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STUDIES ON THE BIOSORPTION ON REMOVAL OF HEAVY METAL COPPER IN PRINTED CIRCUIT BOARDS

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Abstract - *Electronic waste, or e-waste, is an emerging problem as well as a business opportunity of increasing significance, given the volumes of e-waste being generated and the content of both toxic. The PCB board contains valuable metals Cu, Pb, Sb, Hg, Cd, Ni, polybrominated diphenyl ethers. The potential of metal biosorption by biomass materials been well established in recent years. Biosorption is the most suitable process to eliminate these heavy metals.The present study is carried out using Bacillus Megateirum as dead biomass to remove the heavy metal copper from Printed circuit boards. In batch experiments the effect of contact time, adsorbent dosage, pH, initial concentration and agitation speed were studied. The SEM analyses were carried out for both the biomass in order to study the morphology of the structure. About 65% of copper removal was achieved by using 2 g of Bacillus Megaterium at a contact time of 60 mins, at a pH of 5 and at an agitation speed of 150rpm.The Bacillus Megaterium exhibited good biosorption capacity and the biosorption data fitted with Langmuir model which indicated a monolayer adsorption. Kinetics studies were made which showed pseudo second order was observed to be the rate determining step.*

Key Words*: E-waste, biosorption, copper, Bacillus *Megaterium.

1. INTRODUCTION

Electronic waste or Waste Electrical and Electronic Equipment (WEEE) is the Electrical and Electronic Equipment (EEE) which is no longer fit for its original intended use and are desired for recovery, recycling or disposal.

1.1 Printed Circuit Boards

PCBs are the essential part of the electronic industry. PCBs possess valuable metals like lead, copper, nickel, aluminum, iron and tin. The purity of metals in PCBs is 10 times higher than that of its ore. Recycling of PCBs are most important not only for treatment of waste but also to recover the valuable metals Printed circuit boards are particularly problematic to recycle because of the heterogeneous mix of organic material, metals, and glass fiber. In 2002, only 15% of the 50, 000 tons of scrap printed circuit board produced in the UK was recycled.

1.2 Biometallurgy

Biotechnology is one of the promising technologies in metallurgical processing. Microbes have the ability to bind metal ions present in the external environment at the cell surface or to transport them into the cell for various intracellular functions. They are as bioleaching, biosorption, bioaccumulation, biotransformation, biomineralization

2. BIOSORPTION

Biosorption can be defined as the removal of metal or metalloid species, compounds and particulates from a solution by low cost biological materials. All biological materials can be useful biosorbents for metals sequestration with the exception of mobile alkali metal cations like sodium and potassium ions, and this can be a significant passive process in living and dead organisms several cheap biosorbents for the removal of metals mainly arrive under the following categories: bacteria, fungi, algae, plants, industrial wastes, agricultural wastes and other polysaccharide materials. In general, all types of biomaterials used for biosorption were found to have good biosorption capacities towards all types of metal ions. Many researchers study the b biosorption for heavy metal removal which involved the use of either laboratory-grown microorganism or biomass generated by different processing industries or wastewater treatment units.

2.1 Bacteria as Biosorbents

Bacterial biosorption is mainly used for the removal of pollutants from effluents contaminated with pollutants that are not biodegradable, like metals ions and dyes. However, their isolation, screening and harvesting on a larger scale may be complicated but still remain one of the efficient way of remediating pollutants. Different bacterial strains were used for the removal of different metal ions. Table 1 below shows the biosorption capacity of different metal ions by different bacterial biomass. Bacteria have evolved a number of efficient systems for detoxifying metals ions they develop these resistance mechanisms mostly for their survival.

3. BACILLUS MEGATERIUM

Bacillus megaterium is a rod-like, Gram-positive, mainly aerobic spore forming bacterium found in widely diverse habitats.B. *megaterium* is generally considered a soil microbe and has been shown to precipitate carbonate minerals. *Bacillus megaterium* is a prokaryotic cell, lacking membrane-bound organelles. It is a Gram-positive, rod-shaped and found with other *bacillus megaterium* organisms. It is motile, with the use of its flagella. The cell wall, has large amounts of peptidoglycan. The flow of energy in cellular respiration is considered aerobic, but may undergo anaerobic conditions.B.

megaterium as a biosorbent not only removes metals from wastewaters but also eases the burden of disposal costs. They have been used to remove Cr(VI),Pb(II), Cu(II) and nickel from aqueous solutions. Microbial biomass is one of the low-cost and efficient biosorbents of heavy metals removal from solutions. The process of biosorption has many attractive features including removal of metals ion over relatively broad range of pH and temperature. Many researchers studied biosorption performance of different microbial biosorbents which provide decent arguments for the implementation of biosorption technologies for heavy metal removal from solutions and also to understand the mechanism responsible for biosorption. Consequently, through unrelenting effort and research, above all full-scale on pilot and biosorption process, the situation is expected to change in the near future, with biosorption technology becoming more beneficial than currently used physicochemical technologies of heavy metal removal.

4. ADSORPTION ISOTHERM

The most common relationship between the amounts of solute adsorbed per unit weight of adsorbent q_e and equilibrium concentration C obtains for systems in which adsorption from solution leads to the deposition of an apparent single layer of solute molecules on the surface of the solid. Equations that are often used to describe the experimental isotherm data were developed by Freundlich, Langmuir, Brunauer, Emmet and Teller (BET isotherm).

4.1 Significance of Isotherm

- From an isotherm test, the degree of treatment which is influenced by adsorption can be determined.
- It will show the adsorptive capacity of the carbon and provide a rough estimate of the carbon dosage required.
- Isotherm test also offer a convenient means of studying the effects of pH and temperature on adsorption.
- Isotherm obtained under identical conditions using the same test solutions for two test carbons can be quickly and conveniently be compared to reveal the relative merits of each carbon.

5. OBJECTIVES OF PRESENT STUDY

The present study deals with the biosorption of heavy metals from PCBs using and Bacillus megateriumas biosorbents.

- Culturing of Bacillus megaterium
- To study about the ability of acid leaching for the collected PCBs.
- To conduct batch adsorption using microorganisms as biosorbents.
- To study about the isotherms at batch equilibrium.
- To study about the kinetics in order to relate the experimental data to the biosorption of heavy metal copper.

6. MATERIALS AND METHODS

6.1 Collection of Sample

PCBs used were procured from the local market. The collected PCBs were cleaned and was cut into different dimensions and sizes.

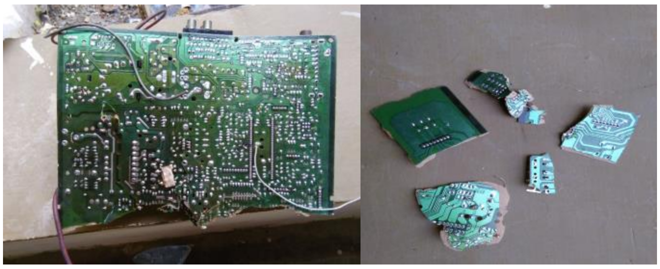

Fig -1: Printed Circuit Board

6.2 Removal of Epoxy Coating

- About 100 grams of PCBs are weighed.
- 10 N NaOH is prepared by dissolving 400 grams of Sodium hydroxide in 1000 mL of distilled water.
- About 10 grams of PCBs are taken in conical flask and soaked in 100 mL of NaOH solution.
- After 24 hours the PCBs are taken out and the coating is scrubbed off using a brush and washed with clean water.

6.3 Acid Leaching

During the leaching of the boards in aqueous nitric acid solution, copper reacts to form copper nitrate and lead is dissolved by nitric acid to form soluble lead nitrate solution. Experiments conducted in 500 ml conical flask as follows:

- 250 mL of nitric acid is made up into 1000 mL using distilled water.
- About 50 g of PCBs are soaked in 100 mL of above nitric acid solution.
- The sample solution is kept in rotary shaker at 250 rpm and 40^0 C for 1 hour.
- After 48 hours the PCBs are removed from the solution.

The PCBs removed from the acid leaching solution is free from metal ions and it contains only wood which is safer to dispose. After acid leaching the solution is filtered with filter paper.

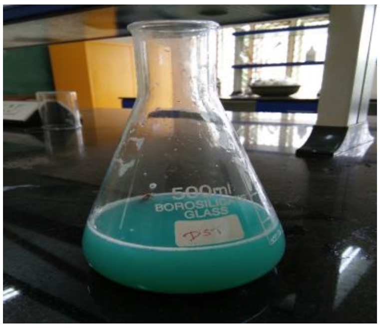

Fig -2: Acid Leaching

6.4 Bacillus Megaterium Culture

Nutrient broths purchased from Hi-Media were used as media for the culture to activate. The prepared media was kept in autoclave for 20 minutes in order to sterilize them. The sterilized media was inoculated with the yeast in the laminar air flow chamber. The prepared culture was incubated in the rotary shaker at 160 rpm for 24 hours at 26^{0} C. From the pure culture sub culturing was carried out for further work.

Fig -3: Pure Culture of B. Megaterium

6.5 Estimation of Copper

- About 20 ml of sample is pipette out in a 250 ml conical flask.
- To that a few drops of KI solution is added.
- The liberated iodine is titrated against standard Sodium thiosulphate solution from the burette.
- When the colour of solution fades to light yellow, a few drops of starch is added followed by a pinch of ammonium thiocyanide.
- The solution is titrated till the blue colour changes to a white or flesh white residue is left in the flask.
- The titration is repeated for three times.

6.6 Characterization

The characterizations were done using sophisticated analytical instruments helps in determining the properties of the materials. The analyses that are carried out in this study are Centrifuge, Rotary Shaker, Scanning Electron Microscopy (SEM) and energy dispersive X - Ray spectroscopy(EDAX).

7. RESULTS AND DISCUSSIONS

7.1 Batch Adsorption Study for B.Megaterium

The batch adsorption study for Bacillus *Megateirum* was carried out for different optimum parameters.

7.1.1 Effect of Optimum Contact Time for B. Megaterium

Table -1: Effect of contact time on copper removal using B. megaterium

Sl.No	Contact time (mins)	Initial concentration C_o (g/l)	Final concentration C_e (g/l)	% removal
1.	15	321	198	38.3
2.	**30**	**321**	**189**	**41.1**
3.	45	321	186	42.1
4.	60	321	183	43.0
5.	75	321	179	44.2
6.	90	321	173	46.1
7.	105	321	165	48.6
8.	120	321	159	50.5

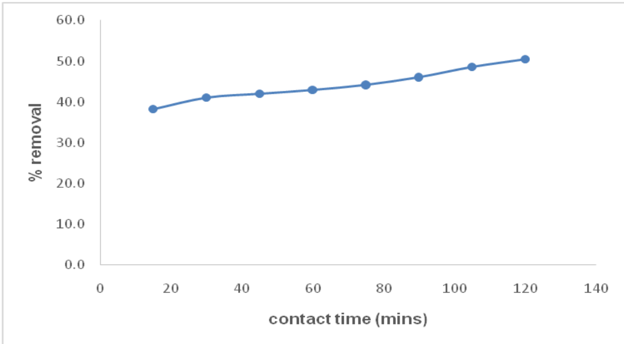

Chart -1: variation of copper removal with optimum contact time

From the graph, the equilibrium attained is at 30 mins, where removal efficiency is about 41% of removal of copper.

7.1.2 Effect of weight of adsorbent on the removal of copper

Table -2: Effect of adsorbent on copper removal using B. Megaterium

Sl.no	Dosage (grams)	Initial concentration C_o (g/l)	Final concentration Ce (g/l)	% removal
1.	0.02	321	305	4.98
2.	0.04	321	290	9.66
3.	0.06	321	275	14.33
4.	0.08	321	260	19.00
5.	0.1	321	245	23.68
6.	0.12	321	235	26.79
7.	**0.14**	**321**	**231**	**28.04**
8.	0.16	321	228	28.97

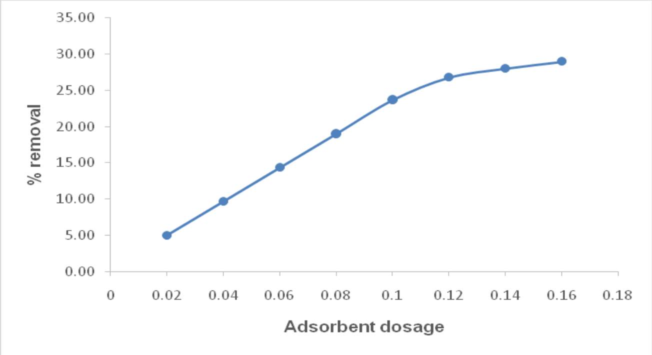

Chart -2: variation of copper removal with optimum adsorbent dosage

From the graph, the equilibrium attained is at 0.14, where removal efficiency is about 28% of removal of copper.

7.1.3 Effect of pH on the removal of copper

Table-3: Effect of pH on copper removal using B. megaterium

Sl.no	pH	Initial concentration C_0 (g/l)	Final concentration C_e (g/l)	% Removal
1.	1	321	318	0.9
2.	2	321	250	22.1
3.	3	321	178	44.5
4.	4	321	152	52.6
5.	5	321	147	54.2
6.	6	321	149	53.6

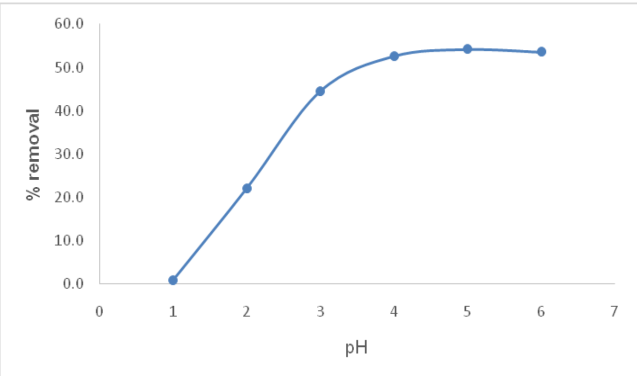

Chart -3: variation of copper removal with optimum pH

From the graph, the equilibrium attained is at pH 4, where removal efficiency is about 52% of removal of copper.

7.1.4 Effect of Initial Ion Concentration on the Removal of Copper

Table -4: Effect of Initial concentration on copper removal

Sl.no	Initial ion concentration (ppm)	Initial concentration C_o (g/l)	Final concentration C_e (g/l)	% removal
1.	50	321	136	57.63
2.	100	321	145	54.82
3.	150	321	156	51.40
4.	200	321	176	45.17
5.	250	321	179	44.23
6.	**300**	**321**	**186**	**42.05**
7.	350	321	192	40.18
8.	400	321	193	39.87
9.	450	321	191	40.49
10.	500	321	199	38.00

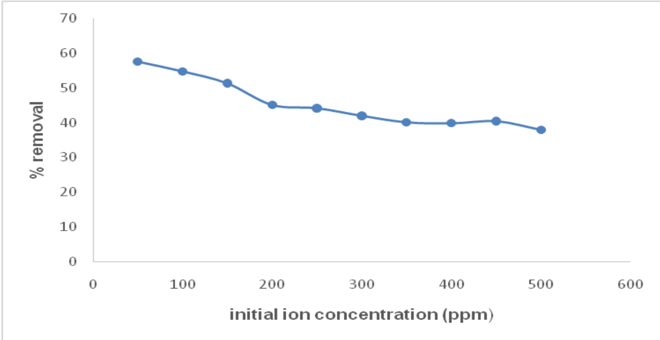

Chart -4: variation of copper removal with optimum pH

7.2 ISOTHERM STUDY

7.2.1 Data for determination of Langmuir Isotherm test

Table -5: Langmuir isotherm for copper adsorption using b.megaterium

Initial Concentration C_0(mg/l)	Final Concentration C_e(mg/l)	volume V(l)	X=(C0-Ce)*V	dosage m (gm)	x/m =Qe	Ce/Qe
321	305	0.05	0.8	0.02	40.0000	7.63
321	290	0.05	1.55	0.04	38.7500	7.48
321	275	0.05	2.3	0.06	38.3333	7.17
321	260	0.05	3.05	0.08	38.1250	6.82
321	245	0.05	3.8	0.1	38.0000	6.45
321	235	0.05	4.3	0.12	35.8333	6.56

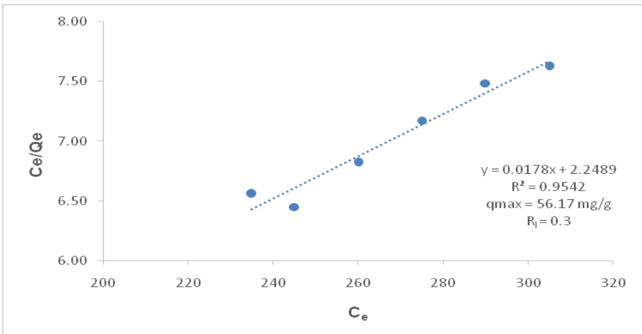

Chart -5: Langmuir isotherm graph

8. CONCLUSIONS

The printed circuit board (PCB) contains metals that are abundant in non ferrous metals such as Cu, Pb, Al, etc. The purity of precious metals in PCBs is 10 times higher than that of rich-content minerals. Therefore, recycling of PCBs is an important subject not only for treatment of waste but also from the recovery of valuable materials.

The batch experiments were carried out to analyze the adsorption efficiency of microorganisms. The parameters such as contact time, biosorbent dosage, pH and concentration of the metal solutions and speed were varied. The isotherms such as Langmuir isotherms obtained from the batch experiments. The optimum contact time was found to be 30 mins for B. *megaterium.* The optimum adsorbent dosage was found to be 0.14 g of *B. megaterium.* The optimum pH and initial ion concentration was found to be 4 and 300 ppm for *B. megaterium.* Therefore 65 % of removal efficiency of *B. megaterium* was obtained respectively.

From the isotherm plots, it was observed that the *B. megaterium* can perform as a better biosorbent in the removal of copper from solution. The isotherm constants were as follows:

Langmuir isotherm parameters was evaluated as q=56.17 mg/g, R_L =0.3 with regression coefficient R^2=0.9542. therefore, Langmuir isotherm have good fit for monolayer adsorption.

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