Environmental Health Engineering and Management Journal 2015, 2(1), 41–45

http ehemj.com

Environmental Health Engineering and Management Journal

Original Article

Open Access Publish Free

Efficiency of lead removal from drinking water using cationic resin Purolite

Ashour Mohammad Merganpour[1], Gholamabbas Nekuonam[2], Omid Alipour Tomaj[3], Yousef Kor[4*], Hasan Safari[5], Khosro Karimi[6], Vahid Kheirabadi[7]

[1]MSc of Golestan province Rural Water &Wastewater Co, Gorgan, Iran
[2]MSc of Environmental Engineering, Environmental Health Engineering Research Center, Department of Environmental Health Engineering, School of Public Health, Kerman University of Medical Sciences, Kerman, Iran
[3]MSc of Watershed Management, Department of Agriculture and Natural Resources, Gorgan Branch, Islamic Azad University, Gorgan, Iran
[4]MSc of Environmental Engineering, Gorgan Healthcare Center, Golestan University of Medical Sciences, Gorgan, Iran
[5]MSc of Civil Designing, Health Faculty, Golestan University of Medical Sciences, Gorgan, Iran
[6]BS of Environmental Helath, Gorgan Healthcare Center, Golestan University of Medical Sciences, Gorgan, Iran
[7]BS of Environmental Management, Golestan Province Environmental Protection Organization, Gorgan, Iran

Abstract

Background: Today, issues such as water shortage, difficulties and costs related to supplying safe water, and anomalous concentrations of heavy metals in groundwater and surface water resources, doubled the necessity of access to technical methods on removing these pollutants from water resources.

Methods: In this lab study, cationic resin Purolite S-930 (with co-polymer styrene di-vinyl benzene structure) was used for lead removal from drinking water containing up to 22 µg/L. Using statistical analysis and designing a full factorial experiment are the most important effective parameters on lead removal obtained through ion exchange process.

Results: Analysis of response and interaction parameters of ion exchange showed that the resin column height has maximum and pH value has minimum effect on the efficiency of lead removal from aquatic environment. Trinary interaction of "effective size, flow rate, resin column high" has the most important for lead removal efficiency in this system. So the maximum efficiency was obtained at the mesh = 40, bed height =1.6 meter, and pH= 6.5. At the best operation conditions, ability to remove 95.42% of lead concentration can be achieved.

Conclusion: Using the resin Purolite S-930 during 21-day service with 91.12% of mean lead removal ratio from drinking water is an economic and technical feasibility.

Keywords: Lead, Resin, Purolite, Interaction

Citation: Merganpour AM, Nekuonam G, Alipour Tomaj O, Kor Y, Safari H, Karimi K, et al. Efficiency of lead removal from drinking water using cationic resin Purolite. Environmental Health Engineering and Management Journal 2015; 2(1): 41–45.

Article History:
Received: 9 October 2014
Accepted: 14 January 2015
ePublished: 2 February 2015

***Correspondence to:**
Yousef Kor
Email: yor54@yahoo.com

Introduction

Concurrent with the environmental changes such as society industrialization, effluent wastewater may result in entering the toxic substances and harmful pollutants such as heavy metals in water resources (1,2).

Also water extraction from the aquifers and watershed containing metal formations which cause the presence of abnormal amounts of heavy metals are considered as serious threats to human health. So, before consumption of drinking water, it is important to ensure about removing pollutant agents which are attainable through various treatment operations. One of the strategies associated with this process is ion exchange. During this mechanism which is in fact a form of adsorption phenomenon, liquid phase components are in contact with solid phase adsorbent isolation. In this mechanism, one of the forms of adsorption phenomenon, some components which are present in the liquid phase are isolated in contact with the adsorbent's solid phase (3-5). In other words , ion exchange is a reversible process during which foreign ions in water are absorbed to functional groups on polymer network (solid phase), and any ionic impurities of water removes. After saturation of the functional groups, the system is under recovery and chemical cleaning operation and re-used. An ion-exchange resin or ion-exchange polymer is an insoluble matrix (or support structure) normally in the form of small (0.5-1 mm diameter) beads, usually white or yellowish, fabricated from an organic polymer substrate. The beads are typically porous, providing a high surface area. The trapping of ions occurs with concomitant releasing of other ions; thus the process is called ion-exchange. The ion exchange is selectively characterized as the gradual elimination of specific ion and then the coefficient will selectively fluctuate by resin type, ionic strength, the relative amounts of different ions and water temperature. Resin selection is a very important factor in the regeneration process, for example the sodium element in the lower concentration of 1000 mg/L excels, but in most concentrations the convertor prefers sodium ion to calcium ion, so it must be regenerated with the salt. The exchanger resins are normally shaped beads with approximately 0.1 to 1 mm diagonal, and according to the exchangeable ion, are classified into two groups of anions and cations (6).

Cation resins are able to remove cations, and Anionic resins are able to remove anions available in solution. The cationic resins are divided into two groups of strong acid and weak acid. The concept of strong and weak is enlargement and small degrees of ionization. In weak form resin there is functional groups of COOH and in the strong resin there is SO_3H functional groups. Resins are formed by three dimensional cross-linking polymer (matrix) (7-9). The matrix often containing polystyrene has a cross-linking with di-vinyl benzene, and charged functional groups are attached to the matrix by covalent bonding. In recent years, special attention has been paid to the ion exchanger functional groups containing iminodiacetic acid. Presence of two carboxyl group and a tertiary nitrogen atom is the special cause of handling this type of resin for separation of species metals (10-14). Chemical structure of this resin was present in below properties (Table 1).

Resin used in this research project is a chelating resin called Purolite S-930. This type of resin contains styrene di-vinyl benzene structure with functional groups containing iminodiacetic acid. These functional groups as chelating ligands, have been linked to the porous body made of poly styrene di-vinyl benzene cross bridges. The resin Purolite S-930 has a tendency to bond with alkaline earth metals and transitions. The selectivity of the bond with metals at neutral pH is shown below (15).

Cr^{3+}> In^{3+}> Fe^{3+}> Hg^{2+}> Cu^{2+} > Pb^{2+}>Ni^{2+}> Zn^{2+}> Cd^{2+}> Co^{2+}> Fe^{2+}>Mn^{2+}> Be^{2+}> Ca^{2+}> Na^+

The apparent selectivity of the resin for a particular metal depends on the metal concentration, pH and presence of other species. For this reason, it is very difficult to determine the absolute selectivity, and so preliminary laboratory operations for selective removal of one or more types of metal is essential. The reaction base of resin Purolite S-930 so that iminodiacetic acid functional groups (as well as Na^+ and H^+) are made chelating with heavy metals through interaction of di-carboxylic acid with nitrogen atoms electron donor.

Methods

This lab study was performed at Azad University of Gorgan with the following conditions.

Resin column selection: Three PET container with 1800 ml volume were provided which benefit from an exit barrier filter to avoid resin beads (Figure 1).

Effect of flow rate: Feed flow rate was calculated based on the proportion of bulk resin column and considering the type of experiment. Evaluation was set on the rate of 2, 2.75, and 3.5 ml/s which was regulated by the peristaltic pump.

Effect of resin column height: To evaluate the effect of resin volume, changes in the height of resin column was applied and was adjusted with proportionality constant volume and surface area of the column height in range of 1.2, 1.4 and 1.6 liters.

Effect of resin particle size: To understand the impact of resin effective size on the ion exchange functioning, differential sizing of resin was done and in each container 1500 ml (1219 g) of resin were cast separately with meshes of 25, 30 and 40.

Experiment: By taking 30 minutes retention time in any format of ion exchange and sampling from resin column effluent water and analysis of them, lead concentration by atomic absorption spectroscopy was performed using a Perkin Elmer model 2380. For regeneration of resin bed, in each frequency sampling, a vertical washing by 2 liters of NaOH was done.

Data analysis: After basing the experimental design completely on randomized factorial, minitab version 16 was used to achieve optimum performance analysis, where the statistical normal distributions such as ANOVA in level 95% was used in order to evaluate the best conditions for maximum efficiency using the analysis of time series. This analysis consists of main risk factors associated with the

Table 1. Chemical properties of resin Purolite S- 930

Macroporous-styrene divinylbenzene	Polymeric structure
Iminodiacetic acid	Function group
>90%	Ion exchange percent
<20%	Reversible swelling (H^+>N^+)
14-52	Particle size range
65%-66%	(H^+)% Residual moisture
1.17	Wet H^+ (density)
Form Na^+: 1.29	Capacity (meq /wet)
Form N^+: 6-11	pH range

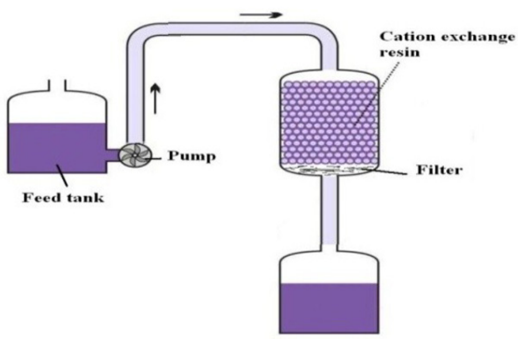

Figure 1. Schematic eliminate lead pilot system

lead removal from water (pH, flow, effective size, height of resin column). Totally 53 samples (32 designing samples and 21 service functions samples) were analyzed, and at the end of each stage, lead removal efficiency was calculated with the following equation.
Efficiency = [(A-B) /A)]× 100

Results

In Figure 2, the effects of main parameters including pH value, flow rate, resin size, and height of resin column on response (the removal ratio of lead) as well as the interactions and the interferences are shown. Since in most cases, the lines of two levels are almost parallel, and factors are independent and apart, there is no interaction between them. Regarding the steep and intersecting lines, severe interaction between two factors (between pH and flow rate, and between size and resin column height) was observed in the form of interacting factors.
The next step was to compare the interaction effects and also statistically evaluate the significance of results, using the half-normal plot. In Figure 3 it can be seen that three of the four main effects (B), resin size (C), and height (D) with the interaction of three pH * flow * height (A.B.D) has the maximum distance from the base line, and therefore has the maximum effect between the main and interactive effects. The direction of effects was also found in this diagram, as a result of the D and the interactive effects A.B.D have a positive impact on levels of removed lead. While the effects of B and C have a negative impact on the rate of elimination. So lead removal efficiency increases due to changes including increasing the resin column height, increasing the interactive effect between pH * flow * height, reducing the flow rate through the column, and reducing resin particle size. The blue line represents the expected path of insignificant effects. In the half normal effects plot between major factors affecting the lead removal (Figure 3) appears that the bed height is greatest elongation positive effect, and this means that if the resin bed height or resin volume increases, (ratio 3 <) the capability of the lead removal from aqueous solution will be increased further.

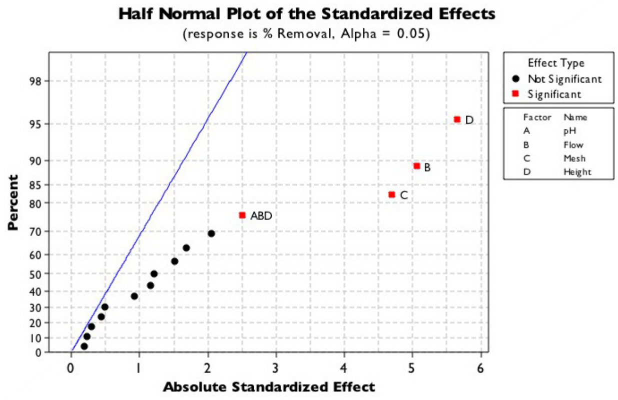

Figure 3. Diagram of half normal effects for lead removal efficiency

The feature is effective for removal of lead from aqueous solution. Therefore, the first step should be to enhance the removal of bed height increase. On the other hand the effect of particle size reduction (C) and flow (B) will appear in the second and third order of effects.
In this diagram, the interaction of pH factor faces a very minor impact on the flow rate and bed height , so changes in the defined range (6.5 and 7.5) will not be very effective in lead removal.
Any effect amount of which exceeds from the line to the right is statistically significant at 95% level. This graph confirms the predominance of flow effects (effect B), resin particle size (effect C) and height (effect D) with the interaction of three pH * Flow * height (effect A.B.D). Level diagram of the same time interaction between flow and column height shows that it has been selected when the pH value is 6.5 and the size of resin is fine. Despite the insignificance of the same effects as a result of 1.6 meter height and negligible unit effects, which corresponds to the loss of efficiency in the flow of 3.4 ml/s, due to the interaction between the main factors on each other, the best results of removing lead is achieved in flow of 2 ml and height of 1.6 meter (Figure 4). The level chart related to resin height and pH effects on lead removal when flow rate sets on 2 ml/s and the resin sizes are kept at small

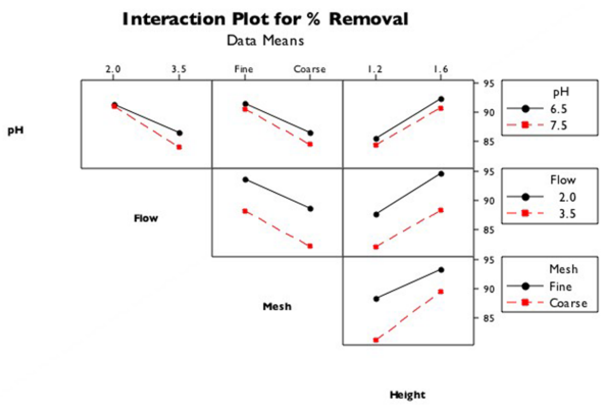

Figure 2. Diagram of main effects results including pH, flow, size and height of resin column on the lead removal

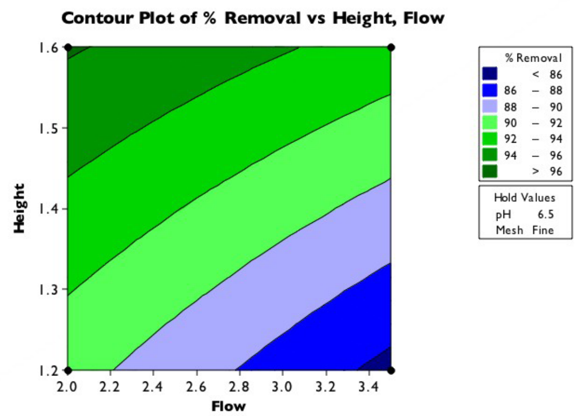

Figure 4. Level chart of simultaneity resin height and flow the lead removal

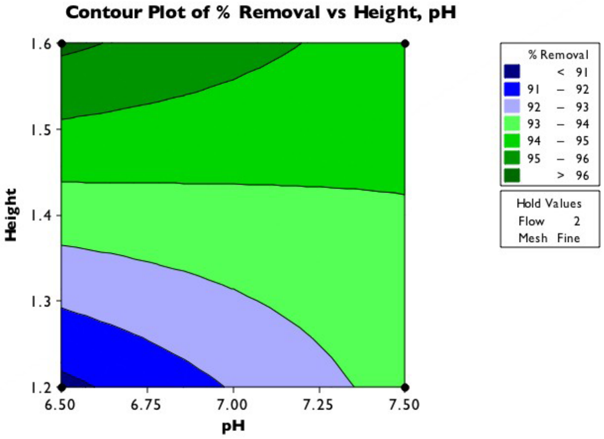

Figure 5. Level chart of simultaneity pH and resin height on the lead removal

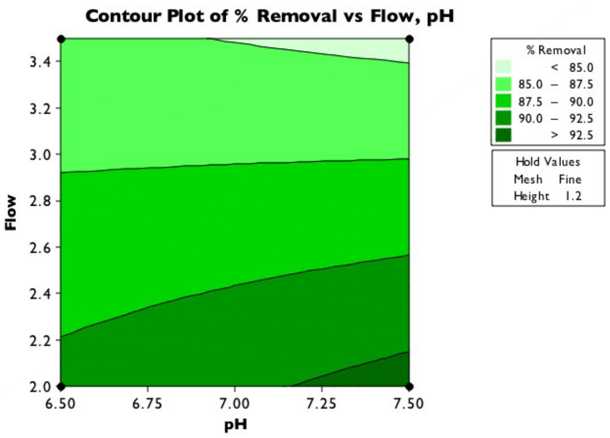

Figure 6. Level chart of optimized pH and flow effects on the lead removal

case (Figure 5). In this diagram it is evident that the effect of simultaneity coincidence of two factors occurs when the darkest green color is shown as the most appropriate height is equivalent to 1.6 meter, although the extent of distribution of 1.4 and 1.5 in height is more. Indeed the best result (96.03%) was obtained when pHset to 6.5 and the height of bed to 1.6 meter. However distribution area at the height of 1.4 and 1.5 is more common. For the values in the column height of 1.6 and kept fine mesh mode, the level chart of simultaneity effects of pH and flow was shown in figure 6. As color differs it is clear that best result appear.

Discussion

There is a significant positive relationship between removal efficiency and increasing the resin column height, also a significant negative relationship between the reducing flow rate and resin particle size reduction. Following the response analyzes it can be inferred that none of the binary and ternary interactions, had no noticeable effect on the removal of lead. It is described as an example at Figure 4, while placing fixed rate flow and size of resin, effects of pH, and bed height fluctuation factors on the removal of lead from the response surface analysis of simultaneous effect of both factors, expressing the positive affect of bed height and negative affect of pH. The maximum process response was achieved at the pH of 6.5 and the bed height of 1.6 meters.

In study of factors affecting lead removal (pH, flow, resin particle size, height) process from water in a completely randomized design through factorial arrangement, with a plotted model of action levels for lead removal efficiency versus the fitted values, the constant of proportionality (r^2) equals to 0.928, ($P= 0.001$), the existence of a linear relationship between the experimental values and the fitted values by model is implied. In a totally software observation it has been shown that when the resin particle size is smaller and the flow rate through the resin column is lower, lead removal operations will be more efficient. In the study of Jha et al the maximum lead absorption by the cationic resin PS-EDTA occurs at pH=5.5 uptake was linearly increased to 50 mg/L (16). Demircivi et al and Khodadadi et al found that there was a liner relation between lead removal efficiency by cationic resin Amberlite IR120 and the lead concentration (17,18). After determining the optimum pilot system operating conditions, the concentration of lead in water was measured during continuous service (19). Results monitored until 21 days. In all charts, a significant relationship was found after the lead concentration in the output system during the days of continuous operation ($P<5\%$). The maximum rate of declining concentration of lead in the 96.03% occurred at third day service. Indeed in a selective competing of ion exchange resin at bed, soluble and non-lead ions success continued until the third day. This process is continued until the eighteenth day when the amount of sodium replaced with resin has gone to above drinking limit (10 μg/L). Although the variation trend of lead concentration and ion exchange efficiency has gone by balanced state. Accordingly variable one-way analyses has shown that operation of resin regeneration on the eighteenth day (before start up resin inefficiency) is required.

Ternary simultaneity interaction of "pH * flow * high" with lead removal efficiency was significant, but had no noticeable effect on the removal of lead through binary and ternary interaction parameters. The most appropriate format for lead removal from aqueous solution containing concentrations of 22 μg/L in the column mode of pilot study was obtained as follows: flow rate of feed water = 2 ml/s, height of resin bed = 1.6 meter, effective size of resin

Conclusion

Based on this research, it is concluded that Purolite S-930 is a chelating resin which has the ability to remove 96.03% of soluble lead concentration in drinking water. In optimized condition during a 21 consecutive days of service period, the mean removal ratio for lead removal from water was equal to 91.27% (up to 22 μg/L). This number has both economic feasibility and technical justification. Using a full factorial experimental design and statistical analysis, the most important effective parameters on the lead removal efficiency was obtained through ion exchange process. Analysis of the responses indicated that height of resin column have the maximum and pH values have minimal effects on the lead removal efficiency in aqueous solution respectively.

Acknowledgments
The authors highly appreciate the sponsorship of Golestan's Rural Water and Wastewater Company and Gorgan's Islamic Azad university.

Ethical issues
We certify that all data collected during the study is presented in this manuscript and no data from the study has been or will be published separately.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
YK, AMM and GAN conceived and designed the study. OAT, KHK, AKH and HS performed the literature search and wrote the manuscript. All the authors participated in the data acquisition, analysis, and interpretation. All authors critically reviewed, refined and approved the manuscript.

References
1. Mahvi A, Leili M. Water treatment. Zistshenasi Khane Publ 2008; (1): 98-90
2. Imran A, Gupta VK . Advances in water treatment by adsorption technology. Nat Protoc 2006; 6(1): 2661-7.
3. Johari D, Rahman TK, Musirin I. Artificial neural network based technique for lightning prediction. The 5th Student Conference on Research and Development, 11-12 Dec 2007, Selangor, Malaysia.
4. Krishnaiah D, Kumaresan SK, Isidore M, Sarbatly R. Prediction of clarified water turbidity of moyog water treatment plant using artificial neural network. Journal of Applied Sciences 2007; 7(15): 2006-10.
5. Schweiker M. Drinking water treatment technologies for groundwater systems under the direct influence of surface water. Commonwealth of Pennsylvania, Department of Environmental Protection; 2001.
6. Sorg TJ. Treatment technology to meet the interim primary drinking water regulations for organics. Journal American Water Work Association 1979; 71(8): 454-66.
7. Yousef NS, Darwish S, Zewail TM, El-Tawail YA. Mass transfer study of heavy metal removal by ion exchange in batch conical air spouting bed. J Chem Eng Process Technol 2013; 4(6): 100-8.
8. Peters RW, Ku Y, Bhattacharyya D. Evaluation of recent treatment techniques for removal of heavy metals from industrial wastewaters. AICHE Symposium Series; 81.
9. Peters RW, Eriksen E, Ku Y. Segregated removal of heavy metal species from mixed-metal plating wastewaters by selective precipitation. Proc. Triangle Conference on Environmental Technology, April 3-4 1985, Raleigh, United States.
10. McIntyre G, Rodriquez JJ, Thackston EL, Wilson DJ. Inexpensive heavy metal removal by foam flotation. J Water Pollut Control Fed 1983; 55(9): 1144-9.
11. Slapik MA, Thackston EL, Wilson DJ. Improvements in foam flotation for lead removal. J Water Pollut Control Fed 1982; 54(3): 238-43.
12. Petersen JJ, Burbank NC Jr, Amy GL. Liquid ion exchange pretreatment for removal of heavy metals from plating rinse water. Proceedings of the 36th Industrial Waste Conference, 1981. p. 472-484.
13. Resta JJ, Daly M, Pressman M. Soluble-Sulfide Precipitation Treatment of Metal Finishing Wastewater,. Proceedings of the 16th Mid-Atlantic Industrial Waste Conference, 1978. p. 265-278.
14. Wang L, Yang L, Li Y, Zhang Y, Ma X, Ye Z. Study on adsorption mechanism of Pb(II) and Cu(II) in aqueous solution using PS-EDTA resin. Chemical Engineering Journal 2010; 163(3): 364-72.
15. Smara A, Delimi R, Sandeaux J, Chainet E. Simultaneous recovery of heavy metals (Pb, Cd, Zn) from diluted solutions by electroextraction technique.Proceedings of the 16th International Conference on Heavy Metals in the Environment, 23 April 2013.
16. Jha MK, Van Nguyen N, Lee JC, Jeong J, Yoo JM. Adsorption of copper from the sulphate solution oflow copper contents using the cationic resin Amberlite IR 120. Journal of Hazardous Materials 2009; 164(2–3): 948-53.
17. Demircivi P, Saygılı G. Removal of boron from waste waters by ion- exchange in a Batch system. World Academy of Science, Engineering and Technology 2008; 47: 95-8.
18. Khodadadi M, Odi Q, Dori H, Azizi M, Talaeean Z, Taheri Z, et al. The survey of microbial and chemical ofmineral andbottled distributed in Birjand city in Winter2007. 10th National Congress on Environment Health, 2007, Hamadan. [In Persian]
19. Standard methods for examination of water andwastewater. 22nd edition. American Public Health Association; 2012.