

**Studies, Synthesis and Characterization of Chelation Ion-Exchange Properties of
Copolymer Resin Derived from 8-Hydroxyquinoline-Formaldehyde-Pyrogallol**

Soumaya GHARBI ^{a,*}, Jameleddine KHIARI ^b, Bassem JAMOUSSE ^a

^a *Research Laboratory Analytical Chemistry, Macromolecular and Heterocyclic. IPEST,
TUNISIA*

^b *Preparatory Institute for Engineering Studies of Bizerte. TUNISIA*

Author details:

Soumaya Gharbi ^{a,*}, Jameleddine Khiari ^b, Bassem Jamoussi ^a

^a Research Laboratory Analytical Chemistry, Macromolecular and Heterocyclic

^b Preparatory Institute for Engineering Studies of Bizerte

***Corresponding author. E-mail address: gharbisoumaya10@gmail.com**

gharbisoumaya10@gmail.com

ABSTRACT

Chelating ion-exchange resin was synthesized by the condensation of 8-hydroxyquinoline with pyrogallol using formaldehyde as a cross-linking agent at 120 °C in DMF in the presence of hydrochloric acid catalyst.

The resin was characterized by elemental analysis and FTIR.

The morphology of the synthesis resin was examined by optical photograph and scanning electron microscopy (SEM).

The physicochemical properties of the resin were studied. The cation exchange capacity was measured and the effect of pH and metal ion concentration on the ability of the ion exchange were studied. The ratio of cation exchange reaction and the distribution coefficient in tartaric acid medium at different pH were also studied using the method of batch equilibration.

Keywords: Chelating resin, Batch equilibration, Physico-chemical properties, Distribution coefficient

26 **Introduction**

27 Over the past years, there has been a growing concern for the immobilization of metal
28 ions introduced into bodies of water and wastewater by increasing human technological
29 activities. It has been established beyond doubt that the ions of heavy metals in the
30 environment (air, soil and water) pose a serious threat to human health. With the exponential
31 growth of the population, it is necessary to control the release of toxic heavy metal ions
32 before entering the complex ecosystem.

33 Separation, removal, and the enrichment of metals in trace amounts in aqueous solutions,
34 have an important role in wastewater, industrial or geological sample analysis. The solid
35 phase extraction on the metal ion was granted fast acceptance due to its various advantages
36 over other the invention also provides methods. The extraction of metal ions using ion
37 exchange resin is a chelating power green analytical method, since it does not involve the use
38 of toxic organic chlorine compounds, which are very frequently used in conventional
39 techniques liquid-liquid extraction.

40 The main objective of much of the research on chelating resins was the preparation of the
41 insoluble part functionalized polymers that can provide in conjunction with more flexible
42 working conditions good stability and high capacity for metal ions. The use of the modified
43 clay minerals for the adsorption of metal ions from aqueous solutions for purification of
44 industrial water or waste water, the treatment has been widely studied.

45 These clay minerals, when used as colloids or powders were found to be effective as ion
46 equally exchange resin, but it is difficult to retrieve from these adsorbents filters after use.
47 This also regeneration and makes possible very difficult to reuse clay adsorbents.

48 Chelating ion exchange resins have also been prepared by copolycondensing or 8-
49 hydroxyquinoline phenol derivatives such as o-aminophenol, resorcinol or resorcylic acid
50 With formaldehyde [1].

51 Antico and al synthesized from a gel-type ion exchange resin, Glycol 8-hydroxyquinoline
52 methacrylate and used to investigate separating Pb (II) and Cu (II) in the chloride solution
53 [2]. Chelating ion exchange resins also have been synthesized by the Friedel-Crafts
54 condensation 8-hydroxyquinoline [3] and substituted 8-hydroxyquinoline with [4] 1,2-
55 dichloroethylene. The synthetic resins have been found selective for certain metal ions over a
56 wide pH range. The chelating behavior poly (8- Quinoline-5, 7-dimethylene) [5] and its
57 crosslinked polymer [6] from the reaction with different amounts of bisphenol-a to certain
58 trivalent ions of lanthanides such that La (II) and Gd (II) was investigated by static a load
59 balancing Method. Vernon and al. prepared and studied chelating properties of toxin resinto
60 the transition metal ions [7,8] stability test, they suggested that the gel polymers must never
61 be allowed to dry; otherwise their favourable properties are destroyed.

62 Shah and al. [9,10] and Warshwsky and al [11] reported certain resins based on 8-
63 hydroxyquinoline and substituted 8-hydroxyquinoline, respectively, and chelating properties
64 to transition and post-transition metal ions. A chelating ion exchange resin was synthesized
65 from 8-hydroxyquinoline and catechol using formaldehyde have been synthesized by Shah
66 and al. [12]

67 Until now, no resin based on 8-hydroxyquinoline pyrogallol-formaldehyde in DMF has been
68 insert for quantitative removal and separation transition metal ions and post transition. As
69 industrial effluents are often rich in transition and transition metal ions after, removing the
70 metals a large industrial task. The study described in the present communication processes of
71 synthesis and characterization of aboveres together with the systematic studies of various
72 properties of ion exchange resin.

73 **Materials and methods**

74 **Materials**

75 8-Hydroxyquinoline (Prolabo, IGT Paris) and formaldehyde were purified by
76 recrystallization method.

77 Pyrogallol (Glaxo extra pure) was purified by rectified spirit.

78 Metal ion solutions (KANTO CHEMICAL CO,INC.) were used as received.

79 **Synthesis Method**

80 8-hydroxyquinoline (14.5 g, 0.1 mole) has been ground into fine powder and taken in a (250
81 ml) round bottom balloon and dissolved in DMF (25 ml) to give a clear yellow solution.

82 Formaldehyde (7.5 ml, 0.25 mol as 37%) added and stirred until a solution of red color.

83 A pyrogallol solution (11 g, 0.1 mole) in (10 ml) DMF has been added to above the solution
84 and stirring for 3 h. Then, the mixture has been heated to reflux on a water bath at 90°C
85 under constant stirring for 3 to 5 h.

86 Condensation reagents was carried out in the presence of an acid HCl 2M on sand bath by
87 heating to 120°C during 7 -8 h until a viscous solution with formation of a hard mass of
88 brown colored resin has been obtained.

89 The synthetic resin has been removed from the reaction vessel and cured in an oven at 70 -
90 80°C during 12 h. The resulting resin having been washed with DMF and deionized water to
91 remove unreacted monomers and impurities. After the complete washing cycle, the reaction
92 yield production of the resin synthesized was 50% (15 g).

93 The resin sample has been purified and dried finely crushed and sieved to obtained
94 uniform particles of 50 -70 mesh and stored in polyethylene bottle. The resin has been then
95 screened characterized using different instrumental analysis techniques and was used for the
96 entire experiments during the search period. Testing of solubility of the resin in a different
97 solvent were performed at room temperature and pressure with intermittent agitation. The
98 resin has been found being insoluble in all common organic solvents such as acetone,
99 ethanol, benzene, chloroform *etc.* and all acids and alkalies of higher strengths.

100 Infra-Red spectra of the synthesized resin sample have been carried out without solvent on a
101 Thermo Scientific Nicolet spectrometer IR-200 FT-IR, which is the measurement accuracy
102 of 4 cm⁻¹ in the area 400-4000cm⁻¹.

103 The allocation FTIR spectra peaks are presented in Fig.1.

104 Elemental analysis was performed on a Carlo ZAF EDAX quantification (Standard Less).
105 The results of the elemental analysis are in good accordance with the calculated values of
106 %C, % H and % N which is presented in Table 1.

107 To convert the resin sample in its H⁺ form, it has been equilibrated with a solution of HCl
108 1M for 24 h and washed with deionized water until it is free from chloride by testing with
109 silver nitrate solution.

110 The H^+ form of the resin have been used for subsequent studies. The batch equilibrium
111 method has been adopted for studying the ion-exchange properties.

112 Physico-chemical properties such as moisture and solid contents, apparent density, true
113 density and void volume fraction have been studied by the methods of the literature [13].

114 The sorption properties such as exchange rate, pH effect on the exchange capacity, effect of
115 the cation concentration on the exchange capacity and distribution coefficient (K_d) values for
116 various metal ions as a function of pH and concentration of the electrolyte have been studied
117 with the literature methods [14,15]. The value of the void volume fraction has been found
118 0.36, while other resins signaled 8-hydroxyquinoline formaldehyde [8], 8-hydroxyquinoline
119 formaldehyde resorcinol [9] and 8-hydroxyquinoline formaldehyde catechol [12] exhibited
120 void volume fraction values of 0.54, 0.59 and 0.36, respectively.

121 **Rate of Exchange of Metal Ions**

122 For the experiment, an accurately weighed (0.250 ± 0.001 g) dry resin in the H^+ form was
123 taken into different glass bottles stoppered and equilibrated with a desired pH values
124 with buffer solution for 24 h. After decanting of the buffer solution, 50 ml (0.2 M) of metal
125 ion solution was added with the same pH. The amount of non-chelated metal ion has been
126 determined by Atomic Absorption Spectroscopy (AAS) at fixed time intervals. The results
127 are shown in Fig. 2.

128 **Effect of pH on Metal Ion Exchange Capacity**

129 To study the pH effect on absorbing metal ions, it is necessary to buffer the resin and
130 solutions used. For this purpose, buffer solutions of pH 3- 6 have been prepared from 0.2 M
131 acetic acid and 0.2 M sodium acetate solutions [16].

132 A pH-meter (Elico, model CL-44) has been used for measuring the pH. Different weighing
133 assemblies (0.250 ± 0.001 g) dry resin have been equilibrated with buffer in different bottles
134 closed during 24 h, so that the resin attained the desired pH value.

135 After 24 h, buffer solutions have been decanted and (50 ml) of 0.2 M metal ion solutions
136 pH ranging from 3 to 6 have been added. Metal ion solutions have been equilibrated at room
137 temperature for 24 h with intermittent agitation.

138 After 24 h, the solutions were decanted and metal ion concentration in the supernatant was
139 measured by a method Atomic absorption spectroscopy (AAS) which is a spectral procedure
140 for the quantitative determination of chemical elements employing the absorption of optical
141 radiation (light) by free atoms in the gaseous state.

142 The same method was followed throughout the study to calculate the ion exchange capacity
143 of the resin as:

144 *Exchange capacity (mmol.g⁻¹)*

145

$$= \frac{[\text{Initial molarity of the metal ion}] - [\text{Remaining molarity of the metal ion}]}{\text{Atomic molar mass of the metal} * \text{Weight of the resin sample}}$$

146 **Effect of Metal Ion Concentration on Exchange Capacity**

147 To study the metal ion concentration effect on uptake of different metal ions by the resin, the
148 resin has been equilibrated with an acetate buffer to desired pH (pH value of highest
149 exchange) for 24 h and buffer solutions were then decanted. An accurately weighed ($0.250 \pm$

150 0.001 g) dry resin has been equilibrated with metal ion solutions (50 ml) with variant mass
151 concentration (eg, 1 ppm, 2 ppm, 3 ppm, 4 ppm to 5 ppm) at the same pH value at room
152 temperature during 24 h with intermittent agitation.

153 After 24 h, the metal ion solutions were decanted and non-chelated metal ions have been
154 estimated by atomic absorption spectroscopy (AAS).

155 **K_d Values for Metal Ions in Presence of Electrolyte (Tartaric Acid) Solution**

156 Measurement of distribution coefficient of metal ions over a wide range of condition is the
157 best method to avoid choosing elution conditions for separation columns by a strictly trial
158 and error process. The batch distribution coefficient, K_d is defined as:

$$159 \quad K_d = \frac{\text{mmole of metal ion on resin} * \text{volume of metal ion solution}}{\text{mmole of metal in solution} * \text{weight of dry resin}}$$

160 Although this distribution coefficient is measured on a base discontinuously, it can be used to
161 predict elution behavior metal ions eluted from an ion-exchange column. For separating two
162 substances, the conditions should be chosen such that the distribution coefficient of one of
163 them is small (preferably 1 or less) so that it eluting the column is fast, while the distribution
164 coefficient of the other substance, under the same conditions should be as large as possible
165 (more than 10 times) such that the substance is firmly held by the resin [17].

166 Effect of different concentrations and pH of the electrolyte (tartaric acid) to adsorbing metal
167 ion the synthetic resin was investigated. A dry resin sample weighed exactly (0.250 ± 0.001
168 g) has been suspended in the electrolyte solution (tartaric acid) of 50 ml different known
169 concentrations (eg 0.1 M, 0.2 M, 0.3 M, 0.5 M and 1 M). The pH of the suspension was
170 adjusted to the desired value using acetate buffer and the resin has been equilibrated for 24 h.
171 To the suspension, 2.0 ml of different metal ion solutions under study (5 mg.ml^{-1}) was added

172 to be equilibrated for 24 h with intermittent agitation. After 24 h, the solutions were decanted
173 and unabsorbed metal ions were estimated.

174 **RESULTS AND DISCUSSION**

175 **Physico-chemical properties**

176 Physicochemical properties of the synthesized resin are presented in Table 2. Moisture
177 content of a resin providing a measure of its water swelling capacity or its loading capacity.
178 The water content depends on numerous factors, such that the composition of the resin
179 matrix, the cross-linking degree or the nature of the active groups and the ionic resin form.
180 The degree of cross-linking a resin has an effect on the moisture content and moisture
181 content of the resin, and therefore, has an effect on the selectivity. In a high moisture content
182 of the resin, the active groups are more spaced apart, eg strong acid cation resins contain
183 about 50% moisture. The water content percentage of synthetic resin, as shown in Table 2 is
184 5.25%.

185 Therefore, the resin has a low moisture percentage range relative to the commercial resins.
186 Resins synthesized from salicylic acid and furfural-benzidine p-hydroxybenzoic acid-
187 furfural-benzidine [18] have lower moisture contents (4.01 and 4.9% respectively) than the
188 synthesized resin.

189 The resin synthesized from 8-hydroxyquinoline-pyrogallol-formaldehyde [12] and salicylic
190 acid formaldehyde-m-cresol [19] had slightly higher moisture content (5.64 to 9.4%,
191 respectively).The moisture differential may be caused by different experimental conditions,
192 such as carriers, wherein the resins have been synthesized, the polymer backbones, the cross-
193 linking degree and the functional groups involved.

194 The true density of the synthetic resin is 0.95 g.cm^{-3} , which is given in Table 2. The actual
195 density commercial resins is generally between 1.1 to 1.7 g cm^{-3} . To prevent flutter of resin
196 particles, the actual density floating must be greater than a resin particles is not desirable in
197 chromatographic studies, as disturbs forming a compact column. The optimum density and
198 size uniform particles allow the perfect column packing and column performance.
199 Measuring the density of the column or the apparent density is necessary that the resins are
200 commercially available on a volume basis and packed on a weight basis. The bulk density of
201 the polymer synthesized is given in Table 2, from which to see that the apparent density of
202 the resin is in the range of 0.51 g cm^{-3} , which is comparable to the density commodity resins.
203 This can be due to changes in the polymer matrix, different functional groups and the
204 synthesis process.
205 The apparent density parameter gives an indication of the required length of a column packed
206 with a study of the ideal chromatographic column.
207 The value of the void volume fraction resin is also given in table a vacuum volume fraction
208 of the synthetic resin was the order of $0,38$. The sensitive value the void volume fraction is
209 broadcast on the resin and exchangeable ion exchange rate increases leaving ions. The
210 essential minimum void volume has an improved diffusion exchangeable ion and gives the
211 feasibility of the operation of the column thereby.

212 **Spectral Characterization of Resin**

213 The FTIR spectrum of the resin is shown in Fig. 1. A strong band at 3300 cm^{-1} is due to the
214 $\nu(\text{O-H})$ stretching of phenolic group, a medium band at 3066 cm^{-1} is due to the $\nu(\text{C- H})$
215 stretching of aromatic ring and the presence of a medium-strong band at 2900 cm^{-1} is due to
216 the $\nu(\text{C-H})$ stretching of methylene group. The bands at 1666 , 1585 and 1447 cm^{-1} can be

217 assigned to $\nu(\text{C}=\text{N})$ heterocyclic ring and $\nu(\text{C}=\text{C})$ aromatic ring stretching, respectively. A
218 band at 1442 cm^{-1} is also due to $\delta(\text{C}-\text{H})$ deformation of methylene group [9]. The presence of
219 a medium-strong band at 1384 cm^{-1} can be assigned to in plane $\delta(\text{O}-\text{H})$ bending of aromatic
220 and a band at 1285 cm^{-1} is due to aromatic $\nu(\text{C}-\text{O})$ stretching. A sharp single band at 781 cm^{-1} ,
221 which can be assigned to the presence of 1,2,3,4,5-penta substituted benzene ring [10],
222 confirms the polymerization of monomers.

223 **Elemental Analysis**

224 The theoretical percent of carbon, nitrogen and hydrogen content of the resin have been
225 calculated from the general formula ($\text{C}_{17}\text{H}_{13}\text{NO}_4$) of the repeating unit of the structure likely
226 (Scheme 1). Table 1 show that the results of the elemental analysis are in good accordance
227 with the calculated values. The elemental analysis results are supported the proposed
228 structure of the resin presented in Scheme 1.

229 **Optical and SEM Photographs**

230 The morphology of the insert resin sample was investigated by scanning electron
231 micrographs, which are represented in Fig. 2 and Fig. 3, respectively. The synthetic resin
232 optical photographing showed that it is of a brown color. The morphology of the resin shows
233 a fringed model of the, crystalline-amorphous structure.

234 The fringes represent transition state between the crystalline and amorphous phase [20]. The
235 resin exhibits more amorphous character with closed packed surface having deep pits (Figs.
236 3a and 3b) as it compared with anthranilic acid-formaldehyde-resorcinol resin and 8-
237 hydroxyquinoline-formaldehyde-pyrogallol resin reported earlier [12 -20].

238 Surface analysis has been found to be useful in the understanding surface features of the
239 material. The morphology of the resin parts crystal growth from polymer solutions

240 corresponding to the largest organization large scale in polymers, eg in size spherulites of a
241 few millimeters. Ideally, the spherulites are aggregates of size sub-microscopic particles.
242 Spherulites are characterized by the secondary structure features, such as faint corrugations.
243 The higher magnification 500 'shows the coexistence of an appreciable amorphous fraction
244 with a small amount of shallow pits.
245 The surface of the resin (Fig.3) contributes greater segments of crystalline regions.

246 **Rate of Exchange for Metal Ions**

247 As the base resin structure is important in physical absorption metal ions by the different
248 copolymers of the resin. From the results, viewed that the metal ion exchange rate is faster at
249 the beginning and then slow. These occur due to the removal or exchange of ions of the
250 solution the surface of the resin and after the entire available site (group) were occupied
251 resin. It results in slower rate of the exchange. Fig . 4 shows the rate of exchange of the metal
252 ion of the synthetic resin.

253 Metal ion exchange on the resin has a time dependent phenomenon. The rate of different
254 metal ion exchange was to determine the shortest time interval for which equilibrium can be
255 performed [21]. The graph represented on Fig. 4 indicates that time required for the exchange
256 of 50% ($t_{1/2}$) for Cu (II) is 30 min and Zn (II) and Pb (II) are 50 and 56 min, respectively.
257 This is assigned to the Cu (II) hydrated have radii smaller (0.419 nm) that hydrated Zn (II)
258 (0.430 nm) and thus have greater access to the resin surface. The order of the exchange
259 capacity is:



261 Rapid exchange rate in the beginning can be explained on the basis of mass action of the law
262 and the equilibrium state.

263 The exchange rate greater facilitates the chromatographic separation column. Metal ion
264 exchange kinetics mainly depends on various physical properties, including the particle size
265 distribution, the size pores, the physical base structure and diffusion of counterion [13,14]

266 **Effect of pH on Exchange Capacity**

267 Metal removal ions from an aqueous solution by sorption is strongly dependent on pH of the
268 solution which influences the surface charge of the sorbent [20]. Chelating ligands form
269 complexes with various metal ions in specific pH conditions [21]. Therefore, the synthesis
270 resin has been used to study the effect of varying pH on its chelating ability to various
271 metal ions. The results of the exchange capacity depending on the pH for different metal ions
272 are presented in Fig. 5. The results show that the sorption metal ions is increased with
273 increasing pH to a maximum value and thereafter decreased.

274 Maximum sorption occurred Cu (II) at pH 6, Zn (II) at pH 4 and Pb (II) at pH 4. The order of
275 selectivity for the metal ions is : Cu (II) > Zn (II) > Pb (II).

276 An increase in pH increases the negatively charged nature of the sorbent surface. This leads
277 to an increase in the electrostatic attraction between positively charged metal ions and
278 negatively charged sorbent and results in increased sorption of metal ions. At lower pH, the
279 removal of metal ions is decreased due to the higher concentration of H^+ ions present in the
280 reaction mixture which compete with the metal ions for the sorption sites at the surface.

281 Meanwhile, the observed decrease in sorption capacity is due to the formation of insoluble
282 metal ion hydroxides [22].

283 In the case of Pb(II) purely electrostatic factors are responsible. Due to the less deep pits,
284 resin exhibits lower ion exchange capacity for Pb(II). Pb(II) has bigger hydrated radii, so it
285 cannot easily penetrate to originate in more crystalline region of the polymeric network.

286 Therefore, the cleaner separation can be obtained from the browser binary mixture Pb (II)
287 with transition metal ions such as Cu (II) or Zn (II).

288 **Effect of Metal Ion Concentration on Exchange Capacity**

289 Examination data presented in Fig. 6 shows that the amount of adsorbed metal ions
290 increases with increasing concentration of metal ions in the solution to a maximum value,
291 and will remain constant while new increase of metal concentration. A low concentration of
292 metal ions, the available number of metal ions in the solution is low relative to the
293 arrangement sites on the sorbent [22]. However, at higher concentrations, the sorption
294 available sites remain same as more metal ions are available for sorption and subsequently
295 sorption becomes almost constant then after [9,10].

296 **Effect of Electrolyte Concentration and pH on Distribution Coefficient (K_d) Values**

297 Batch process of equilibrium is useful to determine the distribution coefficient (K_d) for the
298 metal ions depending on the concentration of tartaric acid. Tartaric acid is a potent chelating
299 elution agent. It contains six oxygen atoms with unshared electron pairs, which from
300 complexes of chelating metal ions more stable with resin-metal complexes. Tartaric acid can
301 easily eluting resin metal ions and give clear separation.

302 Distribution coefficient values (K_d) for different metal ions have been determined by the
303 batch equilibration method. The K_d values have been investigated metal ions depending on
304 pH and the concentration of the electrolyte solution and the results are shown in table 3. The
305 present survey limit distribution studies to a certain pH to each metal ion to avoid hydrolysis
306 metal ions at a pH above [9]. As is evident from the following table 3, any electrolyte
307 concentrations and the entire pH range, the values of K_d decrease in order Pb (II) > Zn (II)
308 > Cu (II).

309 Meanwhile, in all cases, the K_d values decrease with increasing electrolyte concentration and
310 increase with increasing in pH. It is expected that distribution coefficients metal ions can
311 vary depending on the stability metal complexes with chelating groups of the resin. Best
312 results for stabilizing higher distribution coefficients.

313 This study limit distribution studies to a certain pH to each metal ion to avoid hydrolysis
314 metal ions at a higher pH.

315 It is evident that to obtain sharper separation metal ions, large values of ΔK_d should selected
316 from the same experimental conditions [23].

317 **Analytical application**

318 **Removal of toxic metal from industrial effluents.**

319 The efficiency of recovery of metal ions from the effluent has been examined using the
320 synthetic resin. The effluents have been collected from waste industry discharges batteries
321 (Tunisian Plant) and industrial emissions galvanizing (Tunisian Plant too) for the Pb (II) and
322 Zn (II), respectively. The initial concentrations of Zn (II) and Pb (II) in the effluents are
323 found to be 165 and 101 mg dm⁻³, respectively. Industrial effluent analysis has been carried
324 out in a simple manner using the synthetic resin. The resin has been introduced into a column
325 (diameter is 0.5 cm) for a length of 15 cm. The filled resin has been pr-equilibrated at pH 3.
326 The pH of the effluent containing Pb has been adjusted to 3 and pass through the resin
327 column at a rate of 1 cm³ min⁻¹, followed by a gentle washing with deionized water. The
328 chelated lead has been eluted with a tartaric acid solution 1 M at pH 3.

329 The chelated lead has been eluted with a tartaric acid solution to 1 M to pH 3. It has been
330 found that removal and recovery of copper from the effluent were quantitative.

331 The pH of the industrial effluent containing Zn (100 cm^3) has been adjusted to 3 using a
332 buffer solution and passed through the resin column at a rate of $1\text{ cm}^3\text{ min}^{-1}$ stream, followed
333 by washing with water carefully.

334 The results showed 92% Pb (II) and 89% Pb (II) recovery of industrial effluents using the
335 resin. The synthetic resin may be adopted for the industrial processing(treatment) of
336 wastewater.

337 CONCLUSIONS

338 In conclusion, the chelating resin derived from Pyrogallol and 8-Hydroxyquinoline with
339 formaldehyde was useful cation exchanger for divalent metal ions. A SEM image of the
340 resin establishes the amorphous nature of the resin which helps for the higher metal ion
341 uptake. The synthesized resin can be used for the removal of toxic heavy metals from
342 aqueous media and industrial wastewater containing Cu(II) and Pb(II). The recovery of the
343 metals from Industrial effluents gives an indication of the utilization potential of the
344 synthesized resin for wastewater treatment.

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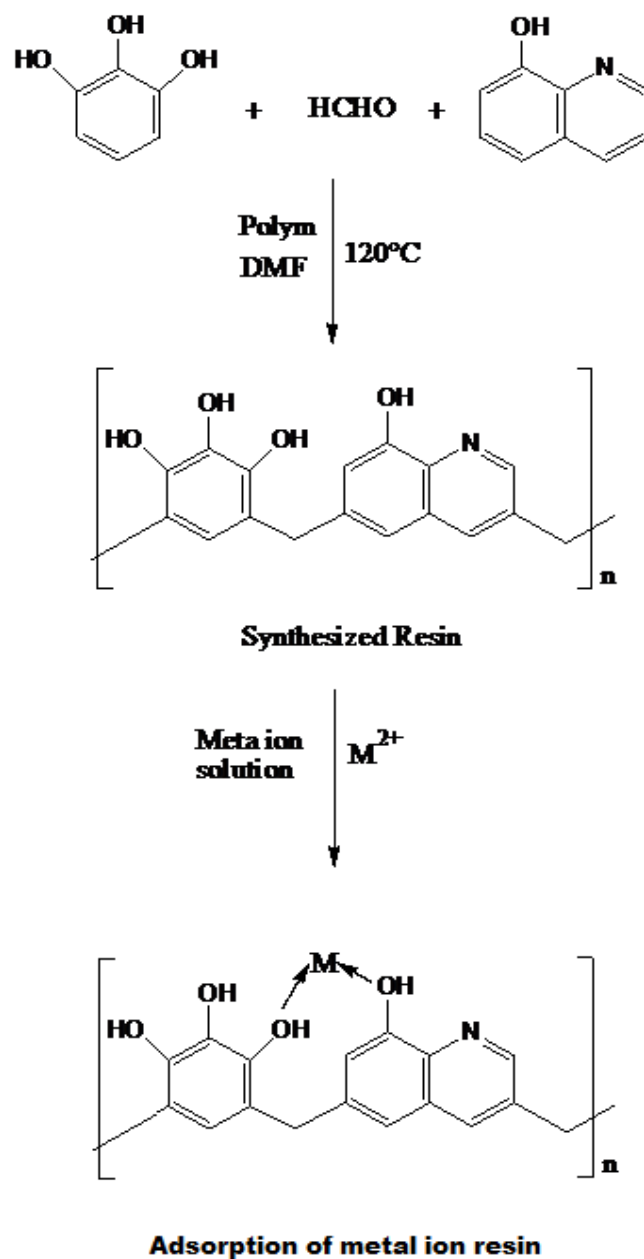
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406

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Scheme 1

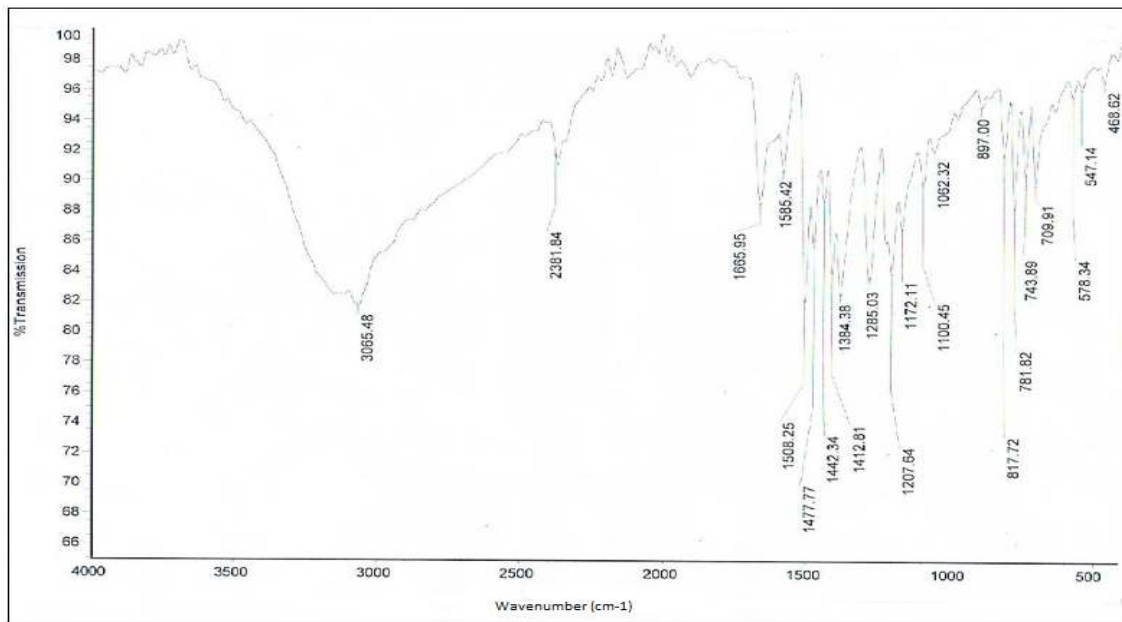


Fig. 1. FTIR spectrum of resin

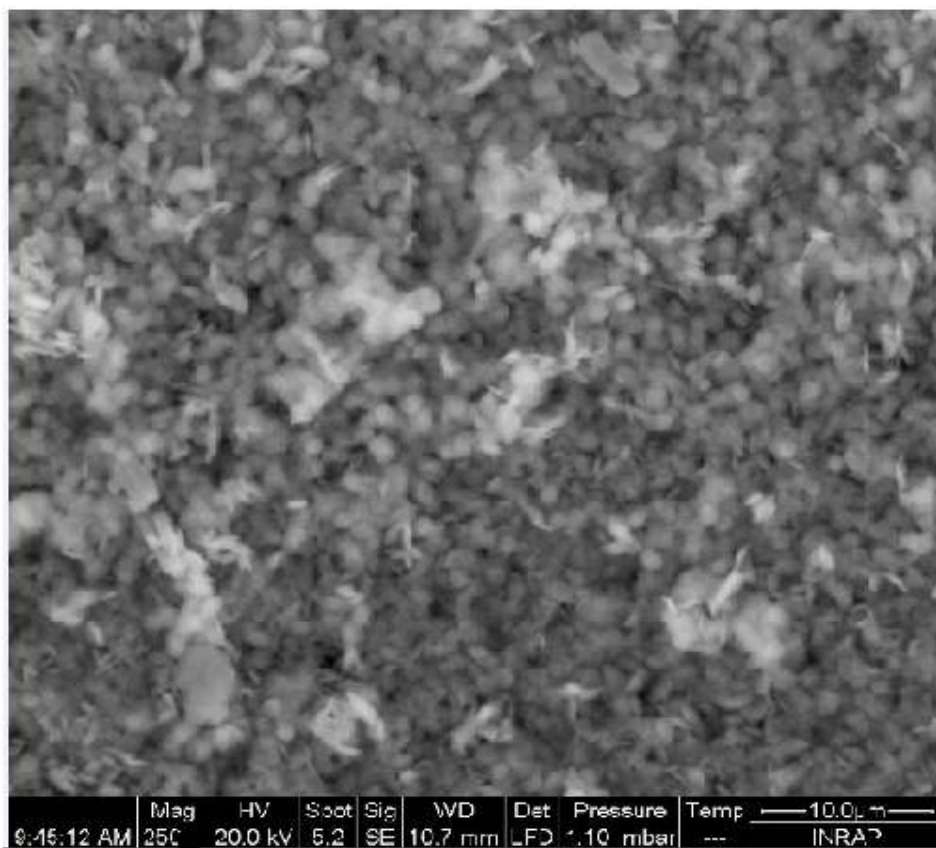


Fig. 2. Optical photograph of resin 250X Magnifications

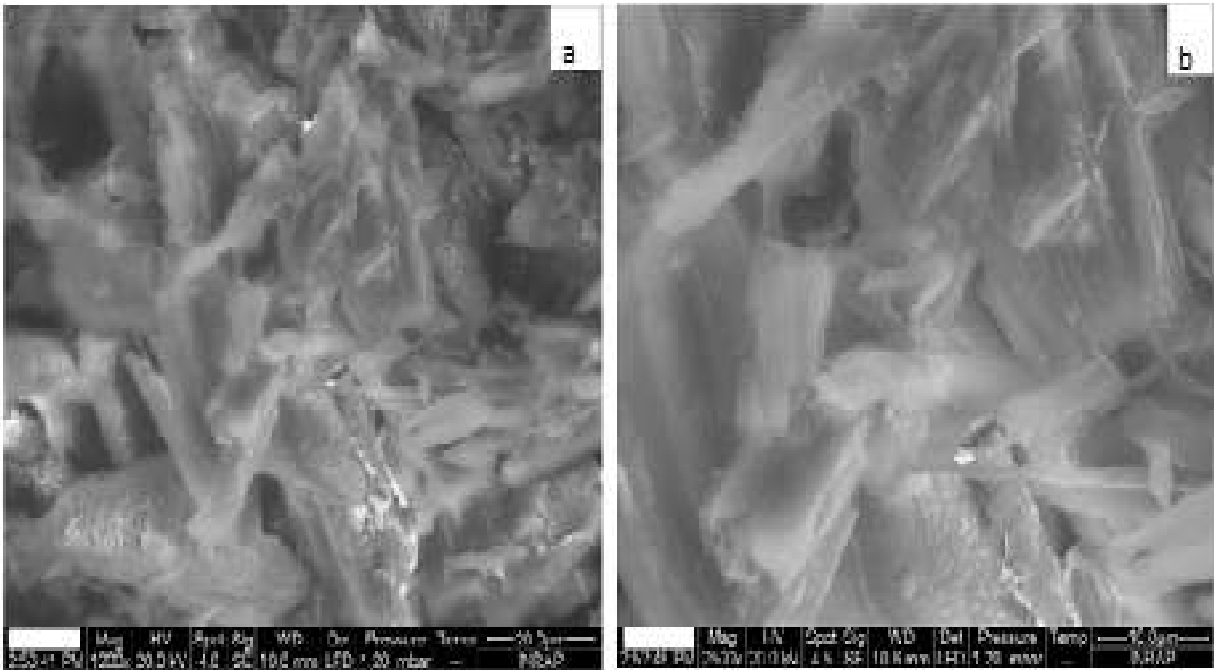


Fig. 3. SEM photograph of resin at (a) 1200X and (b) 2500X Magnifications

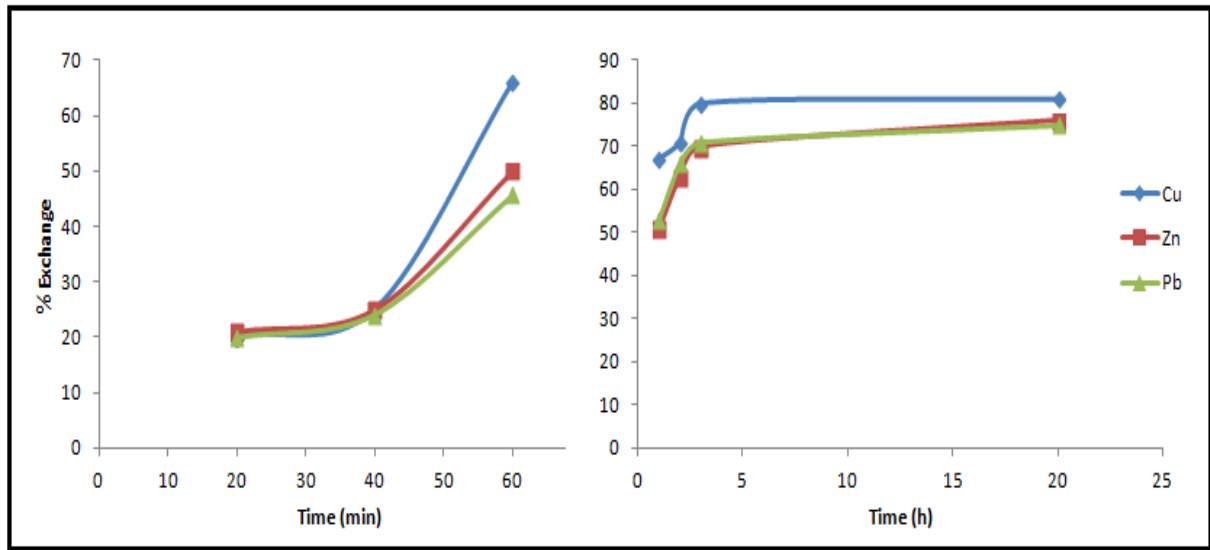


Fig. 4. Rate of exchange of cations on resin

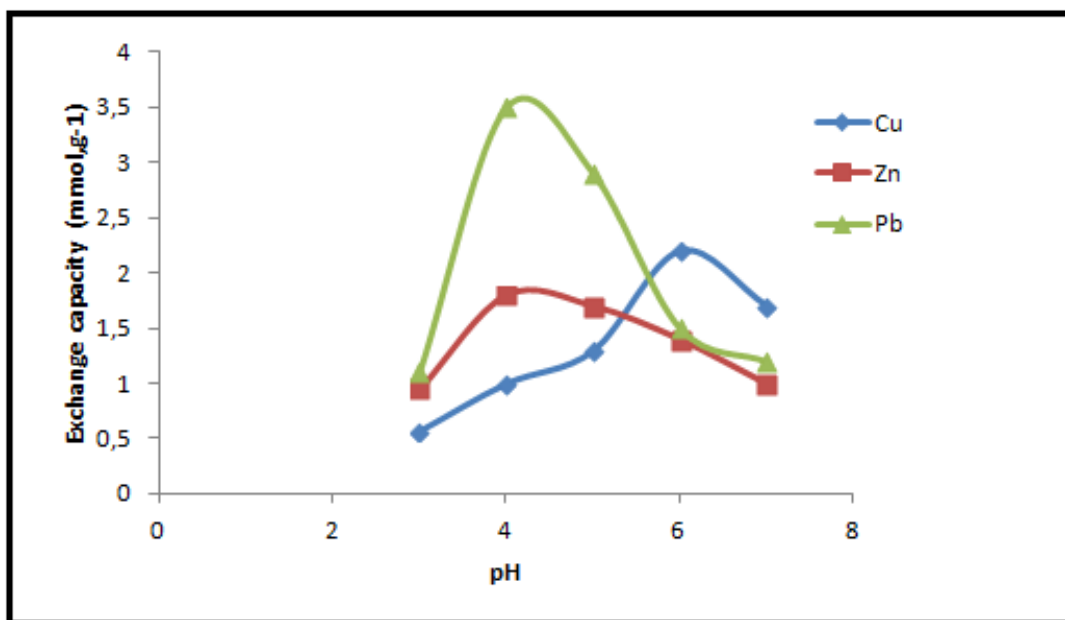


Fig. 5. Effect of pH on cation exchange capacity

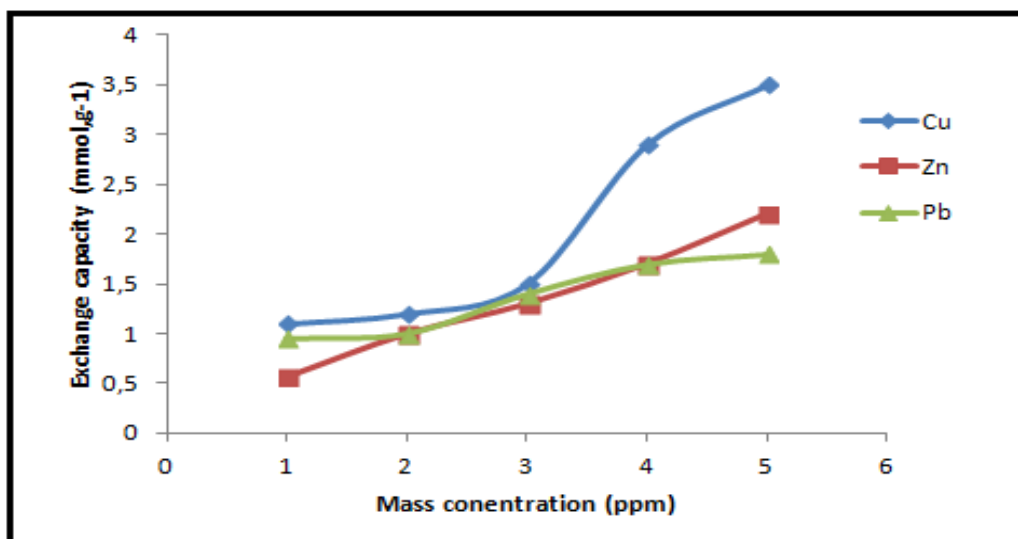


Fig. 6. Effect of cation concentration on exchange capacity

433

434 **Table1.** Element Analysis of the Resin

% Calculated (% Found)		
C	H	N
69.15	4.04	4.74
68.15	3.98	4.65

435

436 **Table 2.** Physicochemical Properties of the synthesized Resin

Property	Values (S.D)
% Moisture content	5.25 (±0.05)
% Solid	93 (±0.05)
True density	0.95 (±0.01) g.cm ⁻³
Apparent density	0.51 (±0.01) g.cm ⁻³
Void volume fraction	0.38 (±0.025)

437

438

439

441 **Table 3.** K_d Values of Metal Ions at Various Tartaric Acid Concentrations and pH Values

Metal ion		[Tartaric acid] (M)	K_d values at different pH				
			3	3.5	4	5	6
Cu(II)	0.1		1101	670.8	527.1	201.7	155.2
	0.2		698.3	320.2	129.9	110	79.7
	0.3		250.1	105.5	80.5	50.8	38.9
	0.5		55.6	55.6	39.7	52.3	55
	1		14	19.3	11.8	8.4	6.5
Zn(II)	0.1		1800	1320	432.4	401.9	200
	0.2		640.7	617.8	220.1	110.9	130.5
	0.3		588.2	300.4	95	71.8	59
	0.5		134	115.1	74	28.1	36.8
	1		81	35.5	25.2	11.8	5.3
Pb(II)	0.1		2221.3	980.4	610.3	420.9	261.2
	0.2		668.4	640.2	230.7	116	142.3
	0.3		435.9	340.7	95.3	82.2	30.4
	0.5		130.2	82.5	80	40.3	4.7
	1		10.8	45.4	34.9	17	2.8