Desalination and Water Treatment
www.deswater.com

doi: 10.1080/19443994.2015.1109556

57 (2016) 19917–19926
September

Taylor & Francis
Taylor & Francis Group

Removal of Cu^{2+} and Pb^{2+} ions by surfactant based cationic exchanger using cetylpyridinium chloride-cerium (IV) phosphate

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Received 14 January 2015; Accepted 26 September 2015

ABSTRACT

The surfactant-based organic–inorganic fibrous cation exchanger, cetylpyridinium chloride-cerium(IV) phosphate (CPC-CeP), has been synthesized and was characterized for its cationic exchange properties. The physicochemical methods such as Fourier transform infra-red spectroscopy (FTIR), X-ray diffraction pattern, scanning electron microscopy, thermogravimetric and differential thermogravimetric analysis (TGA/DTA/DTG) CPC-CeP were used to characterize the newly synthesized material. The ion-exchange properties were studied through the usual column method. The cation-exchange capacity for CPC-CeP was 2.12 meq g^{-1} for Na^+ ions, and optimum concentration for $NaNO_3$ was 1.0 M for complete elution of H^+ ions. CPC-CeP was found to be more stable thermally and mechanically as compared to CeP. The adsorption studies show that it is selective for Pb^{2+} and Cu^{2+} ions.

Keywords: Fibrous cation exchanger; Ion exchange capacity; Ce(IV) phosphate; Cetylpyridinium chloride; Adsorption studies

1. Introduction

Heavy metal and metal ions are among the health hazard materials found in the environment particularly in hydrosphere due to the various anthropogenic activities. Certain metals and metal ions like mercury, lead, cadmium, zinc, etc. are among the known heavy metals that cause adverse effects on the health of human and animals [1–3]. The removal of such heavy metals and metal ions from aquatic systems has been a major challenging task for the researchers. Heavy metal ions are among the nonbiodegradable pollutants and their continued intake results in increasing concentration and accumulation in the body of organisms. The accumulation of metal ions in human beings may lead to poisoning, kidney damage, neurological and movement disorders, depression, developmental disorders, muscle weakness, brain damage, etc. Few metal ions are also reported to be carcinogenic in nature [4,5]. Researchers from different disciplines are involved in the development of reliable, easy, and cost-effective techniques for the removal of heavy metals and metal ions from the potable water for the betterment of human life.

The ion exchange is one of the easy and effective techniques for the removal of metal ions. The

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improvements in the technique and in the search of suitable materials have always been the subject of studies since its inception with the start of civilization for the softening of hard water. With the advancements in the understanding of the ion-exchange process, lots of researches have been done for the advancement of ion-exchange materials. The studies have also been emphasized for the synthesis of new, reliable, and stable ion-exchange materials using inorganic, organic, polymeric, etc. materials. The advantage associated with the inorganic ion exchangers is its stability at higher temperatures and in the presence of strong radiations but chemically and mechanically poor stability. The organic ion-exchange materials possess better reproducibility and stability in the wide range of pH, but could not withstand the high temperature. The hybrid ion exchangers were developed with the objectives to have good reproducibility and stability by possessing the ion-exchange behaviors of constituent inorganic and organic materials [6–9].

The hybrid ion exchangers were further modified by introducing the surfactant molecules [10–17] into inorganic ion-exchange materials to improve the performance and stability of the synthesized ion-exchange characteristics. Further, the surfactant-based hybrid ion exchangers are more environment-friendly than the polymeric materials because of its nonbiodegradable nature after its use. The surfactant based ion exchangers can be recycled when it is exhausted and, thus, can be recycled and poses no adverse impact on environment. The higher ion-exchange capacity, fast elution behavior, better thermal and mechanical stability were observed to be associated with the surfactant-based synthesized ion-exchange materials. Additionally, the ion exchangers were found to be selective toward the heavy metal ions (Table 1). Pyridine and its derivatives are known for their binding tendency with the d-transition metal ions through the lone pair of electron on nitrogen [18,19]. Sigel et al. [20,21] reported that pyridine forms 1:1 complexes with transition metal ions with high stability constant in 0.1 M $NaNO_3$ solution. The present work describes the synthesis and characterization of CPC-based cationic ion exchanger by incorporating it into CPC-CeP. The influence of CPC on the stability, mechanical strength, and ion-exchange properties of CPC-CeP were studied and are reported in this paper.

2. Experimental

2.1. Reagents and chemicals

Ceric sulfate (CDH, India), cadmium(II) nitrate (CDH, India), magnesium(II) nitrate (CDH, India), strontium(II) nitrate (CDH, India) were used during the experiment. Cetyl pyridinium chloride (CPC, Merck-Schuchardt, Germany), calcium nitrate (Merck-Schuchardt, Germany), barium nitrate (Merck-Schuchardt, Germany), nickel nitrate (Merck-Schuchardt, Germany), sodium nitrate (Merck-Schuchardt, Germany) were used as obtained from supplier. Phosphoric acid, copper(II) nitrate, lead(II) nitrate were obtained from Qualigens (India) and mercuric(II) nitrate, zinc(II) nitrate were obtained from Thomas Baker. Doubly distilled demineralized water with specific conductance, $1–2 \times 10^{-6}\ \Omega^{-1}\ \mathrm{cm}^{-1}$ was used throughout the experimental work.

2.2. Instruments used

X-ray diffractions (XRDs) studies were performed on a Philips Analytical X-ray B.V. diffractometer

Table 1
The ion exchange capacity of CPC-CeP and other surfactant based ion exchange materials

S. no.	Name of the materials	Ion exchange capacity (meq dry^{-1}g^{-1})	Selective metals	Refs.
1	TX-100-SnP	2.75	Hg(II), Pb(II), Fe(II)	[10]
2	TX-100-CeP	3.00	Hg(II)	[11]
3	SDS-CeP	2.92	Pb(II)	[12]
4	SDBS-CeP	2.17	Pb(II)	[13]
5	AOT-SnP	2.40	Cd(II), Zn(II), Hg(II)	[14]
6	AOT-CeP	3.02	Cu(II), Pb(II), Cd(II), Zn(II), Hg(II)	[15]
7	SDBS-SnP	2.20	Cu(II), Cd(II), Pb(II), Hg(II)	[16]
8	N-dodecyl pyridinium chloride-Ce(IV) phosphate	3.15	Hg(II)	[17]
9	Cetyl pyridinium chloride-Ce(IV) phosphate	2.12	Cu(II), Pb(II)	Present work

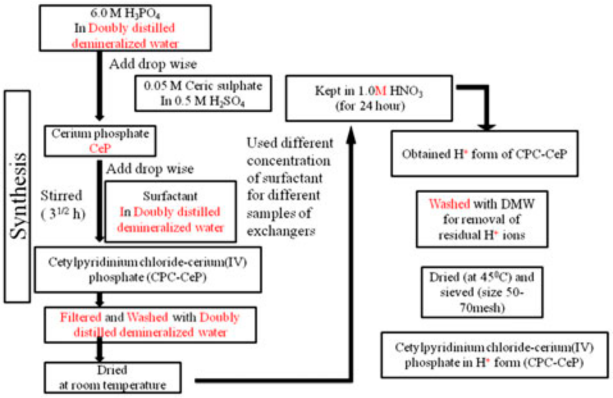
type PW 170 B.V. The IR studies were carried out on Shimadzu 8201 PC spectrophotometer. The presence of cetylpyridinium chloride (CPC) in the matrix of cerium(IV) phosphate was confirmed using elemental analysis through Heraeus Carlo Erba-1108 analyzer. Differential pulse polarograms were recorded using an Elico CL-362 Pulse Polarograph and the scanning electron microscopy (SEM) studies were performed on SEM Hitachi-S520, Japan. For TGA/DTA/DTG, Perkin Elmer Pyris Diamond model was used.

2.3. Preparation of the reagent solutions

The stock solutions of 0.10 M cetylpyridinium chloride (CPC), 6.0 M phosphoric acid, 0.10 M sodium hydroxide, 1.0 M sodium nitrate, 0.01 M cadmium nitrate, 0.01 M lead nitrate, 0.01 M zinc nitrate, 0.01 M copper nitrate, 0.10 M sodium nitrate, 0.10 M magnesium nitrate, 0.10 M potassium nitrate, 0.10 M calcium nitrate were prepared in the doubly distilled water. Solution of cerium(IV) phosphate was prepared in 0.50 M H_2SO_4.

2.4. Synthesis of the ion-exchange material

Different samples of CPC-CeP were prepared by adding 0.05 M cerium(IV) phosphate solution dropwise to the mixture of 6.0 M H_3PO_4 and cetylpyridinium chloride solutions (1:1). The mixture was stirred at room temperature using a magnetic stirrer for 2 h. The obtained slurry-like product was further stirred for $3\frac{1}{2}$ h at room temperature, then filtered and washed with demineralized water till pH ~4 was achieved. The samples were dried at room temperature and, sheet-like material was obtained finally. The sheet-like product was then crushed into small pieces and kept it in 1.0 M HNO_3 for 24 h to charge it in H^+ form. The cation exchanger in the H^+-form was thus obtained. It was filtered and washed several times with double-distilled water to remove the residual H^+ ions completely. Then, the material was left to dry at 45˚C for a day and then sieved to obtain particles of size 50–70 mesh. The ion-exchange capacities of these synthesized samples were determined by taking the weighed amount of the ion-exchange material in a burette fitted with glass wool. The sample 4 possessed the highest values of ion-exchange capacity, and, therefore, it was selected for subsequent studies. The various experimental procedures adopted during the studies were displayed through the flow chart for better understanding.



2.5. Ion-exchange capacity (i.e.c)

To determine the number of ionogenic groups present in the synthesized exchanger, 1.0 g of the material in H^+-form was taken in a glass burette having internal diameter ~1 cm, fitted with glass wool at the bottom. About 250 mL of 1.0 M $NaNO_3$ solution was used as eluant, maintaining a very slow flow rate (~0.5 mL min^{-1}). The effluent was titrated against a 0.10 M NaOH solution to determine the total H^+—ions liberated during ion-exchange process using phenolphthalein as an indicator (Table 2).

2.6. Concentration behavior

About 250 mL $NaNO_3$ solution of different concentrations ranging from 0.2 to 1.2 M was passed through the column containing 1.0 g the cation exchanger to determine the optimum concentration of the eluant needed for complete replacement of H^+ ions. The H^+ ions eluted out was titrated against a standardized 0.10 M NaOH solution using phenolphthalein as an indicator. The dependence of the ion-exchange capacity at different $NaNO_3$ concentrations is presented in Table 3.

2.7. Elution behavior

Elution behavior demonstrates the optimum volume of eluant used for complete elution of H^+ ions from the cation exchanger. A similar column, as described above, containing 1.0 g cation exchanger was used. The H^+ ions were eluted with 1.0 M $NaNO_3$ solution in different 10 mL fractions with a minimum flow rate as given above. The histogram (Fig. 1) shows the elution behavior of CPC-CeP.

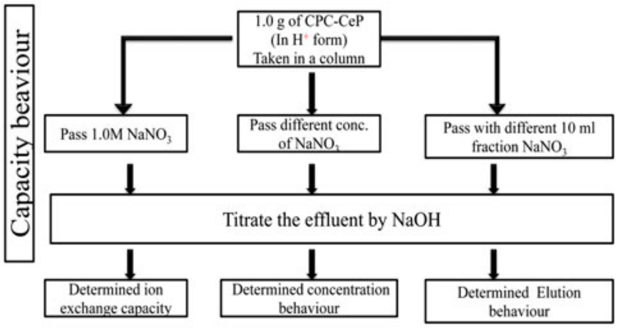
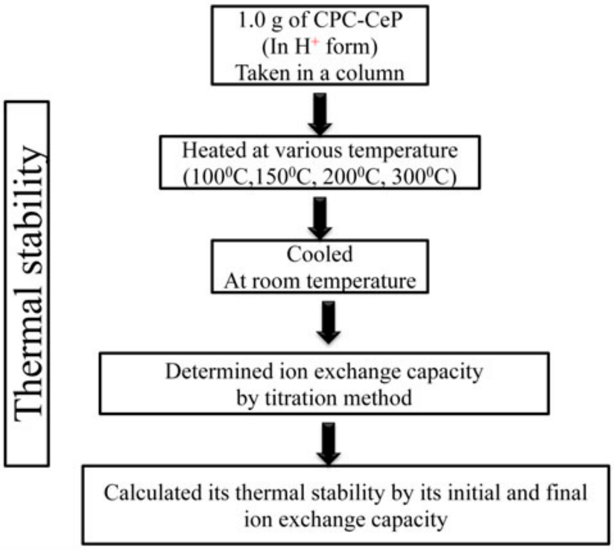


Table 3
Variation of ion exchange capacity of CPC-CeP cation exchanger at different eluent concentrations

Concentration of $NaNO_3$ (mol dm^{-3})	Ion exchange capacity (meq g^{-1})
0.2	1.10
0.4	1.48
0.6	1.67
0.8	1.83
1.0	2.12
1.2	2.12

2.8. Thermal stability

To determine the thermal stability, several 1.0 g sample of CPC-CeP was heated to 100, 150, 200, and 300°C for one hour in a muffle furnace. After cooling to room temperature, the values of the ion-exchange capacity were determined. The physical appearance of the material after heating, and the values of ion-exchange capacity are given in Table 4.



2.9. Adsorption studies

About 200 mg of CPC-CeP in H^+—form was taken into a conical flask containing 20 mL of metal ions solution. The mixture was thermostated at room temperature (25 ± 0.5°C) for 24 h, shaking intermittently to achieve equilibrium. The concentration of the metal ions was determined before and after the equilibrium was achieved. The concentrations of Hg^{2+}, Ni^{2+}, Ba^{2+}, Mg^{2+}, Ca^{2+}, and Sr^{2+} ions were determined by titration with standardized disodium salt of EDTA solution [22]. The concentrations of Cu^{2+}, Cd^{2+}, Pb^{2+}, and Zn^{2+} ions were determined by measuring the diffusion current through differential pulse polarography. The concentration of Fe^{2+} was determined by measuring the intensity of the color at 510 nm by spectrophotometric method using hydroxyl amine, sodium acetate and 1,10-phenanthroline. The distribution coefficient (K_d) for these metal ions were calculated using the following relationship (Eq. (1)) and the obtained values are given in Tables 5 and 6:

$$K_d = \frac{I-F}{F}\frac{V}{M}\left(\text{mL g}^{-1}\right) \tag{1}$$

where K_d is the distribution coefficient (mL g^{-1}), I is the initial amount of metal ions in the solution, F is the final amount of metal ions in the solution, V is the volume of the solution (mL) and M is the amount of the exchanger taken (g).

2.10. Binary separations

The binary separation for the metal ions on the columns using CPC-CeP was carried out by taking 2.0 g

Table 2
Na^+ ion exchange capacity of the synthesized CPC-CeP samples

Sample no.	[CPC] (Moles)	Na^+ ion exchange capacity (meq g^{-1})
Sample-1	0	1.30
Sample-2	0.01	1.73
Sample-3	0.001	1.92
Sample-4	0.0001	2.12

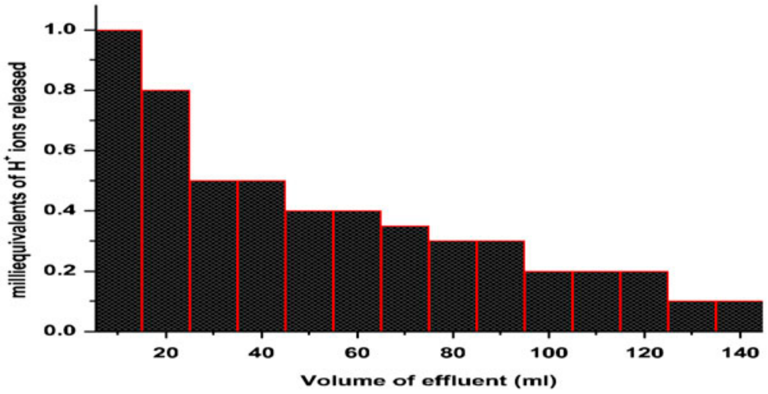


Fig. 1. Histograms showing the elution behavior of CPC-CeP.

Table 4
Heating effect on the ion exchange capacity and physical appearance of CPC-CeP cation exchanger after heating to different temperatures for 1 h

Heating temperature (°C)	Na^+ ion exchange capacity (meq g^{-1})	Appearance	% retention of ion exchange capacity
100	1.97	Yellow	92.92
150	1.80	Yellow	84.90
200	1.11	Light yellow	52.35
300	0.83	Cream	39.15

Table 5
K_d values of some metals ions on CPC-CeP cation exchanger in DMW and in presence of acidic media by batch method

	K_d values						
		HNO_3		$HClO_4$		CH_3COOH	
Metal ions	DMW	0.10 mol dm^{-3}	0.01 mol dm^{-3}	0.10 mol dm^{-3}	0.01 mol dm^{-3}	0.10 mol dm^{-3}	0.01 mol dm^{-3}
Ba^{2+}	3,150.0	194.5	226.5	185.7	460.00	305.4	584.2
Mg^{2+}	3,233.3	111.1	160.0	294.4	723.5	214.5	390.5
Ca^{2+}	850.0	152.0	466.6	282.7	437.3	206.5	341.5
Sr^{2+}	800.0	172.0	290.0	387.8	534.9	150.0	255.5
Ni^{2+}	778.0	215.7	291.3	100.0	252.9	483.0	133.2
Hg^{2+}	9,400.0	201.8	1,263.6	1,057.8	2,047.7	307.4	1,037.0
Cu^{2+}	5,583.0	547.6	1,232.7	–	–	–	–
Pb^{2+}	15,900.0	1,195.8	1,816.8	–	–	–	–
Cd^{2+}	2,869.6	172.1	430.2	–	–	–	–
Zn^{2+}	10,693.0	106.2	184.0	–	–	–	–

of the synthesized material into a column with internal diameter ~0.6 cm. The column was washed thoroughly with the doubly distilled water and then the mixture containing Hg^{2+}–Ni^{2+}, Hg^{2+}–Ba^{2+}, Hg^{2+}–Mg^{2+}, and Hg^{2+}–Sr^{2+} was loaded onto it, maintaining a flow rate of ~2–3 drops min^{-1}. The separation was achieved by passing a suitable solvent through the column as eluent and the metal ions in the effluent were determined quantitatively by EDTA titrations (Table 7).

Table 6
K_d values of Cu^{2+}, Pb^{2+} ions on CPC-CeP cation exchanger in the presence of alkali and alkaline earth metals (0.1 M)

	K_d value	
Metal ions	Cu^{2+}	Pb^{2+}
Na^+	698.6	746.3
K^+	1,130.1	1,312.6
Mg^{2+}	1,203.7	1,602.4
Ca^{2+}	1,753.0	2,725.2

Table 7
Binary separation of metal ions achieved on CPC-CeP cation exchanger

S. no.	Separation achieved	Eluent used	Volume of eluent (ml)	Amount loaded (μg)	Amount found (μg)	Error (%)
1	Hg^{2+}	0.1 M CH_3COOH	70	6,852.4	6,903.79	0
	Mg^{2+}	0.1 M HNO_3	60	5,128.2	5,179.48	+0.9
2	Hg^{2+}	0.1 M CH_3COOH	70	6,852.4	6,852.40	0
	Ba^{2+}	0.1 M HNO_3	80	5,226.8	5,252.93	+0.4
3	Hg^{2+}	0.1 M CH_3COOH	80	6,852.4	6,920.92	+0.9
	Sr^{2+}	0.1 M $HClO_4$	70	4,232.2	4,147.94	−1.9
4	Hg^{2+}	0.1 M CH_3COOH	70	6,852.4	6,852.40	0
	Ni^{2+}	0.1 M $HClO_4$	80	5,816.2	5,961.60	+2.4

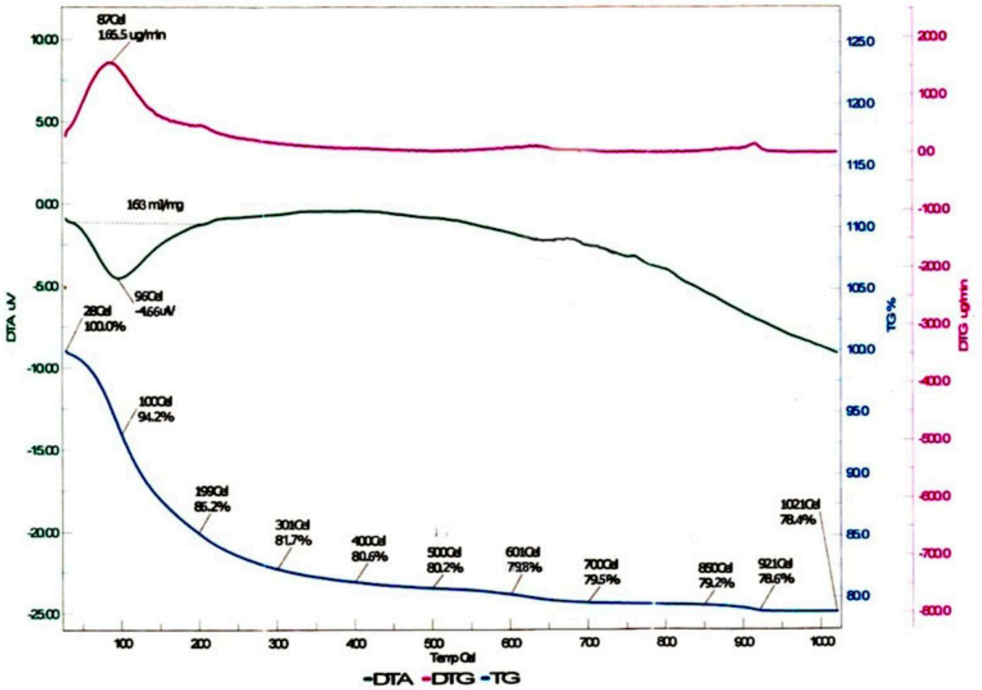


Fig. 2. TGA/DTA curve of CPC-CeP.

2.11. Quaternary Separations

About 2.0 g of CPC-CeP was taken in a column with internal diameter ~0.6 cm and was washed thoroughly with the demineralized water and the mixture containing Cu^{2+}, Cd^{2+}, Pb^{2+}, and Zn^{2+} ions was loaded onto it with a flow rate of ~2–3 drops min^{-1}. Quaternary separations for Cu^{2+}, Cd^{2+}, Pb^{2+}, and Zn^{2+} ions before and after adsorption were determined by recording the differential pulse polarogram.

2.12. Separation in the presence of acid, alkali, and alkaline earth metals

To study the effectiveness of the exchanger for the removal of Cu^{2+} and Pb^{2+} ions in the presence of acid, alkalis and alkaline earth metals, the experiment was repeated by taking a mixture of Cu^{2+} and Pb^{2+} ions solutions containing 0.01 and 0.1 M acid, alkalis, or alkaline earth metals. It was observed that Cu^{2+} and Pb^{2+} ions were completely removed by the cation

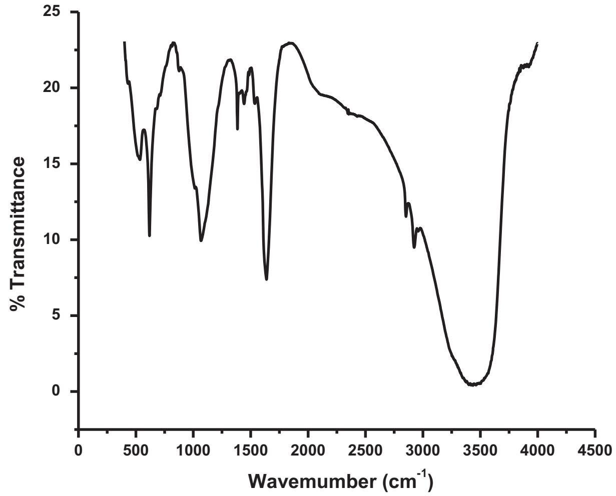


Fig. 3. IR spectrum of CPC-CeP.

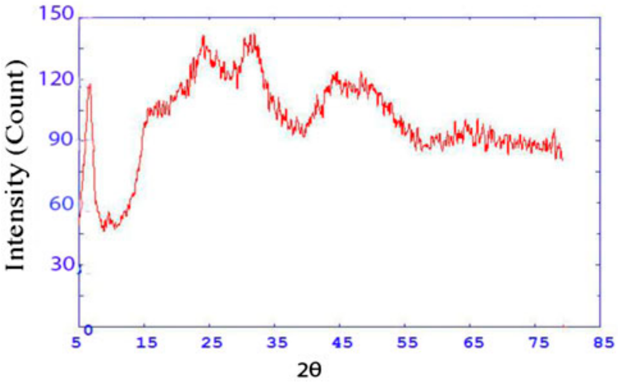


Fig. 4. XRD patterns of CPC-CeP.

exchanger in the presence of acid, alkali, and alkaline earth metals.

3. Results and discussion

The addition of CPC to the cerium(IV) phosphate inorganic ion exchanger influenced the values of ion-exchange capacity and its elution characteristics. The values of ion-exchange capacity (in terms of Na^+ ions equivalents) for cerium(IV) phosphate (1.50 meq g^{-1}) was increased to 2.12 meq g^{-1} for CPC-CeP. Like other cationic exchangers, the ion-exchange capacity depended upon the concentration of $NaNO_3$ (as eluant) in which the ion-exchange capacity increased with the increase in the concentration of $NaNO_3$. The ion-exchange capacity reached to a maximum value of 2.12 meq g^{-1} for 1.0 M $NaNO_3$, afterwards, the further increase in [$NaNO_3$] did not influence the values of ion-exchange capacity. Thus, the optimum concentration of $NaNO_3$ for the complete replacement of H^+ ions was found to be 1.0 M (Table 3). Fig. 1 depicts that all the replaceable H^+ ions are completely eluted by 140 mL of 1.0 M $NaNO_3$, indicating the elution behavior of CPC-CeP is fast.

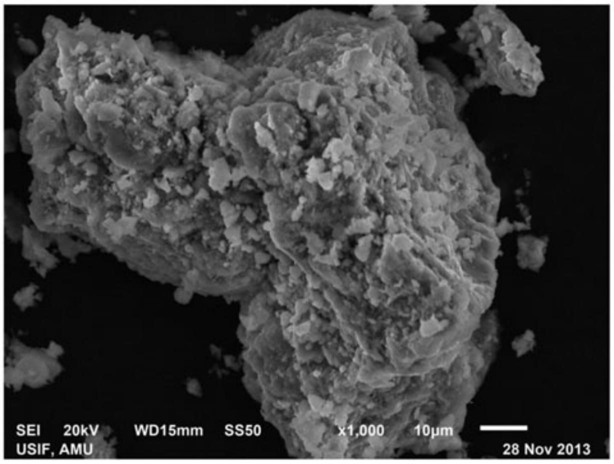


Fig. 5. SEM photograph of CPC-CeP.

The values of ion-exchange capacity were determined after heating to different temperatures. From Table 4, it is observed that CPC-CeP retains 92.92, 84.90, 52.35, and 39.15% of its initial values of ion-exchange capacity on heating it to 100, 150, 200, and 300°C for 1 h, respectively. On the contrary, Ce(IV) phosphate retains 61.8, 13.1, and 5.15% of its initial ion-exchange capacity when heated to 100, 200, and 300°C, respectively, for 1 h. This study shows that CPC-CeP is thermally more stable than Ce(IV) phosphate cation exchanger. The observed data suggest that the removal of external water molecules has little effect on the ion-exchange capacity of CPC-CeP. A change in ion-exchange capacity between the temperatures 200 and 300°C is may be due to the partial removal or degradation of surfactant molecules accompanied with the removal of strongly coordinated water molecules from CPC-CeP. Thus, the removal of water and the degradation of surfactant molecules result into the sharp decrease in the values of ion-exchange capacity upto 300°C. This may lead to the formation of CeO_2 accompanied with the disruption in the intercalated fibrous structure of the ion-exchange material [23]. The thermal behavior of CPC-CeP was further studied by recording the thermograms of CPC-CeP. CPC-CeP lost 8.0% its initial mass on heating to temperature 199°C with endo effect at 96°C with the removal of external water molecules associated with

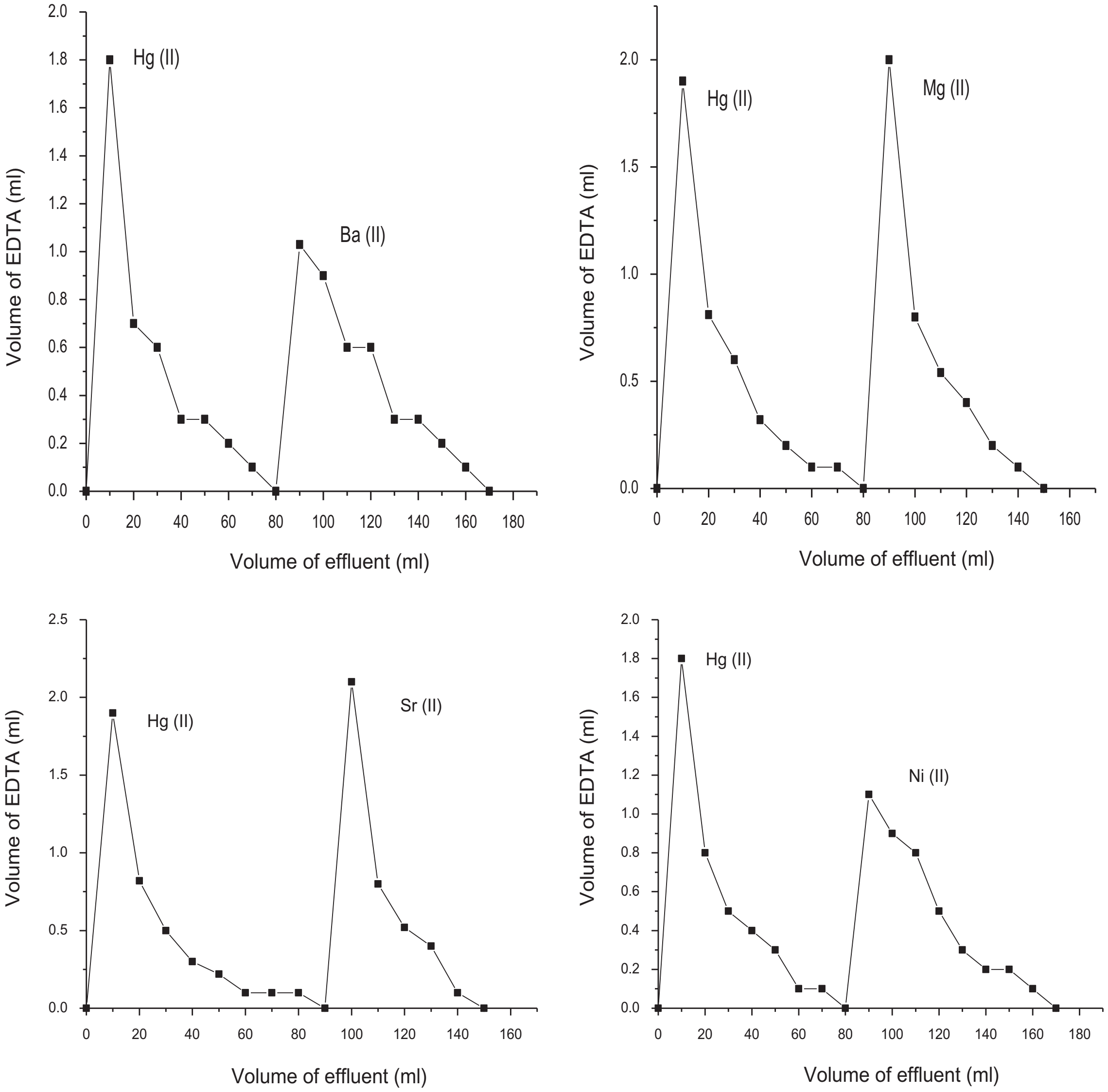


Fig. 6. Chromatograms of binary separations of metal ions on SDBS-SnP cation exchanger columns.

the material. 4.5% loss in weight occurs on heating from 200 to 300℃ and, further 1.1% weight loss takes place when the material was heated to 400℃ (Fig. 2). This loss in weight is may be attributed to the decomposition and removal of surfactant molecules from the matrix of ion exchange material. The further heating causes the removal of strongly coordinated water molecules from cerium(IV) phosphate. The weight loss of 0.3% was recorded at 700℃ due to elimination of the residual surfactant molecules [24]. On heating to higher temperature, the weight of the material remains almost constant up to 1,021℃ with the slight losses of 0.6% at 921℃ and 0.2% at 1,021℃ with the formation of CeO_2 [23].

The IR spectrum recorded for CPC-CeP shows the presence of phosphate group at 536 cm^{-1} [25] and the presence of metal-oxygen and metal-hydroxide bonding are confirmed by the appearance of peak at 613.88 cm^{-1} [26]. The peak at 1,064.00 cm^{-1} is attributed to the presence of metaphosphate [25], and the peak at 1,647.17 cm^{-1} represents the external water molecules [27]. The appearance of peak at 3,498.00 cm^{-1} is observed due to −OH group [28] (Fig. 3). The XRD study was carried out on CPC-CeP using Rigaku Cu Kα radiation with the wavelength 1.54 Å. The absence of any defined peak shows that the material is amorphous in nature (Fig. 4). The presence of CPC in the ion exchanger material was

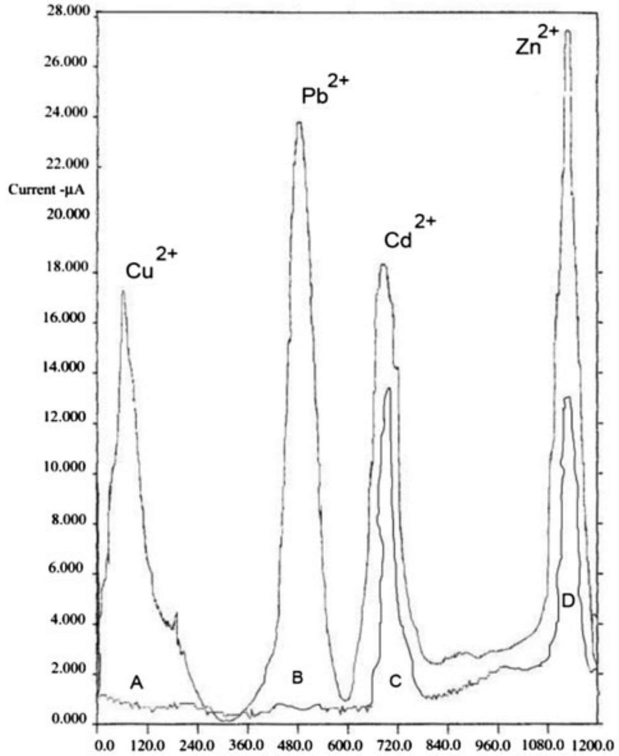


Fig. 7. Differential pulse polarogram curves for Cu^{2+}, Cd^{2+}, Pb^{2+}, and Zn^{2+} ions before (upper curve) and after (lower curve) passing through the column containing the CPC-CeP cation exchanger. A, B, C, D denote the peaks of polarogram of Cu^{2+}, Pb^{2+}, Cd^{2+}, and Zn^{2+} ion, respectively, with exchanger (CPC-CeP).

confirmed by the elemental analysis of CPC-CeP. The CPC molecules coat the cerium(IV) phosphate matrix and also lie in-between the inorganic cerium(IV) phosphate. The intercalation of CPC changes the morphology of CPC-CeP texture into the fibrous form (Fig. 5).

The adsorption of the ionic species on the cation exchanger is driven by the ionic interaction between the oppositely charged ions in the mobile phase and polar or ionic group in the cation exchanger (i.e., CPC and cerium(IV) phosphate). The CPC-CeP cationic exchanger has been observed to possess high selectivity toward Cu^{2+}, Pb^{2+} ions. The selectivity of these metal ions was effective even in the presence of solutions (0.1 and .01 M) of nitric acid, acetic acid, and perchloric acid, 0.1 M alkali metals (Na^{+} and K^{+}), 0.1 M alkaline earth metals (Mg^{2+} and Ca^{2+}) and other transition metal ions. The polar group, i.e. pyridine in the surfactants, binds the metal ions reversibly and has higher values of stability constants [18,19]. Kapinos and Sigel [21] observed the binding of metals with the pyridinium group through the lone pair of electrons of nitrogen atom. They observed the preferential binding of Cu^{2+} ions with the pyridinium group. Thus, this ability of pyridinium makes the CPC-CeP more effective toward the removal of Cu^{2+} and Pb^{2+} ions through forming Cu^{2+}-CPC and Pb^{2+}-CPC, ion pairs. The Cd^{2+} and Zn^{2+} ions are weakly adsorbed by the cationic exchanger. The values of distribution coefficients for Cu^{2+} and Pb^{2+} ions with CPC-CeP in the presence of acidic, alkaline, and alkaline earth metal are given in Tables 5 and 6.

The separation capability of CPC-CeP for the different ions has been demonstrated by achieving some binary separations involving Hg^{2+}–Mg^{2+}, Hg^{2+}–Ba^{2+}, Hg^{2+}–Sr^{2+}, Hg^{2+}–Ni^{2+} ions and quaternary separation of Cu^{2+}, Pb^{2+}, Cd^{2+}, and Zn^{2+} ions on the column of the ion-exchange material. The sequential elution of the ions from the column depends upon the metal-cation-exchange stability. The elution profiles of metal ions separated are shown in Fig. 6. The weakly retained metal ions on CPC-CeP are eluted first and the strongly retained metal ions on CPC-CeP are eluted in the last. The polarogram presented in Fig. 7 illustrates the preferential adsorption of Cu^{2+} and Pb^{2+} ions by CPC-CeP from the mixture of metal ions. The upper polarogram was recorded before passing the solution through the column of CPC-CeP. The lower polarogram shows the absence of peaks for Cu^{2+} and Pb^{2+} ions when passed through the column of CPC-CeP. Table 7 summarizes the binary separation of metal ions which is quite sharp and the recovery is quantitative. The adsorption behavior of CPC-CeP demonstrates that the material is highly selective for Cu^{2+} and Pb^{2+} ions and can be potentially used for the removal of these ions from the water. The high selectivity of exchanger towards Cu^{2+} and Pb^{2+} ions can be helpful in analytical and environmental chemistry for the separation and removal of Cu^{2+} and Pb^{2+} ions during the treatment of wastewater.

4. Conclusion

The synthesized CPC-CeP fibrous cation exchanger possessed higher ion-exchange capacity than CeP alone with better elution behavior. It is observed to be mechanically and thermally more stable than the parent inorganic ion exchanger. CPC-CeP is found to be selective for Cu^{2+} and Pb^{2+} ions. Thus, CPC-CeP efficiently removes Cu^{2+} and Pb^{2+} ions from water and can be used for the removal of such impurities during water treatment. Furthermore, the cation exchanger can also remove Cu^{2+} and Pb^{2+} ions effectively in the presence of acid, alkalis, and other metal ions.

Acknowledgment

The author (Nazia Iqbal) is thankful to the CSIR, New Delhi for the award of the fellowship (No. 09/112 (0496)/2K13-EMR-I). The authors (H.A. Al-Lohedan and M.Z.A. Rafiquee) extend their appreciation to the Deanship of Scientific Research at King Saud University for funding the work through the research group project No. RGP-148.

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