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Characterization of Hemodialysis Reverse Osmosis Wastewater From Yazd Educational Hospitals

Mohammad Saleh Ali-Taleshi,[1,*] and Farhad Nejadkoorki[2]

[1]Department of Environment, Faculty of Natural Resources, University of Tehran, Karaj, IR Iran
[2]Department of Environment, Faculty of Natural Resources, Yazd University, Yazd, IR Iran

[*]*Corresponding author*: Mohammad Saleh Ali-Taleshi, Department of Environment, Faculty of Natural Resources, University of Tehran, Karaj, IR Iran. Tel: +98-9113914839, Fax: +98-3518210312, E-mail: s.taleshi@ut.ac.ir

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Abstract

This paper evaluates the technical feasibility of reusing hemodialysis reverse osmosis wastewater from educational hospitals in Yazd, Iran, as an alternative water source. For this study, from October to December 2013, hemodialysis reverse osmosis wastewater samples were obtained from two dialysis facilities and analyzed for biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, and electrical conductivity (EC) using standard methods. Furthermore, concentrations of heavy metals such as Ag, Ba, Cd, Cu, Pb, Se, and Zn were calculated. Results were analyzed using the one sample t-test and independent t-test in SPSS 16 software. Mean concentrations of Ag, Ba, Cd, Cu, Fe, Pb, Se, and Zn in the hemodialysis reverse osmosis wastewater were 0.0960, 0.0611, 0.0186, 0.3381, 0.2153, 0.2212, 0.4196, and 0.0667 mg/L at S. Dr. Rahnamoon hospital, and 0.0963, 0.0849, 0.0177, 0.2942, 0.2160, 0.1827, 0.3420, and 0.0867 mg/L at S. Sadoughi hospital, respectively. The results also showed that the important challenges for reusing hemodialysis wastewater were its high EC and the presence of some elements, such as Se and Pb. Unlike Se and Pb, the concentrations of the other parameters were below discharge emission standards. Because of the large volumes of water used in hemodialysis, it is important to study the potential for reusing or recycling it. Through evaluation of the technical feasibility of hemodialysis wastewater reuse, this study draws attention to this neglected issue, especially in hemodialysis therapy.

Keywords: Hemodialysis, Reverse Osmosis, Environment, Wastewater, Iran

1. Introduction

One of the components of green hospital management is wastewater management. Hospitals, as well as other organizational managements around the world, are trying to create innovations in patient treatment while maintaining high quality standards. Such programs include "green hospitals" (1). The results of a study conducted in the US showed that a hospital plan toward greener hospitals was an appropriate method for reducing costs and improving hospital environments (2). The relationship between environmental sustainability and green hospitals was determined and the researcher found that the first and most important motivation toward green hospital standards was energy efficiency (3). Since hospitals and other medical centers have been created as organizations for the screening, treatment, and maintenance of public health, these organizations are responsible for their own environmental management systems (EMS). In hospitals, one of the components of an EMS is the optimal management of water and wastewater. The importance of this issue has been proposed in several studies and in different situations. An environmental analysis in 2008 was conducted in Moroccan dialysis centers for alternative water sources in arid regions. This feasibility study on wastewater consumption for agriculture and landscape irrigation showed that it was necessary to implement recycling due to the high volume of water used in the dialysis process (4). In a study in 2013, reuse of treated wastewater was investigated in arid and semiarid regions. The findings showed that the legal challenges, such as the adoption of relevant standards for water reuse in agriculture, socio-economic issues, and farmers' precipitations, must be considered in the development of options and strategies (5). The quality of wastewater in the Thessaly region in Greece was evaluated to determine its potential use in watering. The findings revealed that if the legal restrictions for toxicity are considered, it can be used for farming and watering landscape plants (6). In all of these studies, special attention was given to the importance of water and wastewater management. This issue is even more important when there is a scarcity of water, especially in arid countries such as Iran. Furthermore, by 2025, 1.8 billion people will live in countries or regions with absolute water scarcities (7). Water is an essential element for life and an important component in the treatment of patients requiring hemodialysis. During this process, large volumes of water are commonly used to prepare dialysate and clean and reprocess dialysis membranes and machines (8). Assuming a dialysate flow rate of 500 mL/min, patients are exposed to 120 L of purified water during a 4-hour dialysis session. Without considering the water rejected during treatment by the carbon filters and reverse osmosis membranes before dialysis usage, the yearly consumption of water for operating 12 hours, 6 days a week for a single-pass dialysis system was estimated to be 112 m^3 (8). An extrapolation of data for a dialysis population that was conducted in 2012 showed that from ~ 2 million patients worldwide, world dialysis services use ~ 156 billion liters of water and discard around two-thirds that amount during reverse osmosis and one-third at the end of the hemodialysis process (9). It is important to minimize this water use, especially in Iran and other water-poor countries in which the scarcity of water sources and lack of water management represents a serious impediment to long-term development. There are few reports about the possible impact of hemodialysis reverse osmosis wastewater discharges on the environment. On the other hand, it has been proven that the per capita carbon footprint of each dialysis patient in dialysis programs are top-heavy (10). Since hemodialysis reverse osmosis wastewater before dialysis can enter municipal and natural water systems through residential or commercial discharges, including hospital effluents, we analyzed the technical potential of reusing hemodialysis reverse osmosis wastewater from educational hospitals in Yazd, Iran, for agriculture, irrigating the hospital grounds, and for drinking water for livestock and poultry. We hope that the results of this study will be useful for reducing a part of the current challenges in water management at hospitals and healthcare facilities.

2. Materials and Methods

2.1. Characteristics of Dialysis Facilities and Wastewater Sampling

The average number of patients requiring dialysis services at S. Dr. Rahnamoon hospital was 1,900 and at S. Sadoughi hospital, this number was 450. The volume of water needed for each dialysis machine was 120 L in 4 hours for each patient. The hospital dialysis effluent discharge rate for water treatment systems was 150 L per hour and 350 L per hour, respectively. The dialysis treatment machines considered in this study were made in Belgium and Germany and the models were Eurothechnic and BMA. Wastewater samples were obtained from two educational hospitals (S.Dr. Rahnamoon and S. Sadoughi). Using sterile 240-mL bottles, samples were collected from the outlet pipe that drains the hemodialysis sewage (including water rejected during treatment by the carbon filters and reverse osmosis membranes) directly into the municipal sewage line. The samples were collected over a period of three months (October to December) in 2013. The number of samples required was calculated with 0.15 precision and the standard deviation (SD) was obtained from the pilot study. One sample was collected each week of each month. Samples were transported to the laboratory in a closed cooler.

2.2. Wastewater Physicochemical Analyses and Quality Criteria

Wastewater samples were analyzed in the laboratory of university for chemical oxygen demand (COD), biochemical oxygen demand (BOD), chloride, sulfate, and total dissolved solids (TDS) using standard wastewater analysis methods (11). Electrical conductivity (EC) and pH testing were also performed. Furthermore, concentrations of heavy metals such as Ag, Ba, Cd, Cu, Pb, Se, and Zn were analyzed using inductively coupled plasma (ICP, Dv-Optima2100). To perform the test, after turning on the machine, the wavelength of the optical system was adjusted. Then the amount of metals in the blank and standards were respectively measured; after reading the standards, calibration curves were controlled. Finally, the samples were injected into the machine to determine the concentrations of the metals. The suitability of using hemodialysis reverse osmosis wastewater for agriculture was evaluated through the comparison of its characteristics with the food and agriculture organization of united nations (FAO), world health organization (WHO) (12, 13) sea water (14, 15) and Iran national standard (16) for water use in agriculture and irrigation. The suitability of its use was further evaluated through comparison with Iran's national standards for discharge water for absorbing wells, drinking water standards for livestock and poultry, and discharge water standards for surface water.

3. Results and Discussion

3.1. Hemodialysis Reverse Osmosis Wastewater Composition

The physiochemical characteristics of the wastewater standards are listed in Table 1 and the physiochemical characteristics of wastewater from the hospitals are presented in Table 2. As well as information on other wastewater that is presented in Tables 1 and 2, and except for EC and Se values that were higher than the standard values, parameters showed values lower than those specified in the standards.

Table 1. Physiochemical Characteristics of the Wastewater Standards

Parameter	FAO/WHO Standards for Irrigation Water[1]	Iran National Standards for Agriculture and Irrigation[2]	Iran National Standards for Discharge to Surface Water[3]	Iran National Standards for Discharge to Catchy Wells[4]	Iran National Standards for Livestock and Poultry Drinking[5]
pH	6.5 - 8	6 - 8.5	6.5 - 8.5	5 - 9	-
EC, μs/cm	300 - 700	-	-	-	-
BOD, mg/L	5 - 45	100	30	30	100
COD, mg/L	-	200	60	60	200
Chloride, mg/L	0 - 30	600	600	600	-
Sulfate, mg/L	0 - 20	500	400	400	-
TDS, mg/L	< 450	-	-	-	-
Ag, mg/L	-	0.1	1	0.1	-
Ba, mg/L	-	1	5	1	-
Cd, mg/L	0.01	0.05	0.1	0.1	0.05
Cu, mg/L	-	0.2	1	1	0.5
Fe, mg/L	5	3	3	3	-
Pb, mg/L	-	1	1	1	0.1
Se, mg/L	0.2	0.1	1	1	0.05
Zn, mg/L	2	2	2	2	24

Abbreviations: BOD, biochemical oxygen demand; COD, chemical oxygen demand; FAO, food and agriculture organization of the united nations; TDS, total dissolved solids; WHO, world health organization.

Table 2. Composition of the Hemodialysis Wastewater from the Dialysis Facilities at S. Dr. Rahnamoon Hospital and S. Sadoughi Hospital

Parameters	S. Dr. Rahnamoon Hospital			S. Sadoughi Hospital		
	Mean ± SD	Max	Min	Mean ± SD	Max	Min
pH	7.84 ± 0.10	8.12	7.71	7.93 ± 0.03	7.99	7.91
EC, μs/cm	854.25 ± 50.42	936	782	774.92 ± 133.83	947	606
BOD, mg/L	7.73 ± 0.46	8.71	6.81	8.50 ± 0.18	8.94	8.16
COD, mg/L	16.10 ± 0.96	18.15	14.19	17.73 ± 0.39	18.63	17.01
Chloride, mg/L	25.93 ± 3.51	29.98	20.59	27.39 ± 3.74	35.50	21.3
Sulfate, mg/L	133.86 ± 21.22	161.4	107.58	108.88 ± 14.38	127.44	82.86
TDS, mg/L	546.69 ± 32.28	599	500.40	495.95 ± 85.64	606.08	389.12
Ag, mg/L	0.0960 ± 0.0029	0.0999	0.0906	0.0963 ± 0.0045	0.1059	0.0901
Ba, mg/L	0.0611 ± 0.0438	0.149	0.0108	0.0849 ± 0.0616	0.2017	0.0132
Cd, mg/L	0.0186 ± 0.0178	0.0474	0.0017	0.0177 ± 0.0163	0.0420	0.0024
Cu, mg/L	0.3381 ± 0.1875	0.581	0.1170	0.2942 ± 0.2111	0.5903	0.1211
Fe, mg/L	0.2153 ± 0.0186	0.2563	0.1945	0.2160 ± 0.0258	0.2563	0.1692
Pb, mg/L	0.2212 ± 0.0483	0.2816	0.1261	0.1827 ± 0.0409	0.2514	0.1328
Se, mg/L	0.4196 ± 0.0867	0.5698	0.2879	0.3420 ± 0.0689	0.4786	0.2446
Zn, mg/L	0.0667 ± 0.0239	0.0975	0.0316	0.0867 ± 0.0388	0.1467	0.0487

Four samples were collected each month for a test period of three months; Figures 1 and 2 show the measured concentrations of heavy metals for all 12 samples.

The differences between the measured values and the standard values were calculated for both hospitals. These results showed that there was a significant difference between EC values and the minimum value in the FAO/WHO standard ($P < 0.0001$). However, there was no significant difference between EC values and the maximum value of the FAO/WHO standard for wastewater from the dialysis facility at S. Sadoughi hospital ($P = 0.079$). In other words, the EC values in the samples were higher than the minimum FAO/WHO value. Furthermore, there was a significant difference between Se values and the available standard values ($P < 0.0001$), and Se values were higher than the FAO/WHO irrigation standard. The results of the one-sample t-test showed that there was a significant difference between EC values with both minimum and maximum values in the FAO/WHO standard at S. Dr. Rahnamoon hospital ($P < 0.0001$). On the other hand, the EC values in the samples were much higher than the standard limits in the FAO/WHO standard in current hospital. Similarly, for the S. Sadoughi dialysis facility, there was a significant difference between the Se values and the available standard val-

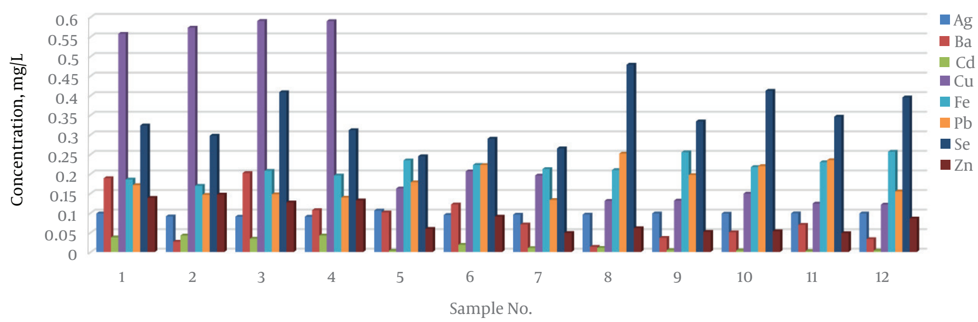

Figure 1. Heavy Metal Concentrations in Samples from S. Sadoughi Hospital

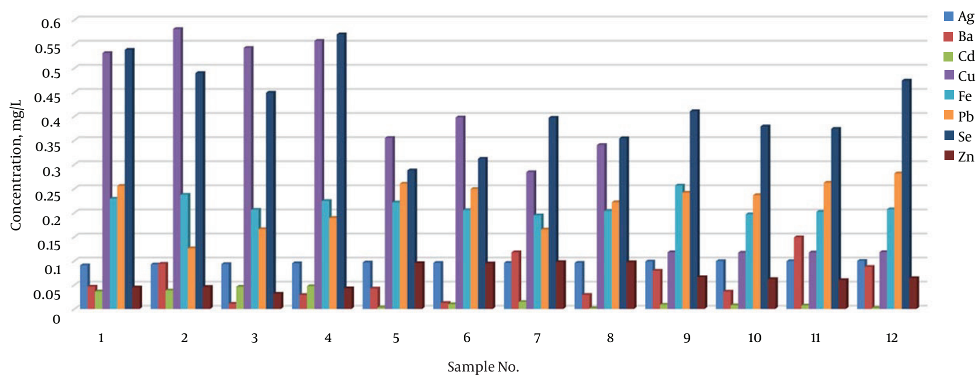

Figure 2. Heavy Metal Concentrations in Samples from S.Dr. Rahnamoon Hospital

ues for the S. Dr. Rahnamoon dialysis facility. The results of the independent t-test and the differences between the measured parameters in the hemodialysis reverse osmosis wastewater from the two hospitals are summarized in Table 3.

The results showed that among the heavy metals, there were significant differences between Se and Pb values in the two dialysis facilities. For the other measured parameters, there were significant differences between the BOD, COD, and sulfate values in the two dialysis facilities with a 99% confidence interval. These results revealed that the most significant challenges in the reuse of hemodialysis wastewater are its high EC and the presence of high concentrations of some other elements. In contrast, the concentrations of other parameters were below the discharge emission standards. Since high EC is the main problem, the application of membrane technology could be suitable for the treatment of such wastewaters. This technology is more economical than other processes.

Water scarcity problems in arid and semiarid regions of the world, including Iran, are increasing. As the population grows, water is a limited resource. Therefore, many efforts must be made to use water more effectively and new practices in the fields of water use and conservation must be developed. Due to the high consumption of water resources in the hemodialysis process, this process was studied as an environmental issue. In regions with scarce water resources, such as Yazd in Iran, high consumption of water can lead to a water crisis.

In this study, we discussed the characterization of hemodialysis reverse osmosis wastewater in educational hospitals in Yazd, Iran, with regard to the technical feasibility of reuse. The studied parameters showed that except for EC values, which were higher than the FAO/WHO standard, the values for the other tested parameters were within acceptable limits. Therefore, wastewater must be treated to acceptable standards before reuse. A study was conducted on wastewater reuse in irrigation in Portugal; the researchers found that irrigating with wastewater may have two affects. The first effect is on the physicochemical and microbiological properties of the soil, and the second effect is the contribution to the accumulation of chemical and biological contamination in the soil (17). The results of the current study show that the measured EC was

Table 3. Results of the Independent T-Test

Parameter	P Value[a]
pH	0.014 *
EC, μs/cm	0.068 ns
BOD, mg/L	< 0.0001
COD, mg/L	< 0.0001
Chloride, mg/L	0.333 ns
Sulfate, mg/L	0.003 **
TDS, mg/L	0.075 ns
Ag, mg/L	0.865 ns
Ba, mg/L	0.288 ns
Cd, mg/L	0.899 ns
Cu, mg/L	0.595 ns
Fe, mg/L	0.940 ns
Pb, mg/L	0.047 *
Se, mg/L	0.024 *
Zn, mg/L	0.146 ns

[a] ns, Not significant; **, Significant difference at 0.01 (2-tailed); *, Significant difference at 0.05 (2-tailed).

much lower than the guidelines for wastewater reuse in irrigation in different world regions (18-20). Therefore, in the case of Yazd, the two effects mentioned above will not be observed in the future. Separate treatment of hospital wastewater, particularly in this part, would also reduce the pharmaceutical load and risk for wastewater treatment plants. For such high EC wastewaters, membrane separation technology has proved to be the preferred treatment technology (21, 22). Moreover, this method has been shown to be more efficient than other approaches (23, 24). This issue was validated in a study on recycling wastewater after hemodialysis in Morocco. The simulations in this study showed that nanofiltration and reverse osmosis methods had greater benefits than desalination of seawater, resulting in a cost savings (or benefit) of 20% to 30% (4). Because there is no such information to compare with the FAO standard, in the current study, we have referenced the Moroccan study. In contrast, the feasibility of industrial saline wastewater reuse in irrigation was studied in 2006 and the findings showed that it was a suitable method for watering halophytes (22); this could be considered a suggestion in our study. In a study conducted in the Middle East and North Africa, researchers investigated sustainable water management. The findings presented an integrated approach to wastewater management in these regions as an opportunity to optimize the use of renewable water sources (25). In this regard, investigation of the concentrations and distribution of pharmaceuticals and environmental risk assessment in Italy revealed a high risk of pharmaceuticals showing up in hospital effluent. This effluent represented high environmental risk (26). In the current study, the effluent in the reverse osmosis systems did not show high contamination, however, its combination with pharmaceutical substances before treatment would probably increase treatment costs. Pharmaceuticals and personal care products (PPCPs) in treated wastewater discharging into Charleston Harbor, South Carolina, were studied in 2012. The results showed seasonal trends in the measured parameters (27). This finding was similar to our results, as shown in Figures 1 and 2, particularly for Cd. In a review study, the characterization of the ecotoxicity of hospital effluents was evaluated and the findings showed that the ecotoxicity of effluents must be taken into account (28). This issue was not investigated in the current study. It is also necessary to monitor the effluents of each of the specialized departments of the hospital studied (28); however, due to the high cost of this project, this issue was also not investigated. This is a necessary step to define realistic environmental management policies for the replacement of toxic products with less pollutant ones. Potential environmental toxicity from hemodialysis effluent was monitored in Brazil. The samples in this study were collected directly from hemodialysis machines after patient treatments. However, the measured EC was higher than the other parameters, which reflects the fact that the hemodialysis process has a significant impact on raising EC (29). This finding was similar to our results. In a study that was conducted on the water scarcity issue and the need for wastewater reuse in north China, due to economic constraints, the researchers introduced a decentralized system as a suitable reuse strategy in this region (30). These studies showed that the use of wastewater will not happen unless appropriate management and methods are considered.

4. Conclusion

In conclusion, because of high water consumption during hemodialysis, it is essential to study its potential for reuse or recycling. Although, the "hospital-end-of-pipe" approach used in the current study does not allow for evaluation of the local risks linked to the emissions of such effluents in ecosystems, future works must consider risk assessment and exposure to non-target organisms. Through the evaluation of the technical feasibility for the reuse of hemodialysis wastewater, this study draws attention to the issue, which has been a neglected aspect of hemodialysis therapy. This issue can offer an approach to "green" or eco-dialysis.

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Footnote

Authors' Contribution The overall implementation of this study, including experiments, data analyses, and manuscript preparation, were conducted by those listed as co-authors of this paper. All authors have made extensive contribution to the review and finalization of this manuscript.

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