

## Application of biosorption as a pollution control treatment

\*V. Karthik<sup>1</sup>, K. Saravanan<sup>2</sup>, B.Suganya Devi<sup>3</sup>, P.D.Sharmilee<sup>3</sup>, A.Manimegalai<sup>3</sup>

<sup>1</sup> Department of Industrial Biotechnology, Government College of Technology, Coimbatore, 641 013, Tamil Nadu, India

<sup>2</sup> Department of Chemical Engineering, Kongu Engineering College, Perundurai, Erode 638 052, Tamilnadu, India

<sup>3</sup> Department of Environmental Engineering, Government College of Technology, Coimbatore, 641 013, Tamil Nadu, India

\*Corresponding author: E.Mail: karthikbt88@gmail.com

### ABSTRACT

The presence of heavy metals in water has become a menace nowadays, when its harmful physiological and biological effects are considered. Challenges lies in the development of suitable system for mitigation of heavy metal concentration in water, thereby increasing its potable value. This paper focuses on the study of the general principles behind the application of biosorption to remove the heavy metals present in water. Copper and Chromium have been considered as examples. Prospective biosorbent and their characterisation, effects of factors such as pH, biosorbent dosage, equilibrium time and initial metal concentration have been dealt, giving adequate importance.

**Keywords:** Biosorbent, mitigation, potability, concentration.

### INTRODUCTION

Pollution has been a perennial problem, ever since man began marching in the path of industrial revolution. Continued contamination of the three elements of earth- air, water and land- is a result of the so called developmental activities carried out by man. Water, which is the basic necessity for the existence of life on this planet, can be said to be the worst affected among the three elements. Heavy metal discharge is one of the major causes of water pollution. The adverse effects of the heavy metals, even in trace amounts are diverse and include immune system destruction, hindrance to the synthesis of certain vital bio-enzymes, cancer and nerve disorder especially in children (Deepti Pranay Samarth et. at., 2012). The two metals that are considered in this study are Chromium and Copper. Both these metals are largely employed in many industries ranging from dyeing, electroplating and electrical fields (S. Sugashini & K. M. Meera Sheriffa Begum, 2012). The presence of these metals, in trace amounts, tend to bio magnify when they enter into the food chain of living organisms. In the past, various methods were employed like chemical precipitation, reverse osmosis, evaporation and electrochemical treatment for the removal of heavy metals (Tomas Agustin Rearte et.al, 2013). Though these methods proved effective in the removal of metals, severe setbacks were perceived in the form of cost, maintenance and toxicity (B. Ashok Kumar et al, 2014). Biosorption is witnessed as a redeemer in the field of environmental engineering owing to the simplicity in operation, readily available materials and increased elimination percentage of toxic metals. In this review, an attempt has been made to look into the different materials that can be used as a sorbent and a general gestalt of the process has been offered.

### MATERIALS AND METHODS

**Living organisms as adsorbents for Chromium:** Certain types of algae, bacteria and fungi act as operational adsorbents and their efficacy in removal of toxic metal ions have been put forth in numerous works across the world. A typical biosorbent must prove its compatibility to the environment in various cadres like simplicity in refinement, ability to withstand exterior stress factors, spore producing aptitude etc. (Deepti Pranay Samarth et. at., 2012). Fungal biomass, with its filamentous morphology and higher cell wall percentage, is a highly suited way to tackle heavy metal pollution. A detailed study on fungi *Aspergillusoryzae* isolated from tannery discharge for its sorption abilities indicate a good 96% removal of hexavalent Cr (Reya Isaac et. al., 2012). Scarcity of literature on the usage of white rot fungi motivated Muhammad Asif Hanif et.al, (2011), to study the adsorption capacity by engaging three species namely *Pleurotus sajor-caju*, *Agaricus bitorquis* and *Ganoderma lucidum*. Several fungi species under *Penicillium* sp are also considered as useful biosorbents (Jeevitha M and Judia Harriet Sumathy. V 2012). Another abundant resource comes in the form of algal biomass. Brown marine algae *Sargassum* sp (Mehdi Farzadkia et. al 2012), *Porphyra umbilicalis* red algae and *Fucus vesiculosus* brown-green alga (Ioana- Raluca et.al. 2010) are few examples. A revolutionary measure by entrenching algae in steady and permeable silica milieu was demonstrated by Ulrich Soltmann et. al, (2009). Bacteria like *Bacillus licheniformis* have properties such as increased concentration of teichoic and teichouronic acid, which make them ideal in biosorption studies (Deepti Pranay Samarth et. at., 2012).

**Non-living materials as adsorbents for Chromium:** Use of living biomass as adsorbents poses certain difficulties in the form of toxicity produced by the organisms, periodic supply of nutrients and increased cost for maintenance. Hence non living or dead plant biomass presents a unique way to overcome all the before mentioned contingencies.

Tomas Agustin Rearte et.al,(2013) explored the use of *Schoenoplectuscalifornicus*, an aquatic plant for the deduction of heavy metals, Pb(II) and Cr(III). Peat is a light brown to very dark organic compound that has admirable metal binding properties due to the existence of powerful metal binding ligands viz, humic acid and fulvic acid (A. Robalds et.al. 2011). The use of calcined brick powder as a possible sorbent was investigated by Hemalatha P. V and PrasadaRao P. V. V (2012). The nuts and leaves of *Eugenia jambolana* are said to have significant toxic metal ion extracting potential (RabiaRehman et.al. 2014). Another innovative effort in the current scenario of biosorption was elucidated by M. JamshaidIqbal et.al, (2012), where the filtrate of *Rosa damascena* was used as the phytomass. *Eriobotrya japonica* also belonging to the group *Rosaceae* had been included as a prospective sorbent (M. M. Abuein and A. M. Belazi, 2009). It is interesting to note that brown seaweeds, a marine macro-algae, have carboxyl and sulphate groups in their chemical composition, that enable them to act as adsorbents ( Seung- Hoon Lee and Chang-Ho park, 2012). The roots of *Tephrosiapurpurea*(B. Ashok Kumar et.al. 2014), pig bristles, poultry feathers and crustacean shells (Fernando I. Ramirez- Paredes et.al. 2013) are also being in use around the scientific world as adsorbents, owing to its profusion and ease. A revision done by utilizing rice husk as a antecedent for carbonization, with its exterior tailored by chitosan and cross linking agents, furthermore demonstrates the usage of residue as a latent adsorbent (S. Sugashini and K. M. MeeraSheriffa Begum, 2012).

**Living organisms as adsorbents for Copper:** Various species of microorganismssuch as algae, fungi, bacteria are used as biosorbents to remove a range of heavy metals depending on the characteristics of the microorganism opted. The biosorption behavior of biocomponent depends on the composition of binding surface (Ulrich soltmann et. al, 2010). Fungi are a versatile group capable of adapting and growing in various extreme conditions such as pH, temperature, nutrient availability as well as high metal concentration, *Trichoderma*, one such species is used as adsorbent in removing copper, a heavy metal(ShafiquzzamanSiddique et al.,2013). *Bacilluslicheniformis* is recurrently used in waste water treatment due to the production of extracellular enzymes, mainly protease, lipase and the high proportion of teichoic and teichouronic acid in the cell wall responsible for 60%metal binding (Deepti Pranay Samarth et al., 2012) .Two strains of green microalgae *C.Rinhardtii*, *C.Pyrenoidosa* were also found to be useful in adsorbing different heavy metals (Zhao Yanchuang et. al, 2013).

**Non-living materials as adsorbents for Copper:** Coconut shell, an abundant agricultural product is used as biosorbent for its low-cost and heavy metal removal efficiency (Mike. A.Acheampong et al., 2013).Agriculture waste such as peel of *Citrus sinensis*, Rice straw and Wood saw dust , a byproduct of world industry is chosen as adsorbent not only for its cellulose, lignin content which are capable of binding metal cations due to the presence hydroxyl, carboxylic and phenolic group but also due to their relatively high fixed carbon content and the presence of porous structure(Salwa A.Ahmed 2011,Saman Khan et al., 2013 and AchanaiBuasri et al., 2012).Carboxylic acid functionalised deacetylatedkonjacglucomannan(CADKG)being a weak acid cation showed relatively high adsorption capacity for the removal of copper ion (XugangLuo., et al 2011).*Peat*, an organic material is found to have naturally high sorbing capacity, relatively robust and its ability to be used in batch wise and dynamic regime.(A.Robalds et al., 2011).Naturally and abundantly available leaves of *Punicagranatum* and *Polyalthialongifolia*leaf powder were also found to have good sorption properties(PeymanSalehi et al., 2010).Powdered mycelium of *fusariumflocciferum* is used as adsorbent for its important properties which includes low nutritional requirements, simple biomass separation from growth liquid medium andoptimization of particle size (A.Delgado et al., 1998). Paper mill sludge is opted for its easy access and cost effective chattels (Suryan S et al., 2012). Silica gel immobilized microalgae formed by combining dried algae along with silica sols are also used as biosorbent adopting sol-gel technology has the advantages such as low cost and the presence of wide range of functional groups(Ulrich Soltmann et al.,2010,R.Ramsenthil et al.,2010).

**Characterization of materials:** The main goals behind the categorization of substances in biosorption studies are to determine the surface properties of the adsorbent, concentration of the heavy metal ion in the solution before and after adsorption, the surface of the adsorbent after adsorption etc. (Muhammad AsifHanif et. al., 2011, Mehdi Farzadkia et. al., 2012). There are various systems and instruments available for this purpose. The type of analysis methodology adopted varies for different adsorbents. Atomic Absorption Spectroscopy, Flame Emission Spectroscopy and Fourier Transform Infrared Spectroscopy are few of the devices. Environmental Scanning Electron Microscopy (ESEM) is used to observe the exterior of the biomass and filters (Tomas Agustin Rearte et.al, 2013). The biosorption experiments may bring about certain changes in the adsorbent surface, which can successfully studied by Scanning Electron Microscopy (SEM) (Reya Isaac et. al., 2012). M. M. Abuein and A. M. Belazi, (2009) incorporated FTIR to assess the functional groups that were responsible for the adsorption of heavy metals, Cr (VI) and Hg (III). RabiaRehmanet. al., (2014) used the FT- IR spectrum to record the resulting vibrational frequencies groups present in the adsorbent.Scanning Electron Microscopy was incorporated to stumble on the surface

morphology (Salwa .A.Ahmed, XuegangLuo et. al, 2011). An overall review of the materials is presented in table 1 (A) and 1 (B).

**Biosorption experiment:** The experimental part in any biosorption study includes the assessment of the adsorbent to take on the metal ion (B. Ashok Kumar et. al., 2014). It is also conducted to bring out the effects of various factors such as pH, temperature, equilibrium time, initial metal concentration, biosorbents dosage etc. (S. Sugashini and K. M. MeeraSheriffa Begum, 2012 and Tomas Agustin Rearte et.al, 2013). The amount of remaining metal ion in the system is calculated by separating the supernatant from the biosorbent and subjecting it to any of the characterization methods elucidated above (Reya Isaac et. al., 2012). Precautions must be taken to carry out the tests in a controlled manner so as to ensure best results. The amount of metal adsorbed in  $\mu\text{mol g}^{-1}$  and the removal efficiency in % can be expressed by the following formula:

$$q_t = [(C_o - C_t)V] / m$$

$$R (\%) = [(C_o - C_e)/C_o] \times 100$$

$C_o$  – Initial metal concentration ( $\mu\text{mol/L}$ )  
 $C_t$  – Concentration at time t ( $\mu\text{mol/L}$ )  
 $C_e$  – Final metal concentration ( $\mu\text{mol/L}$ )  
 $V$  – Volume of the solution (L)

## INFERENCES AND OBSERVATIONS

**Effect of pH:** The negative logarithm of the concentration of hydrogen ions in a solution is defined as pH of that particular solution. Authors have noted that pH is the one of the most important factors that is to be properly maintained for effective biosorption (Tomas Agustin Rearte et.al, 2013). It is generally observed that the adsorption of the chromium ions is considerably higher at lower pH values. A possible reason for this behaviour is due to the fact that the surface of the adsorbent contains positively charged functional groups that attract the oxyanions of chromium. At higher pH values, the functional groups tend to be negative thereby repelling the metal ions (S. Sugashini and K. M. MeeraSheriffa Begum, 2012). pH values in the range of 2-5 are preferable, beyond which insoluble metal hydroxides come out as precipitate (Muhammad AsifHanif et.al, 2011). For Copper, effective biosorption of the heavy metal ion was found to be at a pH of 2.5 (Deepti Pranay Samarth et al., 2012). The maximum removal of copper ion took place at pH of 4.5 which inferred that the biosorption affinities took place in a slightly acidic medium and increases between 2 and 6.5 (Suryan S. et. al, 2012 and Saman Khan et. al, 2013). The reason is that, with increase in pH, the negative charge density on the biosorbent rises that results in attraction between these negative charges and metal ions, thus making biosorption more effective (PeymanSalehi et al, 2010).

**Effect of Equilibrium time:** According to B Ashok Kumar et. al, (2014), the equilibrium time is the time involved in the attainment of saturation, after which the uptake of metal ion by the solution reaches cessation. The knowledge of equilibrium or contact time is highly beneficial in the designing of suitable adsorption systems for the pollutants (Tomas Agustin Rearte et.al, 2013). Reya Isaac et. al, (2012), opinions that the adsorption is rapid in the initial stages and steadily touches the stability as time goes above the contact time. It can range from several minutes to few hours and differs for each sorbent material. For e.g. from table 2 for chromium, it can be seen that *Eugenia jambolana* takes 25 minutes whereas *Schenoplectus californicus* takes around 4 hours. The increased uptake of metal ions with contact time can be due to the decreased mass transfer coefficient of diffusion controlled reaction between adsorbent and metal ion (Achanai Buasri et al., 2012).

**Effect of initial metal concentration:** It is advised that a certain amount of metal ion concentration should be present in the solution so as to initiate the biosorption process. The initial metal ion concentration gives the necessary motivating energy to overcome the bulk relocation of ions between liquid and solid phases (Ashok Kumar et. al, 2014). Chromium follows that, in the initial stages there is an effective rise in the percent adsorption of the metal ion which decreases as the concentration increases (Muhammad AsifHanif et.al, 2011). This is caused because of the requirement of intraparticle diffusion and slow transmission of ions into the adsorbent material at higher concentrations. At lower metal concentration, the ratio of number of moles of Cu(II) in solution to available surface area is low and hence binding is independent of initial concentration whereas at higher concentration the available sites for binding is less and hence metal removal is highly dependent on initial concentration (Salwa A. Ahmed et al., 2011). This implies that the fact behind the relation between initial metal concentration and their amount i.e. the surface saturation of adsorbent was contingent on initial concentration (RabiaRehman et al., 2013).

**Effect of biosorbent dosage:** The biosorbent dosage expressed in g/L is another important parameter when it comes to carrying out the unspoiled sorption experiment. It is seen that the adsorption of chromium metal ions increases with the increased dosage of the adsorbent, as there are more number of active sites are feasible for the process (Reya

Isaac et. al, 2012). This may not be entirely true as fractional accumulation of the adsorbent materials occur at higher amounts, which hinder the metal assimilation of Chromium (Tomas Agustin Rearte et.al, 2013). Higher amounts of Copper were removed under constant initial metal concentration. However copper uptake decreased when biosorbent concentration increased which infers that addition of biomass to a metal solution lead to affecting the complete metal removal even though the process efficiency is not always the same (A. Delgado et. al, 1998). The biosorption was observed to be better with 1% concentration of biomass for Copper (Suryan S. et. al, 2012). An panoramic view of the various points discussed above is shown in table 2(A) and 2 (B).

**Table.1(A).An overview of the various experimental components involved in the Biosorption of Cr**

Adsorbent	Type of water	pH	Concentration (mg/L) or mL	Temperature (in Celsius)	Method of analysis	Capacity removed (%)	Model used to calculate adsorption capacity	Reference
White rot fungi- <i>Pleurotussajor-caju</i> , <i>Agaricusbitorquis</i> , <i>Ganodermalucidem</i>	Double distilled water	4.5	25-100	30-60	AAS	41.93	Langmuir and Freundlich	Muhammad AsifHanif et.al., (2011)
Brown algae- <i>Sargassumsp</i>	Tap water, double distilled water	4±0.2	1000	23±2	Flame AAS		Langmuir and Freundlich	Mehdi Farzadkia et.al., (2012)
<i>Penicilliumsp</i>	Distilled water	3-9	-	-	-	-	-	Jeevitha and Sumathy (2012)
<i>Aspergillusoryzae</i>	Deionized water	1-9	25-100	37	Scanning Electron Microscopy (SEM)	90.1	Langmuir and Freundlich	Reya Isaac et.al., (2012)
Algae- Silica hybrid	Deionized water	4.5	30	30	Inductively coupled plasma mass spectroscopy	71-78	-	Ulrich Soltmann et. al., (2009)
<i>Bacillus licheniformis</i>	Deionized water	2.5-4.5	1200	20-37	-	52	-	Deepti Pranay Samarth et.al., (2012)
<i>Mayaca fluviatiles</i> , <i>Porphyra umbilicalis</i> , <i>Fucus vesiculosus</i>	-	5.5	1000	-	ICP- AES Spectroscopy	-	-	Ioana- Raluca et.al., (2010)
Peat	-	5.5	1000	20	AAS	95	Langmuir and Freundlich	A Robaldis et. al., (2011)
Calcined brick powder	Double distilled water	2-9	-	27	Spectrophotometer	81	Langmuir and Freundlich	Hemalatha P. V &PrasadaRao (2012)
<i>Eugenia jambolanaleaves</i>	Deionized water	1-8	1000	25±1	AAS	80.16	Langmuir, Freundlich and Temkin	RabiaRehman et. al., (2014)
<i>Schoenoplectuscalifornicus</i>	Distilled water	3-11	-	25±2	EDX & ESEM	-	Langmuir, Freundlich, Temkin and Dubinin-Radushkevich	Tomas Agustin Rearte et. al., (2013)
<i>Rosa damascenabiomass</i>	-	2-5	-	30	-	81.35 ( Cr III), 86.81 ( Cr VI)	Langmuir	M JamshaidIqbal et. al., (2012)
<i>Eriobotrya japonica</i>	Tap and deionized water	2-8	10-100	-	Fourier Transform IR Spectroscopy	95	-	M. M. Abuien & A. M. Belazi (2009)
Brown seaweeds	Pure water	2-8	1000	20±1	-	88.9	Langmuir and Freundlich	Seung- Hoon- Lee & Chang – Ho (2012)
<i>Tephrosiapurpurea</i>	-	1-7	1000	33±1	Spectrophotometer	-	Langmuir and Freundlich	B. AshokKumar et. al., (2014)
Cross linked chitosan Carbonized Rice husk (CCCAR)	Double distilled water	-	-	-	SEM & FTIR	55.4	Langmuir, Freundlich and Temkin	S. Sugashini& K. M. MeeraSheriffa Begum (2012)

**Table.1(B).An overview of the various experimental components involved in the Biosorption of Cu**

Adsorbent	Type of water	pH	Concentration (mg/L) or mL	Temperature (in Celsius)	Method of analysis	Capacity removed (%)	Model used to calculate adsorption capacity	Reference
Coconut shell	Distilled, double distilled water	7	-	-	Atomic Absorption Spectroscopy	-	Dynamic models(Thomas, Yoon-Nelson and Clark)	Mike A Acheampong et al, (2012)
Wood sawdust	Distilled water	1-8	200	-	Fourier Transform of IR Spectrophotometer	-	-	SalwaA.Ahmed (2010)
Carboxylic acid functionalized deactylatdkonjacglucomannan	Distilled water	5	-	15	Fixedbedcolumn technique	-	-	Xuegangluo et al,(2011)
Leaves of <i>Punicagernatum</i>	Deionised water	4	5-1000	-	Flame atomic absorption spectrophotometer	-	Langmuir	PeymanSalehi et al,(2010)
<i>Polyalthialongifolia</i> leaf powder	Double distilled water	6	30-80	-	Fourier Transform of IR Spectrophotometer	-	Langmuir, Freundlich and Temkin isotherms	RabiaRehman et al,(2013)
<i>Citrus sinensis</i> peel and wood saw dust	Distilled water	6.5	1-50	-	Fourier Transform of IR Spectrophotometer	-	Langmuir, Freundlich isotherms	Saman khan et al, (2013)
Ricestraw	Deionised water	7	500	30 -70	Inductive coupled plasma emission spectrometer (ICP-ES)	-	Langmuir, Freundlich, Temkin & Dubinin-Radushkevich	Achanai Buasri et al, (2012)
Peat	-	5.5	25	20	Atomic Absorption Spectroscopy	-	Langmuir and Freundlich isotherms	A.Robalds et al, (2011)
Paper mill waste	Milli Q water	4.5	50	-	Atomic Absorption Spectroscopy	70	Langmuir and Freundlich isotherms	Suryan S. et al,(2012)
Algae -silica hybrid materials	Deionised water	-	-	-	Inductively coupled plasma mass spectrometry (ICP-MS).	81-99	-	Ulrich soltmann, et al,(2010)
Micro algal resin	Deionised water	-	50-250	-	Atomic Absorption Spectroscopy	90-95	Langmuir and Freundlich isotherms	R.Ramsenthil, et al.,(2010)
Powdered mycelium of <i>Fusariumflosiferum</i>	Distilled water	-	-	-	-	80	Langmuir isotherm	A.Delgado, et al.,(1998)
Filamentous fungi	Distilled water	-	-	-	ICP-Optical Emission Spectrometer	-	-	ShafiquzzamanSiddiquee, et al.,(2013)
<i>Bacillus licheniformis</i>	Deionised Water	2.5	1500	28	Inductive Coupled Plasma-Atomic Emission Spectrophotometer	32	-	Deepti Pranay Samarth,etal., (2012)
Green microalgae	Artificialfresh water	-	-	-	Atomic Absorption Spectroscopy	-	Freundlich isotherm	ZHAO Yanchuang et al.,(2012)

Table.2(A).A panoramic view of the parameters analysed in the Biosorption of Cr

Adsorbent Used	Ideal pH Range	Effective Biosorbents Dose (g/L)	Equilibrium time (min)	Initial Metal Concentration (mg/L)	R <sup>2</sup> values			Reference
					Langmuir Isotherm	Freundlich Isotherm	Temkin Isotherm	
Brown seaweeds	2-4	-	-	-	0.9838	0.9868	-	Seung- Hoon- Lee & Chang- Ho (2012)
<i>Tephrosiapurpurea</i>	1-5	20	180	20-100	0.9990	0.9820	-	B. AshokKumar et. al., (2014)
Cross linked chitosan Carbonized Rice husk (CCCAR)	2	4.4	120	255	0.9849	0.9927	0.9465	S. Sugashini& K. M. MeeraSheriffa Begum (2012)
<i>Bacillus licheniformis</i>	2.5 – 3.5	-	-	-	-	-	-	Deepti Pranay Samarth et.al., (2012)
<i>Schoenoplectuscalifornicus</i>	5-7	5 (at pH 7) 15 (at pH 5)	240	-	0.9980	0.9950	0.9760	Tomas Agustin Rearte et. al., (2013)
<i>Rosa damascena</i>	5 (Cr III) 2 (Cr VI)	50	-	100	0.9748 (Cr III) 0.9968(Cr VI)	0.7500 (Cr III) 0.8000 (Cr VI)	-	M JamshaidIqbal et. al., (2012)
<i>Aspergillus oryzae</i>	1-2	1-5	240	25	0.9724	0.9900	-	Reya Isaac et.al., (2012)
<i>Eriobotrya japonica</i>	2-6	-	-	-	-	-	-	M. M. Abuien & A. M. Belazi (2009)
White rot fungi- <i>Pleurotuss ajor-caju</i> , <i>Agaricusbi torquis</i> , <i>Ganoderm alucidem</i>	5 (Cr III) 2 (Cr VI)	0.5	-	25-200	0.9999	0.8813	-	Muhammad AsifHanif et.al., (2011)
Brown algae- <i>Sargassum sp</i>	3-4	0.5	60	100	0.9900	0.9740	-	Mehdi Farzadkia et.al., (2012)
<i>Penicillium sp</i>	3-5	-	-	4 mM*	-	-	-	Jeevitha M and Judia Harriet Sumathy. V (2012)
Marine natural products	-	-	30	20	-	-	-	Ioana- Raluca et.al., (2010)
Peat	2-6	-	150	-	0.9900	0.8000	-	A Robalds et. al., (2011)
Calcined Brick Powder	2	8	60	-	0.9986	0.9692	-	Hemalatha P. V &PrasadaRao (2012)
<i>Eugenia jambolana</i>	1-4	0.6	25	-	0.9820	0.9870	0.9860	RabiaRehman et. al., (2014)

Table.2(B).A panoramic view of the parameters analysed in the Biosorption of Cu

Adsorbent Used	Ideal pH Range	Effective Biosorbent's Dose (g/L)	Equilibrium time (min)	Initial Metal Concentration (mg/L)	R <sup>2</sup> values			Reference
					Langmuir Isotherm	Freundlich Isotherm	Temkin Isotherm	
Wood sawdust	1-8	-	45	200	0.99	0.94	-	Salwa A. Ahmed (2010)
Leaves of <i>punicagaranatum</i>	4	-	60	5-1000	0.9990	0.914	-	Peyman Salehi et al., (2010)
Polyalthialongifolia leaf powder	6	5-50	40	30-80	0.993	0.994	0.990	Rabia Rehman et al., (2013)
Citrus sinensis peel and wood saw dust	5.5-6	20	60	1-50	-	-	-	Saman Khan et al., (2013)
Ricestraw	7	2	120	500	0.9951	0.9961	0.9942	Achanai Buasri et al., (2012)
Peat	5.5	12.5	150	25	0.9900	0.9400	-	A. Robalds et al., (2011)
Paper mill waste	4-9	-	-	50	0.9814	0.9800	-	Suryan S, et al., (2012)
Micro algal resin	-	5	-	50-250	0.985	0.9978	-	R. Ramsenthil, et al., (2010)

**Adsorption isotherms:** An adsorption isotherm is a quantitative relationship describing the equilibrium between the concentration of adsorbate in solution and the concentration of the adsorbed material. Researchers and scientists practice the concept of establishing symmetry of heavy metal adsorption by the adsorbent. Isotherms find application at this stage (Seung- Hoon Lee and Chang-Ho Park, 2012). The name isotherm implies that the relationship is for a given temperature. In this study, three isotherms are found being used comprehensively. *Langmuir* isotherm works on the assumption that a single adsorbate binds on a single site and all sites have the same attraction to the incoming metal ion. The linear form of the isotherm is,

$$C/q = (1/q_{\max}) C + (1/b q_{\max})$$

where  $q$  is the heavy metal uptake (mg/g),  $C$  is the concentration of heavy metal (mg/L),  $q_{\max}$  is the maximum uptake (mg/g) and  $b$  is a Langmuir constant (L/mg). On obtaining a plot of  $C/q$  set against  $C$ , a straight line shows the data is in accordance with Langmuir isotherm.

*Freundlich* isotherm is a derivation of the Langmuir isotherm, in the fact that this isotherm assumes that there exists a distribution of sites on the adsorbent that have varying affinities for various adsorbates, with each site behaving accordingly to the Langmuir isotherm (Clair N. Sawyer, Chemistry for Environmental Engineering and Science). The linear form is expressed as,

$$\log q = \log K_F + 1/n \log C$$

where  $K_F$  is equilibrium constant and  $n$  is an empirical parameter greater than 1.

*Temkin* model of adsorption isotherm points out that, the heat of adsorption of the layers decreases linearly rather than in a logarithmic fashion. The linear expression is as below,

$$q_e = B \ln A_T + B \ln C_e$$

where  $A_T$  is Temkin isotherm equilibrium binding constant (L/g),  $b_T$  is Temkin isotherm constant,  $R$  is universal gas constant (8.314 J/mol/K),  $T$  is Temperature at 298K and  $B$  is Constant related to heat of sorption (J/mol). The combined list of all the above discussed aspects have been laid out in table 2.

## CONCLUSION

Sorption processes are very important to the fate and transport of contaminants in the environment and for the removal of contaminants in engineered reactors. From this study, it can be seen that almost any material can be used as an adsorbent, provided they have the ability to perform well under the given atmospheric and environmental conditions. The various parameters that can influence the biosorption process have been dealt in detail. The field of biosorption is mammoth and growing, with the advent of new researches and innovation. By striking a balance between the need and availability, it is possible to bring forth a pollution and contamination free environment for our future generations.

## REFERENCES

- A. Delgado, A.M. Anselmo, J.M. Novais, Heavy Metal Biosorption by Dried Powdered Mycelium of *Fusarium flocciferum*, *Water Environment Research*, 70, 1998, 370.
- A. Robalds, M. Klavins, A. Zicmanis, Peat as Sorbent for Copper (II) and Chromium(III) ions, *Latvian Journal of Chemistry*, 1/2, 2011, 149-158.
- Achanai Buasri, Nattawut Chaiyut, Kessarin Tapang, Supparok Jaronsin and Sutheera Panphrom, Removal of copper(II) from aqueous solution by Biosorption on Rice Straw – an Agricultural Waste Biomass, *International Journal of environmental Science and Development*, 3, 2012.
- B. Ashok Kumar, S. Jothi Ramalingam, S.K. Thiyakarajan, T. Hidayathulla Khan and V. Thirumurugan, Biosorption of Cr (VI) from aqueous solution using *Tephrosia purpurea*, *Asian Journal of Research & Chemistry* 7, 2014, 503-508.
- Clair N. Sawyer, Perry L. McCarty, Gene F. Parkin, *Chemistry for Environmental Engineering and Science*, Edn 5, McGraw Hill, New Delhi, 2014, 99- 100.
- Deepti Pranay Samarth, Chandrashkar Janglujji Chandkar and Rama Kaustubh Bhadekar, Biosorption of Heavy Metals from Aqueous Solution using *Bacillus licheniformis*, *International Journal of Pure and Applied Science and Technology*, 10, 2012, 12-19.
- Fernando I. Ramirez-Paredes, Teresa Manzano-Munoz, Juan C. Garcia-Prieto, J. Felipe Bello-Estevez, Galina G. Zhadan, Valery L. Shnyrov, John F. Kennedy and Manuel G. Roig, Biosorption of Heavy Metals from Acid Mine Drainages onto Pig Bristles, Poultry Feathers and Crustacean Shells Industrial Biowastes, *Journal of Basic and Applied Sciences*, 9, 2013, 510-524.
- Hemalatha P. V and Prasada Rao P. V. V, Adsorption of Cr (VI) ions from aqueous solutions using Calcined Brick Powder (CBP), *International Journal of Environmental Sciences*, 2, 2012.
- Ioana- Raluca Bunghez, Rodica- Mariana Ion, Irina Dumitriu, Radu- Claudiu Fierascu, Heavy Metal Ions Depollution By Marine Natural Products, 1, 2010, 73-78.
- Jeevitha M and Judia Harriet Sumathy V, Biosorption of Chromium by *Penicillium*, *International Journal of Environmental Sciences*, 3, 2012
- M. Jamshaid Iqbal, Farhan Cecil, Khalil Ahmad, Munawar Iqbal, M. Mushtaq, M. A. Naeem and T. H. Bokhari, Kinetic Study of Cr (III) and Cr (VI) Biosorption Using *Rosa damascena* Phytomass: A Rose Waste Biomass, *Asian Journal of Chemistry*, 25, 2013, 2099-2103.
- M. M. Abuein, A. M. Belazi, Biosorption of Chromium (VI) and Mercury (II) from Aqueous Solutions by *Eriobotrya japonica* (Rosaceae), *Asian Journal of Chemistry*; 21, 2009, 1707-1712.
- Mehdi Farzadkia, Mitra Gholami, Majid Kermani and Kamyar Yaghmaeian, Biosorption of Hexavalent Chromium from Aqueous Solutions by Chemically Modified Brown Algae of *Sargassum* sp. and Dried Activated Sludge, *Asian Journal of Chemistry*, 24, 2012, 5257-5263.
- Mike A. Acheampong, Kannan Pakshirajan, Ajit P. Annachatre, Piet N.L. Lens, Removal of Copper (II) by Biosorption onto Coconut Shell in Fixed-bed Column Systems, *Journal of Industrial and Engineering Chemistry*, 19, 2013, 841-848.
- Muhammad Asif Hanif, Haq Nawaz Bhatti, Ijaz Ahmed Bhatti and Muhammad Asghar, Biosorption of Cr (III) and Cr (VI) by Newly Isolated White Rot Fungi: Batch and Column Studies, *Asian Journal of Chemistry*, 23, 2011, 3375-3383.

- PeymanSalehi , BehvarAsghari, Fatemh Mohammad, Biosorption of Nickel (II),Copper (II)and lead (II)by PunicaGeneratum from Aqueous solution, Journal of Water Resources and Protection,2, 2010,701-705.
- R.Ramsenthil and Rm .Meyyapan , Single and Multi-component Biosorption of Copper and Zinc Ions using Microalgal Resin, International Journal of Environmental Science and Development, 1,2010.
- RabiaRehman, Jamil Anwar and Tariq Mahmud, Adsorptive Elimination of Chromium (III) and Nickel (II) from Water by Spent Eugenia jambolana Leaves: Isothermal and Thermodynamical Studies, Asian Journal of Chemistry,26, 2014, 644- 648.
- RabiaRehman, UmerShafique, JamilAnwar and SaminaGhafoor, Kinetic and Isothermal Studies of cobalt (II), copper (II) and nickel (II) Using PolyalthiaLongifolia Leaf Powder, Asian Journal of Chemistry, 25, 2013, 8285-8288.
- ReyaIssac.I, Lakshmi Prabha M, EmilinRenitta. R, Murugan S, Equilibrium and Kinetic studies on biosorption of Cr (VI) by Aspergillusoryzae isolated from tannery effluent, International Journal of Environmental Sciences, 2, 2012.
- S. Sugashiniand K. M. MeeraSheriffa Begum, Optimization using central composite design (CCD) for the biosorption of Cr (VI) by cross linked chitosan carbonized rice husk (CCACR), Clean Techn. Environ. Policy, 15, 2012, 293-302.
- Salwa A.Ahmed, Batch and fixed – bed column techniques for removal of copper (II) and iron (II) using Carbohydrate Natural Polymer Modified Complexing Agents, Elsevier, 83, 2011, 1470-1478.
- Saman Khan, AbidaFarooqi, M.Ihsan Danish &AkifZeb, Biosorption of Copper (II) from Aqueous Solution Using Citrus Sinensis Peel and Wood Saw Dust: Utilization in Purification of Drinking and Waste Water, International Journal of Research and Applied Sciences, 16, 2013.
- Seung-Hoon Lee and Chang- Ho Park, Biosorption of Heavy Metal Ions by Brown Seaweeds from Southern Coast of Korea, Biotechnology and Bioprocess Engineering ,17, 2012, 853-861.
- ShaffiquzzamanSiddiquee , Sallh N. Aishah , Sujjat A. Azad ,SailiN.Shafawati, LailaNaher,Tolerance and biosorption capacity of Zn<sup>2+</sup>, Pb<sup>2+</sup>, Ni<sup>3+</sup> and Cu<sup>2+</sup> by filamentous fungi (Trichodermaharzianum, T. aureovirideand T. virens),Advances in Bioscience and Biotechnology, 4, 2013, 570-583.
- Suryan S, Ahluwalia S.S, Biosorption of Heavy Metals by Paper Mill Waste from Aquous Solution, International Journal of Environmental Sciences, 2, 2012.
- Tomas Agustin Rearte, Patricia Beatriz Bozzano, Maria Luisa Andrade and Alicia Fabrizio de lorio, Biosorption of Cr (III) and Pb (II) by Schoenoplectuscalifornicus and Insights into the Binding Mechanism, ISRN Chemical Engineering, 2013.
- Ulrich Soltman, Sabine Matys, Gunter Kiszig, Wolfgang Pompe,Horst Bottcher, Algae-Silica Hybrid Materials for Biosorption of Heavy Metals, Journal of Water Resource and Protection, 2, 2010,115-122.
- XuegangLuo , Feng Liu, Zaifang Deng, Xiaoyan Lin, Removal of copper (II)from Aqueous solution in Fixed-bed Column by Carboxylic Acid FunctionalizedDeacetylatedKonjacGlucomannan, Elsevier Carbohydrate Polymers, 86, 2012,753-759.
- ZHAO Yanchuang , WANG Baoli, LIUCongqiang and WU Yanyou, Biosorption of Trace Metals from Aqueous Multi- Metal Solutions by Green Microalgae, Chin.J.Geochem, 32, 2013, 385-391.