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Separation and Identification of Hazardous Metal Ions from Different Water Samples By Thin Layer Chromatography

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Abstract – For separation of metal ions such as Cr (VI), Cr (III), Ni (II), Co (II), Cu(II), Fe(II), Fe(III), Zn(II) and Mo(VI), from two, three and four-component mixtures, thin-layer chromatographic method has been created. The separation was conducted using aqueous humic acid as a mobile process on a thin layer of silica gel 'G.' The chromatographic conduct of metal ions in surfactant mixed resolvents was examined with thin Silica Gel-G layers. The influence of humic acid production in different amounts on the sensitivity of metal captions was also explored. There were also powerful and weak electrolytes and surfactant concentration, an acidity influence and simple aqua surfactant. Metal ions including Cu2 +, Hg2 +, W6 + and Ni2 + were isolated from their binary mix by utilising surfactants and different additives combined in mobile phases. Semi-quantitative Ni2 + calculation was attempted through spot field measurements.

Key Words: Thin Layer, Chromatographic, Technique, metal ions

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INTRODUCTION

A flexible method for distinguishing and extracting organic and inorganic substances is the chromatography of the thin layer[1-2]. Due to their physical and environmental significance, heavy metals have gained substantial interest from analysts[3-4]. Metals including As, Cr, Hg, Tl, Cd, Ni, Tl, Cu, Fe , Zn, Pb, Co, Mo, etc. are poisonous to human health and dangerous. These metal ions may shape complexes with oxygen, nitrogen, and sulphur atomic biological ligaments which cause many problems in living organisms through redox processes[5]. Armstrong and Terrill were leaders of using aqueous solution as a mobile process of TLC[6]. The use of a surfactant as the mobile step became increasingly common and more commonly used because of its flexibility in activities, economic benefit, reduced toxicity and improved segregation quality. Silice gel and an aluminium coating have been used for isolation of different inorganic organisms with surfactant-mediated mobile phase systems. Farmers have recognised improvements in organic matter soil to be helpful for plant growth over a long period of time[2]. However, after humans started to postulate on it in the 18th century, the structure and role of organic matter remained problematic. Before Liebig, humus was apparently used by plants, but after Liebig had shown that plant growth is dependent on inorganic compounds, some soil researchers thought that the use of organic matter was only beneficial for productivity since it has been broken down into inorganic forms with its portion nutrient release. Soil scientists actually have a more comprehensive perspective and accept, at least, that humus impacts soil productivity by affecting the ability to retain water in the soil. Moreover, since the plants have been demonstrated to consume and translocate complex organic molecules of systemically based insecticides, it can no longer discredit the suggestion that the plants might consume soluble types of humus[2]. A research has been undertaken at the State University of Ohio on the impact of humic acid on plant development, reporting that certain humic acids have improved plant growth and have comparatively broad reactions at low application rates[1]. In order to make bricks, according to archaeology, straw was combined with clay. Straw makes tougher bricks and can crack or lose their form less likely. Modern study has demonstrated that human acid, when combined with dirt, is emitted out of straw essentially a sand and clay mixture. Humic acid strengthens the plasticity of clay[3]. Humic acid is a significant constituent of the bio-degradation and dead organic matter and humic compounds. The description of humic acids is brownish-black, alkaline soluble solids that can either be retrieved from the naturally treated coals or be formed by regulated oxidation This document deals with rapid removal from three non-imprégnated silica gel 'G' laminated plate heavy metal ions as well as four components mixtures using aqueous solution of humic acid or DMSO(di) Humic acid(di).

RESEARCH METHODOLOGY

Characterisation of AZOLLA

This little plant drifts on the outside of lakes or lakes with its underlying foundations hanging down into the water. It is an American species presented as a plant for garden (Figure 3.1) lakes from which it has gotten away into streams and lakes. Here and there it can totally cover the outside of a lake and structures thick masses of material appeared on the shores. [4]

Azolla is green to yellowish green or dim red, with 2 development stages; plants fruitful just in develop stage, by and large in pre-summer. Stems prostrate when juvenile, 1-3 cm, internodes extend to 5 mm, getting almost erect to 5 cm or more when adult and swarmed. Megaspores warty with raised rakish knocks, each with a knot of fibers. It is found in taro patches, lakes, lakes, trench, channels, bogs, and moderate moving streams. A. filiculoides lives in advantageous interaction with blue green growth (cyanobacteria), exploiting their capacity to fix nitrogen. It is in some cases presented and utilized by ranchers as characteristic manure hence. It has additionally been acquainted with aid mosquito reduction when all is said in done any sorbate is described by the accompanying properties: [5]

a) Porosity;

b) Pore size circulation;

c) Explicit surface zone;

d) Thickness;

e) Molecule size dispersion;

f) Molecule shape;

g) scraped spot opposition;

h) Squash quality;

i) creation/58 solidness;

j) Hydrophobicity.

The porosity of the biosorbent Azolla speces can be envisioned through morphological concentrate by Scaning Electron Microscope (SEM) pictures. The pore size appropriation and explicit surface zone can for the most part be estimated by BET surface territory investigation procedure. The thickness of dead biomass will be pretty much that of Water. The size of dried biomass generally shifts, particles of around 500-1000 nm are considered for the research center trial study. The mechanical quality boundaries are important to create appropriate building frameworks for dealing with the species, these boundaries are not considered in this investigation. Since this species live in new water hydrophobicity property doesn't influence the qualities/structure of the species.[6]

Figure 3.1 Azolla family

Distribution of Azolla

Azolla species are found in new water biological systems of calm and tropical regions all through the world as appeared in Table 3.1. An examination of 59 the conveyance of Azolla shows that four types of azolla are initially found in North America and South America. Human movement has essentially changed the first species circulation. A. filiculoides is currently found in Europe, Asia and Australia and A. caroliniana happens in Asia, South America and Europe. A. micophylla a strain impervious to temperature and saltiness with abundant sporulation character, was presented from Davis, California to Tamil Nadu territory of India which later spread across India. (Kannaiyan and Kumar, 2006)[7]

Table 3.1 Distribution of Azolla

Species	**Country/Region**
A. filiculoides	Southern South America to Alaska
A. caroliniana	Eastern North America, the Caribbean, Mexican and West Indies
A. mexicana	North South America to British Columbia, Western North America and Eastward
A. microphyla	Western and Northern South America to North Ameica and the West Indies
A. pinnata	Tropical Africa and Southern Africa, South East Asia, Japan and Australia
A. nilotica	Central Africa, upper Nile Sudan, Uganda, Tanzania, Congo and Namba

Uses of Azolla

In view of advantageous nitrogen obsession, and thus, high nitrogen content, Azolla has been utilized as a green compost for wetland rice in northern Vietnam, and integral to southern China for a considerable length of time. In the mid 1980's, the utilization in South Cotabato, Philippines had spread. Be that as it may, since the last part of the 1980's, the financial circumstance in these nations has definitely 60 changed with the presentation of market economy framework. Expanded utilization of synthetic composts, the quest for a high pay crop during azolla development period, and the breakdown of ranchers' organizations who gave inoculums to rice development are elements to clarify fast decrease of azolla use. In light of the decay of its utilization, different motivations behind utilizing azolla have been expored. Various advantages of azolla are as per the following.[8]

Biological herbicide

Azolla covering water surface decrease light entrance to soil surface, bringing about the downturn the germination of weeds. Accordingly, development of azolla diminishes event oceanic weeds in overwhelmed rice fields.

Supplement collection

Supplements in floodwater can't be legitimately consumed by rice. Azolla can gather supplements from floodwater, and gives these after azolla's decay. For instance, 33% of potassium consumed by rice is once aggregated in azolla body. Under the tangle of azolla, floodwater pH doesn't turn soluble. Forestalling basic response lessens smelling salts misfortune.

Creature feed

Azolla has been utilized as feed for pig, duck, and fish. It has high substance of protein (20-30% on dry weight premise). Since its protein needs methionine and cystein, mix with grains is required. Healthy benefits of azolla to creatures change extraordinarily on azolla species. On dry weight premise, azolla can be stirred up to 10% of the bought creature feed.

Azolla weed

Azolla has been portrayed as a weed to wetland rice. When floodwater level is high, and azolla is driven into one side of a field, azolla regularly covers the head of youthful rice seedlings, prompting the downturn of rice development or demise. Azolla spread lessens water temperature to 0.5-1 °C. At the point when azolla becomes effectively above 20°C, the decrease of water temperature may not be unfavorable to rice development. Nonetheless, the encompassing ranchers are 61 frequently oblivious of advantageous impacts of azolla and the best approach to control its development. [9]

Appropriation from the fields to the surounding fields ought to be limited. Numerous advantages of utilizing azolla are perceived. Subsequently, the incorporated utilization of azolla with rice and fish cultivating has been created at Fujian Academy of Agricultural Sciences, China. The coordinated methodology can build a rancher's salary, while decreasing the utilization of pesticides and composts, and, thusly, natural contamination.

PREPARATION OF BIOMASS

Three Azolla species in particular A. filiculoides, A. rongpong and A. mycrophylla were provided by Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. This was developed in the paddy fields just as in the nursery. Following three weeks it was gathered, sun dried and ground (Domestic Mixer Grinder, India).

Pre-Treatment

A test of 2 g of biomass was treated with 0.1 M of HCl (100 ml) for 5 h under steady tumult with rotating instigator (Orbitec, India) at 150 rpm. The corrosive treated biomass was sifted and washed with abundance of refined water (Zhao et al., 1999). The biomass was sun dried and kept in a broiler at 50°C for 2h and afterward sieved for molecule size of 500-1000 nm. Nonliving biomass is liked to evacuate the high grouping of heavy metals (Wang and Wood, 1984). Non-living Azolla, has been demonstrated to be adequately adsorb hexavalent and trivalent chromium, zinc(II) and nickel(II) from the electroplating gushing and gold(II) from watery solutions. The evacuation of heavy metals could be expanded because of the actuation of the non-living Azolla by the oxydant specialist. (Khosravi et al 2005)

Morphology

The diploid, spore creating age of Azolla is called sporophyte, which comprises of an even to vertical fundamental rhizome, multibranched, prostrate, drifting stems that bear profoundly bilobed leaves and determinant, extrinsic roots. The broad stretching design brings about various stem species and a development propensity that ranges from flabellate to polygonal, contingent on the degree and example of fracture. The nearness of abscission layer at the purpose of root and branch connection encourages vegetative spread through discontinuity. Leaves on the rhizome are bilobed with interchange pinnation. Rhizome likewise bears singular roots or root packs at branch focuses. The principle rhizome when full grown may seethe in size from 5 to 70 mm in measurement with singular roots 10 to 50 mm long. The primary rhizome is normally achlorophyllous and has exchanging branches with a few sets of horizontal branches. The species that can develop into an almost vertical morphology when swarmed, for example, A. filiculoides have a profoundly evolved vascular framework. The event of nitrogen fixing Azotobacter, Azospirillum and phosphobacteria on the underlying foundations of A. filiculoides has been accounted for (Kannaiyan and Kumar 2006). The adsorbent made in this investigation was described by examining electron microscopy (SEM) (Model JEOL JSM 6360 Japan) working at 20kV. Tests were gold covered before SEM perception. Figures 3.2-3.3 show that the alga before adsorption had a sporadic and permeable surface, which demonstrated high surface zones. [10]

Identification of Functional Groups

FTIR retention spectra, before sorption is appeared in Figure 3.3 for the biosorbent A. filiculoides. The spectra were standardized to consider for the thickness contrasts in the readied tests and for examination and assurance of changes in the assimilation lines within the sight of the metal ions. Since the infrared radiation can energize the vibration methods of particles, FTIR investigation permits the recognizable proof of sub-atomic bonds present in the biomass. Table 3.3 shows a portion of the practical gatherings present in the biomass.

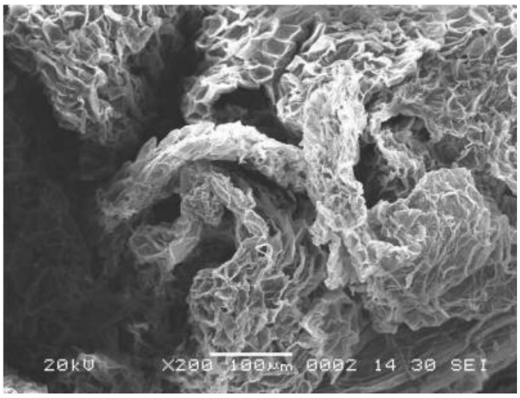

Figure 3.2 SEM image of A. filiculoides before metal ions biosorption 200)×(

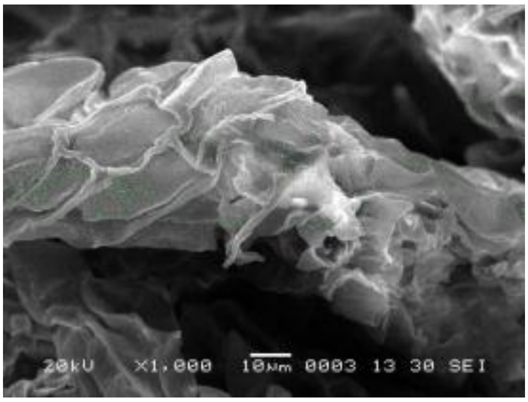

Figure 3.3 SEM images of A. filiculoides before metal ions biosorption 1000)×(

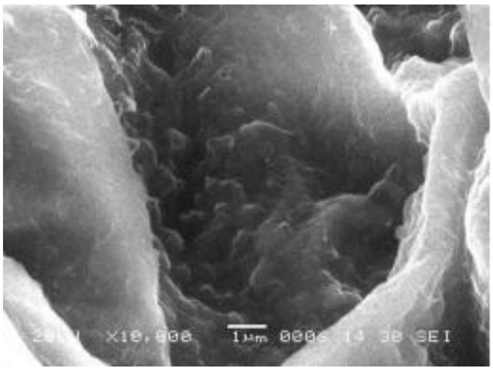

Figure 3.4 SEM image of A. filiculoides before metal ions biosorption 10000)×(

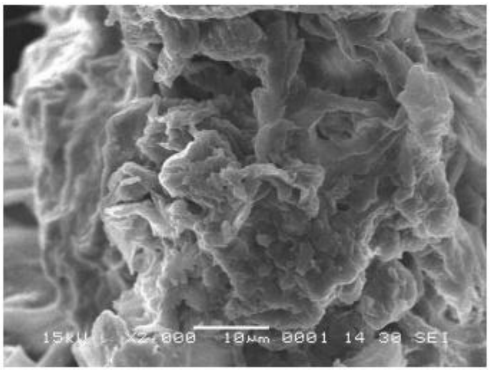

Figure 3.5 SEM images of A. filiculoides before metal ions biosorption 2000)×(

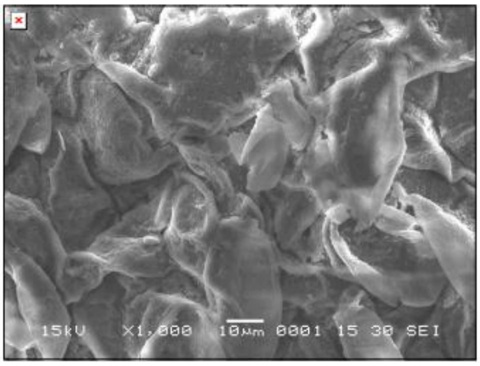

Figure 3.6 SEM images of A. rongpong before metal ions biosorption (1000)

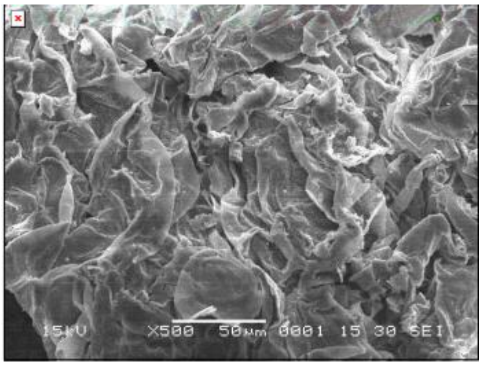

Figure 3.7 SEM images of A. microphylla before metal ions biosorption (500)

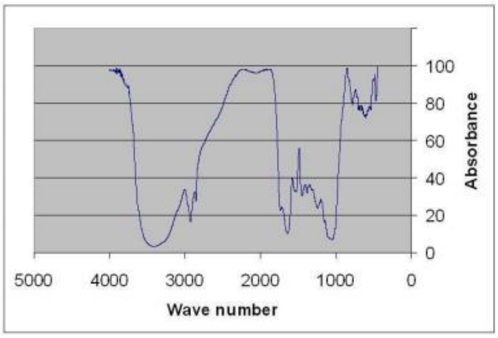

Figure 3.8 FTIR spectrum of A. filiculoides before biosorption

Table 3.3 FTIR - Wavelength and functional group

Wave Number	Functional Group
474	C-C
606	C-H
779	C-H
1058	O-C-C
1237	C=O
1374	-CH3
1446	H-C-H
1533	N-H
1634	C=C-C=C
2851	C-H
3050	-OH

PREPARATION OF STOCK SOLUTIONS

Copper sulfate penta hydrate ($CuSO_4.5H_2O$) stock arrangement was set up with 10,000 mg/l of Cu(II) ions. Cu(II) particle solutions of fluctuating concentrations were set up from the stock arrangement. So also Nickel sulfate ($NiSO_4.7H_2O$) stock arrangement additionally arranged for 10,000 mg/l of Ni(II) ions. [5]

Analytical Methods

Numerous investigative strategies like gravimetry, colorimetry, nuclear retention spectrophotometry, polorography, differential heartbeat anodic stripping voltametry (DPASV) (Singh et al 2000), inductively coupled plasma nuclear discharge spectrophotometry (ICPAES) (Diniz and Volesky 2005b) have been utilized for the estimation of metal ions from arrangement. Colorimetry is utilized for this examination.

Analysis of Copper Ion

The concentration of free Cu(II) ions in the effluent was determined spectrophotometrically. Sodium diethyl dithiocarbamate, 0.2 ml of a 1 % (w/v) solution, and 20 ml of 1.5 N NH_3 solution was added to the sample (1 ml) containing less than 60mg/l of Cu(II) ions and diluted to 25 ml with distilled water. The absorbance of the yellow coloured solution was read at 460 nm (Snell and Snell 1959).[8]

Analysis of Nickel Ion

The grouping of free Ni(II) ions in the gushing was resolved spectrophotometrically. 20 ml of the example arrangement containing under 10 mg of Ni(II) particle per liter was treated with 0.5 ml of 25% HCl and bromine water (2 - 3 drops). After 10 min, 1 ml of alkali arrangement was added to the 69 example arrangement followed by the option of dimethylglyoxime (1 g broke up in 100 ml methanol) and the volume is made up to 50 ml with refined water. The absorbance of wine red to brown hued complex of nickel(II) particle with dimethylglyoxime was perused at a frequency of 440 nm within 15 min in the wake of blending (Snell and Snell 1959; Padmavathy et al 2003b).

RESULT AND DISCUSSION

The central attributes of any biosorbent ought to incorporate examination of energy and harmony of sorption process. The investigation of sorption energy in watery waste treatment is noteworthy as it gives significant bits of knowledge into the system of bisorption. It is imperative to anticipate the rate at which poison is expelled from the solutions.

The balance of sorbate appropriation between the sorbent and arrangement is significant in deciding the degree of sorption limit. Both, energy and balance of the procedure should be portrayed with straightforward, scientific models to foresee the effectiveness of the procedure and to configuration suitable treatment frameworks. An adsorption framework is described by specific constants, the estimations of which express the surface properties and proclivity of the sorbent and can likewise be utilized to locate the biosorptive limit of biomass.[7]

BATCH BIOSORPTION EXPERIMENTS

100 ml of arrangement of realized focus was taken in a funnel shaped flagon. Estimated amount of biomass was included to the arrangement and disturbed at consistent rpm in a revolving shaker. The last convergence of the ions was resolved as referenced in segment 3.3.2 and 3.3.3. All trials were led in copy with the normal introduced in the outcome. Metal take-up 71 by the biosorbent has been determined from the sorption framework mass parity condition (4.1).

$$q_e = \frac{V(C_0 - C_e)}{m} \qquad (4.1)$$

And fractional removal efficiency is determined with the equation (4.2)

$$\eta = \frac{(C_0 - C_e)}{C_0} \qquad (4.2)$$

Effect of Biosorbent Dosage

The impact of dose of Azolla sp. were concentrated by taking 100 ml of copper and nickel ions arrangement with 250 mg/l starting fixation in a funnel shaped cup independently. Measurements of the biosorbent are changed from 1 - 10 g/l of arrangement. The harmony fixation was watched for various measurement of every one of the three Azolla sp. The take-up was determined utilizing condition (4.1). [9]

- **Copper ions**

The take-up of copper ions on the biosorbents is appeared in Table 4.4. Investigation of information shows that the take-up is diminishing regarding dose where as the partial expulsion proficiency of metal ions increments. Increase in measurements expands the biosorption of copper ions because of increment in accessible surface zone of the biosorbent which is corresponding to the dynamic destinations of biosorbents.

Table 4.1 Uptake of copper ions upon Azolla sp. with respect to dosage

Dosage, g/l	Uptake, w/w		
	A. filiculoides	*A .rongpong*	*A. microphylla*
1	0.0349	0.0581	0.0175
2	0.0239	0.0366	0.0062
3	0.0192	0.0260	0.0050
4	0.0151	0.0233	0.0044
5	0.0127	0.0176	0.0030
6	0.0106	0.0141	0.0017
7	0.0091	0.0153	0.0005
8	0.0088	0.0104	0.0016
9	0.0077	0.0101	0.0019
10	0.0064	0.0059	0.0031

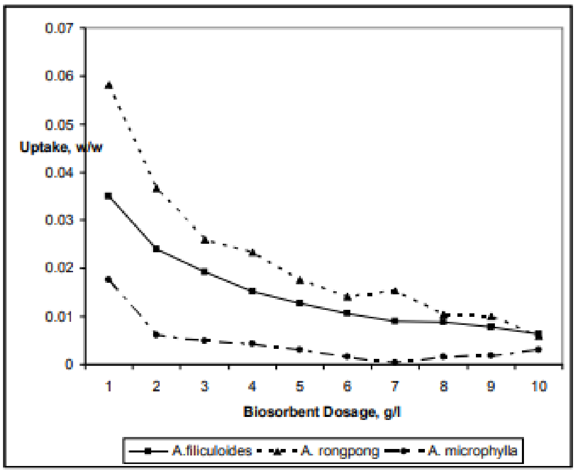

Figure 4.1 Effect of dosage of Azolla sp. on uptake of copper ions

Effect of Initial pH

The arrangement pH is the most significant variable administering the biosorption of metal ions. The analyses were rehashed with different pH conditions, at ideal biosorbent measurements of 1 g/l, with consistent introductory fixation at room temperature.

- **Copper ions**

The underlying pH of the arrangement is a significant factor in copper sorption. Copper take-up was low at pH under 2. Working over pH 5.5 was evaded to forestall the conceivable precipitation of copper hydroxide. The impact of introductory pH on the copper biosorption is given in Figure 4.1 and Table 4.1. Lower estimations of copper take-up at low pH esteems mean that opposition of abundance of protons for similar restricting locales on the algal cell divider (Vijayaraghavan et al 2004). The exhibition of the sorbent is typically relies upon its take-up limit (Volesky 2003a).

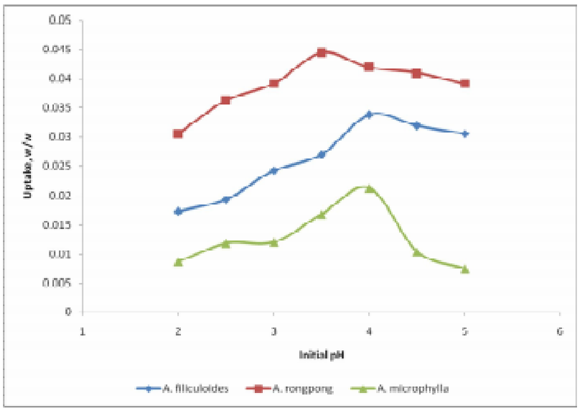

Figure 4.2 Influence of pH on copper ions uptake

Table 4.2 Influence of pH on copper ions uptake

pH	Uptake, w/w		
	A. filiculoides	*A. rongpong*	*A. microphyla*
2.0	0.0173	0.0306	0.0087
2.5	0.0194	0.0363	0.0118
3.0	0.0242	0.0391	0.0120
3.5	0.0269	0.0444	0.0168
4.0	0.0338	0.0419	0.0213
4.5	0.0319	0.0410	0.0104
5.0	0.0306	0.0391	0.0075

Table 4.3 Influence of pH on uptake of copper ions on A. filiculoides

Initial Conc, mg/l	pH 4.0		pH 4.5		pH 5.0	
	Equilibrium Conc, mg/l	Uptake, w/w	Equilibrium Conc, mg/l	Uptake, w/w	Equilibrium Conc, mg/l	Uptake, w/w
200	163.1	0.0368	175.6	0.0244	184.4	0.015
400	289.4	0.1106	318.1	0.0819	326.9	0.073
1000	731.3	0.268	781.3	0.2188	768.8	0.231
2000	1681	0.3188	1656	0.3438	1668	0.331
2500	2093	0.4062	2056	0.4438	2056	0.443

- **Nikel ions**

The expulsion of nickel ions with A. filiculoides is subject to the underlying pH. The take-up changes with the underlying pH. For the underlying grouping of 100 mg/l the greatest nickel take-up was 0.0522 (w/w) got at pH 5 (Table 4.3). The lessening in nickel take-up with increment in pH is expected to hydronium ions contend with cation for trade locales in the framework. For other two green growth nickel take-up expanded with expanding pH, to the most extreme close to pH 4.0 (Figure 4.2), at that point diminished at higher pH esteem. The expansion in metal evacuation as the pH increments can be clarified based on decline in rivalry between protons and metal cations for the equivalent utilitarian gatherings and by decline in the positive surface charge bringing about a lower electrostatic aversion between the surface and metal ions.[6]

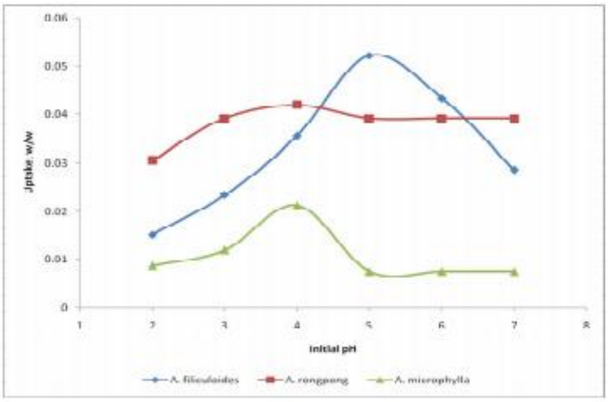

Figure 4.3 Influence of pH on nickel ions uptake

Table 4.4 Influence of pH on nickel ions uptake

pH	Uptake, w/w		
	A. filiculoides	*A. rongpong*	*A. microphyla*
2.0	0.0152	0.0306	0.0087
3.0	0.0235	0.0391	0.0120
4.0	0.0355	0.0419	0.0213
5.0	0.0522	0.0391	0.0075
6.0	0.0433	0.0391	0.0075
7.0	0.0287	0.0391	0.0075

DETERMINATION OF THERMODYNAMIC PARAMETERS

Effect of Temperature

- **Copper ions**

The adsorption of a substance from one stage to the outside of another in a particular framework prompts a thermodynamically characterized dispersion of that substance between the stages as the framework arrives at balance (Lodeiro et al 2005). This circulation can be communicated regarding adsorption isotherms. Isotherm information acquired for three unique temperatures (30°C, 40°C and 50°C) were appeared at Table 4.4. Biosorption rate increments with increment in temperature at first. Since the biosorbent corrupts itself and the structure changes because of delayed presentation of biosorption at raised temperature, the take-up decreases according to the accessibility of dynamic restricting locales.

- **Nickel ions**

The impact of temperature on nickel take-up uopn A. filiculoides and A. rongpong was learned at three unique temperatures, (30°C, 35°C and 40°C) at ideal pH and measurement in Table 4.5 and 4.36. Biosorption of nickel is seen as most extreme at 30°C and the metal take-up diminished with increment in temperature.

Table 4.5 Isotherm of copper ions take-up for various temperatures for A. filiculoides

Initial Concentration, mg/l	Copper ions uptake, w/w		
	30 °C	40 °C	50 °C
0	0	0	0
200	0.024375	0.025625	0.036875
400	0.081875	0.144375	0.144375
600	0.15625	0.25625	0.21875
1500	0.21875	0.29375	0.34375
2000	0.34375	0.36875	0.64375
3000	0.44375	0.39375	0.68125

Table 4.6 Influence of temperature on A. filiculoides on nickel uptake

Initial Concentration, mg/l	Nickel uptake, w/w		
	30°C	35°C	40°C
200	0.0454	0.0446	0.0065
400	0.0785	0.0656	0.0263
600	0.120	0.126	0.0416
800	0.144	0.147	0.0784
1000	0.183	0.199	0.105

PROPOSED MODELS

Lumped Parameter Model

The estimation of the void space of the bed ε, is preposterous measure precisely because of the permeable idea of the biomass. The advancement bend is regularly communicated as products of bed volumes, without reference if this estimation depends on the void or the unfilled volume. The thickness of the biosorbent is likewise a huge boundary. The fundamental fitting boundary of the model was the segment clear pivotal scattering coefficient, which joins biosorption energy and follow non-idealities.

Lumped boundary model is especially utilized when no critical information exist to legitimize numerical solutions to the vehicle condition. They are additionally valuable in early investigations of mostly secret framework. For a circumspect examining site, just the utilization of lumped boundary model is adequately defended.

In spite of the fact that a few agents opined that, in the time of numerical models, this methodology is outdated. Anyway experience shows that various delegate boundaries can be acquired from the lumped boundary way to deal with the understanding of execution of stuffed bed adsorption segment just as the attributes of the biosorbent, viz-a-viz the biosorption active steady in a modest and compelling manner. The model actualizes the base boundaries for portraying a fixed bed biosorption section, utilizing the mathematical dimensions of the bed, the pressing game plan, the working conditions of the framework and the sorptive attributes of the biosorbents (Equations 4.48 and 4.49).

$$\frac{C_t}{C_0} = 1 - \frac{1}{1 + k_{NV} t^2} \qquad (4.48)$$

$$k_{NV} = \left(\frac{\varepsilon^3}{1-\varepsilon}\right)\frac{q_m^2 C_0 f k}{\rho_b A h} \qquad (4.49)$$

From the estimation of kNV got through non-straight fitting of the exploratory information, the biosorption rate steady can be figured with condition (4.49).

Two section tests were led for biosorption of copper and nickel ions utilizing A. rongpong. Figures 4.5 and 4.4 shows the above model. The lumped boundary was gotten by fitting the model condition (4.48). The biosorption rate steady k can be developed with the assistance of condition (4.49). The information was fitted with this model for copper ions with A. ronpong and the estimation of the lumped boundary steady kNV is 0.01204 with r2 estimation of 0.948, the estimation of active consistent k is 0.000937 s-1 . This information is in agrement with the worth acquired through regular strategies. For shorter mass exchange period where the advancement bend is more extreme, this model may not fit well as appeared in Figure 4.4. The estimation of kNV for nickel ions is 0.04506 and r2 vale is 0.875.

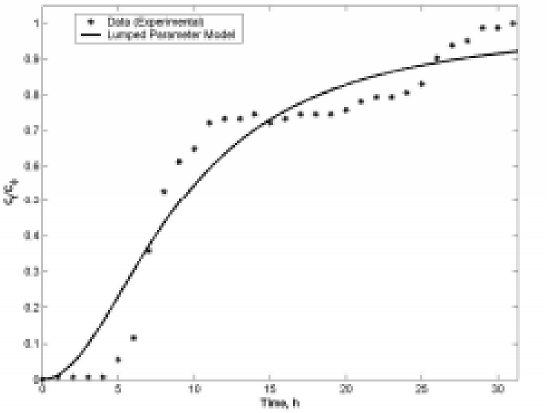

Figure 4.4 Lumped parameter model for breakthrough curve of A. rongpong for copper ion

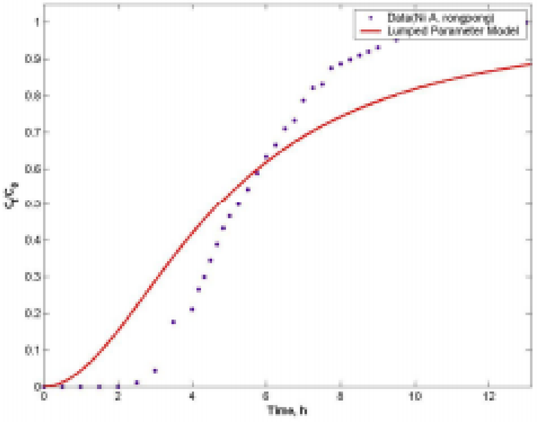

Figure 4.5 Lumped boundary model for advancement bend of A. rongpong for nickel ions 133

An Alternate Empirical Model

The trial information got from the consistent pack bed framework study has been fit into the accompanying structure given in condition (4.50). The lists kNV1 and n1 demonstrate the methodology of advancement time and the steepness of the bend at the mass exchange zone.

$$\frac{C_t}{C_0} = 1 - \frac{1}{1 + k_{NV1} t^{n1}} \qquad (4.50)$$

Figure 4.41 give an acceptable forecast of test and anticipated an incentive with the connection coefficient of 0.997. The estimation of model boundary kNV1 is 0.006527 and n1 is 2.258 for copper ions. Also the estimations of kNV1 and n1for nickel ions are 0.0004993 and 4.59. Higher estimation of n1 shows the shorter mass exchange zone or the advancement is more extreme during that period as appeared in Figure 4.6.

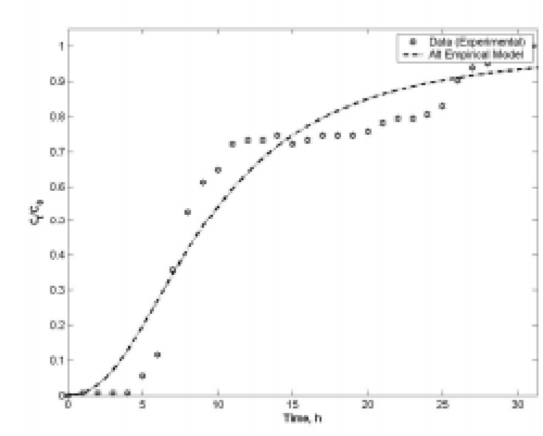

Figure 4.6 Empirical model for breakthrough curve of A. rongpong for copper ions

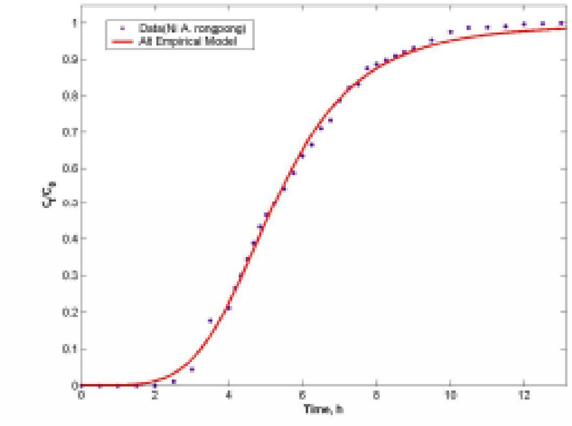

Figure 4.7 Empirical model for the breakthrough curve of A. rongpong for nickel ions

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