binding.

Biosorbent are derived from various sources which include bacteria, fungi, algae, and different plant parts.

Important bacteria used as source of biosorbents are *Zoogloea ramigera*, *E. coli*, *Sphaerotilus natans*, *Bacillus subtilis*, *Enthrobactor agglomerans*, *Anthrobactor sp*., *Ralstonia sp*., *Pseudomonas*, *Aeruginousa*, *Nostoc calcicola*, *Micrococcus sp*., *Rizobium leguminosarum*, *Ochrobactrum intermedium*, *Cupriavidus metallidurans* etc. for the metal removal of Pb, Cr, Cu, Ni, Al, Ba, Zn, Co, Cd, Mg, Mn etc. For the bacteria biosorbents the optimum pH found was 5 to 7 and temperature 22-40^{0}C *Saccharomyces cerevisia*, *Fusarium floccifeum*, *Rhizopus arrhizus*, *Phanerochacte chrysosprium*, *Tametes versicolor*, *cunmighamella elegnas*, *Penicillum cyclopium*, *Schrizosaccharomyces pombe* are commonly used fungi as a source of biosorbents as reported in literature.

Sargassum, Asophyllum, Fucus, Laminaria, Undaria, durvillase, durvillaea, Oocystis, Chlorococcum, Hizikaia, Antiemorpha and Ludwigia are reported algae which are used as source of biosorbent research, Agricultural waste derived from Olivepomace, coconut fiber , source of seed, hempfiber, rapseed, waste etc. have been reported to be used as biosorbent. Biosorption of heavy metals depends on initial metal ion concentration, biosorbent dose, contact time, pH, temperature and presence of other metal ions. Biosorption is reported in terms of biosorption efficiency and biosorption capacity. Langmuir, Freundlich isotherm models have been applied to study biosorption of the metal. Kinetics of the biosorption has been investigated using pseudo- first order kinetics model or pseudo-second order kinetics model. Enormous research investigation is going on in the field of efficient and cost effective biosorbent development as day by day new research articles pertaining to the biosorbent are appearing in peer reviewed journals.

Chapter II: Preparation and Characterization of Adsorbents used

Chapter II deals with the collection, method of preparation, activation and characterization of the adsorbents derived from the agricultural wastes - Tea waste and Sugarcane bagasse. Tea waste is collected from the tea stalls while sugarcane bagasse is collected from fruit market in Lucknow, India. Collected materials were washed using distilled water, dried, powdered and sieved to make particles for increasing surface area. The material thus obtained was carbonized. Sugarcane bagasse biosorbent was activated by treatment with H_2SO_4.

Prepared biosorbents were characterized for their functional groups detection using Fourier Transform Infrared (FT-IR) Spectroscopy obtained from Indian Institute of Technology, Kanpur, Scanning Electron Microscopy (SEM) obtained from Birbal Sahani Institute of Palaeobotany (BSIP), Lucknow is used to investigate the surface area of the biosorbent. Brunauer-Emmett-Teller (BET); N_2 adsorption-desorption isotherm obtained from Babasaheb Bhimrao Ambedkar University (BBAU), Lucknow is used to investigate the pore size and surface area.

Chapter III: Optimization of conditions for removal of Copper(II) using sugarcane bagasse as an adsorbent

The chapter IIIrd presents optimization of conditions for removal of Copper(II) using sugarcane bagasse as an adsorbent. Sugarcane bagasse deals with alternative substitution of activated carbon for the removal of Cu(II) from aqueous solution. Different variable conditions such as pH, initial metal ion concentration, adsorbent dose, contact time and temperature were investigated to find out the adsorption capacity of adsorbent. SEM, FT-IR and BET analysis were used to characterized and analyse the adsorbent. The Biosorption data were obtained by experimental analysis using the Langmuir and Freundlich adsorption Isotherms. The results showed that the sugarcane bagasse can be utilized as a low-cost adsorbent for the removal of Cu(II) ions from its aqueous solution. The pseudo-second order model fitted well (with $R^2 > 0.99$) for the kinetic data. Activation energy for this adsorption process was evaluated using the Arrhenius theory model. From this study, we conclude that activated sugarcane bagasse powder merits further exploration in large-scale continuous systems to evaluate the practical applicability of its use in effluent treatment plants.

Chapter IV:Optimization of conditions for removal of Nickel (II) using sugarcane bagasse as an adsorbent

Chapter IVth Presents optimization of conditions for removal of Nickel (II) using sugarcane bagasse as an adsorbent deals with the study successfully demonstrated the application of sugarcane baggase powder as an adsorbent for the removal of Ni (II) ions from the synthetic waste water. pH 6.0 is found to be the optimum pH for maximum removal of the Ni(II) by the sugarcane bagasse biosorbent. Removal efficiencies increased with increase in adsorbent dose while metal removal capacities decreased. Endothermic nature of the adsorption process is evident from the increased removal at higher temperature. The Langmuir isotherm was demonstrated to provide the best fit for the equilibrium sorption data confirming a monolayer adsorption pattern. The pseudo-second order model fitted well (with $R^2 > 0.99$) for the kinetic data. In this chapter we conclude that activated sugarcane bagasse powder merits further exploration in large-scale continuous systems to evaluate the practical applicability of its use in effluent treatment plants.

Chapter V:Removal of Nickel(II) under optimized conditions using Tea Waste as an adsorbent

Chapter V^{th} present removal of Ni(II) under optimized conditions using Tea Waste as an adsorbent. The adsorbent was prepared from tea waste and it was used for the removal of Ni(II) ions from its aqueous solution. Different variable conditions such as pH, initial metal ion concentration, adsorbent dose, contact time, and temperature were include for find out the adsorption capacity of adsorbent. SEM, FTIR, and BET analysis were used to characterize the adsorbent. The data obtained from experiments were analyzed by using the Langmuir and Freundlich Isotherms. The experiment results showed that maximum removal of Nickel ion by tea waste at optimum condition (pH 6.0, 120 minutes of contact time, 2g/50ml of adsorbent dose and 50mg/L of initial metal ion concentration) is 85.28%. The experimental studies show that the tea waste would be useful as an adsorbent for the removal of heavy metal ions from contaminated industrial effluents due to easy availability and low – cost .