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RESEARCH ARTICLE

Characteristics and quality analysis of wastewater resulting from medical uses in Assiut University Hospitals: A case study on hemodialysis wastewater and reverse osmosis reject water

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Abstract

Hemodialysis water is an essential element necessary for the production of dialysates as well as disinfection generators. Each patient's hemodialysis session requires around 120 liters of filtered water. Assiut University Hospitals' hemodialysis facilities treat more than 300 patients each day and perform over 85,000 hemodialysis sessions per year. This study includes an evaluation of the bacteriological and physicochemical quality of blood dialysis waste and water rejected from the treatment units. Samples were collected and tested in accordance with standard methods of wastewater analysis. The physicochemical investigation focused on the extent of potential hydrogen (pH), electrical conductivity (EC), chemical oxygen demand (COD), biochemical oxygen demand (BOD), chloride, and total dissolved solids (TDS), as well as Magnesium (Mg), Potassium (K), Calcium (Ca2), Nitrogen (N), Phosphorus (P), Sodium (Na), Chloride (Cl), Bicarbonate (HCO3), Oil & Grease, total phenol. Also, enumeration of fecal coliforms was performed by membrane filtration and searches for Streptococci sp. and Pseudomonas aeruginosa were conducted through microbiological investigation. According to the findings, untreated effluents cannot be used directly for irrigation. Prior treatment is required to improve the quality of the wastewater. The results for the heavy metals Lead (Pb), Mercury (Hg), Iron (Fe), Cobalt (Co), Silver (Ag), Nickel (Ni), Cadmium (C), and Manganese (M) revealed compliance with acceptable norms. It would be beneficial to investigate the possibility of recycling effluent from Assiut University Hospital's hemodialysis center. Which leads to saving water resources and protecting the environment? It is critical to investigate the possibility of reusing or recycling it. This work brings attention to this neglected subject, particularly in hemodialysis therapy, by evaluating the feasibility of hemodialysis wastewater reuse.

Keywords: Hemodialysis wastewater; Rejects water; Wastewater treatment; Water Conservation; Heavy metal.

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Introduction

Due to climate change, global warming, and recurring droughts, water is becoming a precious natural resource. It is also far too valuable to waste (Tarrass et al. 2008; Benjelloun and Tarrass 2010). The same water reserves that was once available to the Earth are now shared by a global population of 8 billion people, with more than one-third of them living in water-stressed countries. Egypt now has an annual water shortage of 13.5 billion cubic meters, which is expected to continue increasing to 26 billion m3By 2025. Mohie El Din and Moussa 2016). The yearly water allocation per capita is similarly deficient, having dropped to 700m3 in 2013 (Khayry, 2022). The United Nations has declared that this share is less than the specified quantity required to meet an individual's water consumption and irrigation needs. The UN further said that the share per capita is expected to fall even more to 350m3 annually by 2050 during a normal 4-hour dialysis session; a patient is exposed to 120 liters of filtered water. The annual consumption of a dialysis system that operates 12 hours a day, 6 days a week, is estimated at 112 m3, not considering water rejected during water treatment with carbon, filters, and reverse osmosis membranes. (Hoenich et al. 2010; Ali-Taleshi et al. 2016). Furthermore, for each liter of usable water utilized to generate the dialysis fluid, up to 30–50% of the water entering the water treatment system may be passed on to the drain [this varies depending on the efficiency of the reverse osmosis (RO) system employed]. For producing high-quality water, a multistage process begins with the flow of the main stream through sand micro filters to remove particulate matter. It is then passed through activated carbon, which absorbs chlorine and other toxins. This water is then treated with RO to remove any remaining salts (Agar 2008). Due to the rising scarcity of water around the world, questions are being raised about whether any of this water can be reused (Pescod 1992; Tarrass et al. 2008; Agar 2010). And here two aspects of water must be looked at: may less water be used during treatment, and may reverse osmosis (RO) water and leftover dialysis fluid be reu (Tarrass et al. 2010). Strategies for saving water during hemodialysis have had considerable financial and environmental benefits (Tarrass et al. 2008; Agar 2010; Tarrass 2010). Recycling wastewater for possible reuse also seems to be one of the techniques considered, allowing not only a considerable gain in water resources but also contributing to the resolution of the problem of hospital effluent, which is becoming more and more important following the low potential for processing certain chemical substances of hospital origin by station purification (Bowron et al. 1985). However, there is virtually little written literature on this issue.

This study looks at the properties and quality of hemolysis effluent, as well as the possible economic and environmental benefits of reusing it.

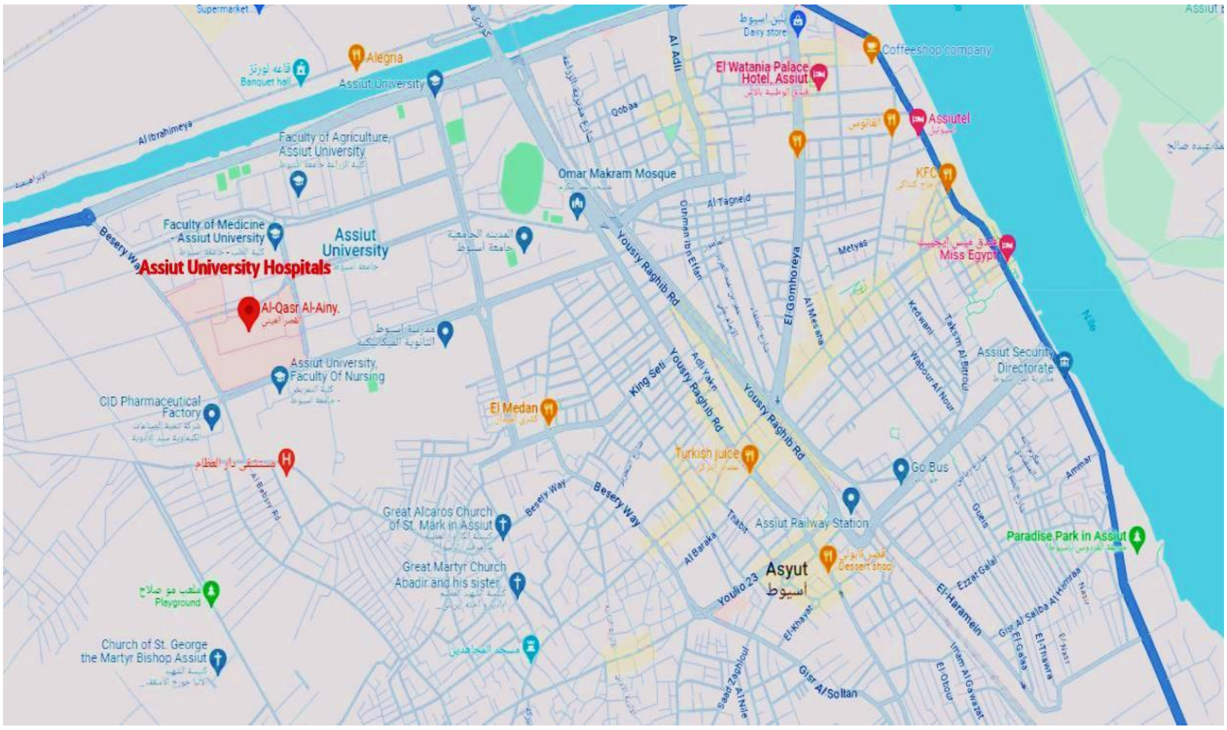

Figure 1. Location of the study area of Assiut University hospitals

The aim of the study was to investigate the chemical, physical, and microbiological characteristics of wastewater in dialysis (water rejected in pre-treatment, concentrate rejected by the osmosis unit, post-generator dialysate) and the resulting environmental risks. Assiut University Hospitals contains four dialysis units Fig 3. The samples from the selected hospitals were taken in 2019 and 2020 Fig 2. The suitability of hemodialysis wastewater use in agriculture was evaluated through a comparison of its characteristics with the standard of Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) standards for wastewater use for agricultural applications, as presented in (Tables 1,2,3, and 4). The optimum procedure for treatment to reach standards is discussed according to the quality of the generated wastewater. Water Conservation: An Emerging but Vital Issue in Hemodialysis Therapy Water (Tarrass et al. 2010; Verlicchi et al. 2012).

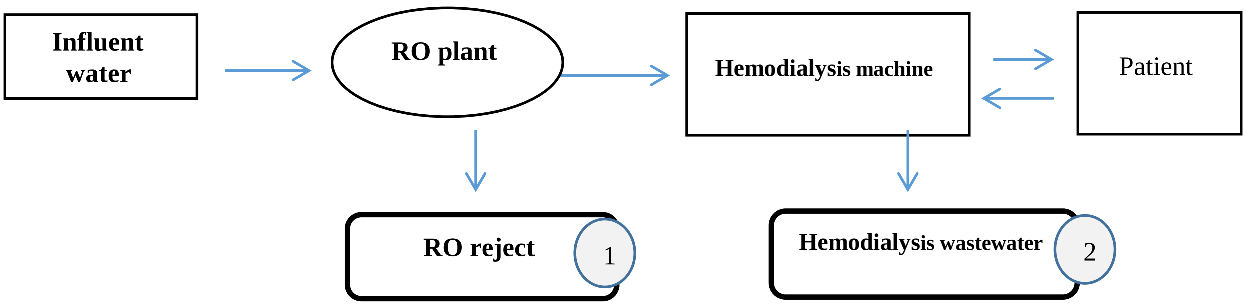

Figure 2. A diagram of the wastewater produced by hemodialysis and the RO treatment process.

Normal kidneys purify the blood from all harmful fluids through urine, and in the event of kidney failure, treatment is through a hemodialysis machine that contains two parts, one for blood and one for dialysate (dialysis solution, see Table 6). And there is a thin membrane between them through which useless molecules such as urea, creatinine, and excess fluids pass. Which is drained into the wastewater pipe, while the blood and essential components that cannot pass through this thin membrane remain? The fluids used in dialysis consist of concentrates, mainly water. The water used may vary in composition and quality. The source of dialysis water is drinking water (tap) that is passed through a purification chain in the dialysis water treatment unit. Plain (tap) water cannot be considered safe for use in dialysis because some of the most toxic contaminants originate from the treatment of plain water. Water treatment systems that supply dialysis machines remove contaminants through various stages, including reverse osmosis, deionization, carbon filtration, and modern advanced purification processes such as chips, filters, and chemical injection. Hemodialysis consumes a lot of water. Water is necessary for the preparation of dialysate, as well as the cleaning and reprocessing of equipment and membranes (Tarrass 2010). The volume of water rejected by most dialysis rejection systems reaches 66%, and the traditional use of water for each case is estimated at 408 liters, in addition to 80 liters for preparation and sterilization between shifts, bringing the total capacity to about 500 liters for each patient. (Tarrass et al. 2008; Tarrass et al. 2010). including priming and washing volumes. Despite escalating water shortages, most dialysis centers continue to waste substantial amounts of this recyclable resource into sewage on a regular basis (Tarrass et al. 2008; Tarrass 2010; Agar 2008; Agar 2010). As the world's population grows, so does the sustainable growth rate of the dialysis patient population. The yearly growth rate of the dialysis patient population is now estimated to be 6%, resulting in approximately 4 million patients by 2025 (Connor et al. 2010; Tarrass et al. 2021). As the number of dialysis patients increases, so does the amount of Ural resources consumed and waste created by dialysis facilities, estimated water consumption in dialysis centers for the United States, Australia, and Morocco is 5 trillion liters, 400 million liters, and 190 million liters of fresh water per year (Agar 2008; Tarrass et al. 2008). Egypt consumes over 2 trillion liters of fresh water per year, based on its 65,000 patients in 2022 According to the Egyptian Society for Kidney Diseases and Transplantation, the percentage of people in need of dialysis reaches 650 cases per million, which is more than double the global rate (Bello et al. 2019). Therefore, this massive waste of water must be reduced, and renal centers must pay close attention to this issue. It is known aware that the water drained from the RO has no contact with the patient and is generally similar to the quality standards of drinking water (Agar et al. 2009). as this water is rich in salts because it results from the removal of ions from the natural water used for drinking. Therefore, ways must be sought to reduce the waste of this water. Reduction and reuse requirements for water treatment equipment differ from one dialysis center to the next based on the type, design, and volume of water processed by the RO system. Water-saving approaches and techniques can range from simple ways, such as picking and developing a RO system, to more advanced ones, such as the reuse of waste dialysate. There are many influences on the amount of water rejected from RO. Temperature is inversely proportional to water flow. Higher temperatures enhance water flow, while lower temperatures reduce it. A large reverse osmosis system wastes a lot of treated water and increases reverse osmosis water (Duman et al. 2023). reverse osmosis systems that are sophisticated and modern greatly minimize the amount of water that is rejected. It enhances the likelihood of conserving water (Agar 2008). Modern reverse osmosis technology in artificial kidney unit No. 2 at Assiut University Hospitals It reduced water loss by 20% (Fig. 3). Financial savings from water recycling in hemodialysis water is used extensively in dialysis units (Ali-Taleshi et al. 2016). A typical water redirection system includes The rejected water is transferred from the reverse osmosis unit to a storage tank equipped with float switches, and then it is pumped for redistribution according to needs. In the event of non-demand, the surplus water is transferred to the to drain (Tarrass 2010). Water conservation can result in significant financial savings (Agar 2008; Tarrass et al. 2008; Agar 2010). It was also observed that treating wasted dialysate for irrigation could potentially lead to a 20–30% reduction in costs when compared to saltwater desalination is presented in (Table 7). A variety of characteristics must be considered when doing a cost-benefit analysis: capital equipment, operating and maintenance costs, and the volume of conserved water (Tarrass et al. 2008; Benjelloun et al. 2010). In most circumstances, the expenses are minimal, with significant potential savings. Environmental Implications Dialysis wastewater may have a significant environmental impact. To drain wastewater with high conductivity and salinity (Tarrass et al. 2008; Benjelloun et al. 2010; Shakir et al. 2017). However, the harm posed by its release into bodies of water is still unknown. There is another important aspect that must be taken into consideration in water conservation, which is that any amount of water saved is offset by a reduction in energy consumption and associated emissions (Zhou et al. 2013; Cornejo et al. 2014) which leads to a reduction in greenhouse gas emissions associated with energy production.

The carbon footprint of the dialysis unit is the total amount of greenhouse gases produced to support its activities, usually defined in equivalent tons of carbon dioxide (CO_2 Related research has confirmed that the carbon footprint of kidney care is estimated at 27 percent. One million metric tons of carbon dioxide is produced annually around the world, which is a very high value. Using 14.5 cubic meters of dialysis water rather than tap water will lead to saving 1240 kg of carbon dioxide equivalents annually and the saving may reach 0.28 kg of carbon dioxide equivalents .Carbon dioxide per cubic meter of reused water. The amount of carbon saved by using waste dialysis water remains undetermined. However, water conservation contributes to lowering carbon emissions (SDU 2009; clake et al.2009).

Materials and Methods

Sample Collection

This is a descriptive cross-sectional study carried out in the nephrology-hemodialysis department of our Assiut University hospitals. From 2019 until the end of 2023, Assiut University Hospitals contain four artificial kidney units. Shown in Fig 3. One was chosen at random to perform a study on it. Samples were collected during different seasons of the year throughout the study period. The wastewater samples were collected from the outflow pipe that drains hemodialysis effluent directly into the municipal sewage line (station 2). and RO concentrate (RO reject-station 1). Using sterile 500-mL bottles.

All samples were transported to the lab in a closed cooler immediately after collection and kept at 4 °C in the refrigerator until testing. About 300 patients go through hemodialysis at the Assiut University Hospitals' hemodialysis units three times per week, or 12 times per month. The volume of influent water needed for each hemodialysis machine (Swedish versions of Gambro and Fresenius Germany) was 30 L/h per patient. The flow diagram of the produced wastewater from hemodialysis and the RO treatment process is schematically shown in Fig 2.

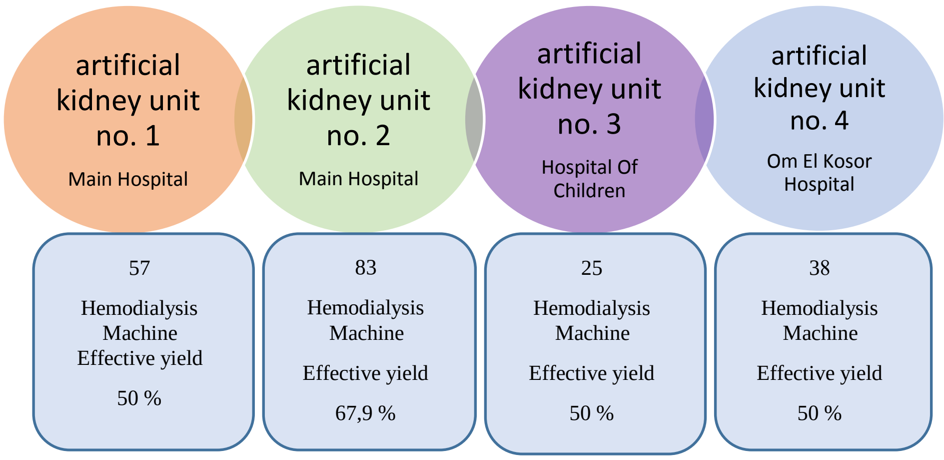

Figure 3. Ahemodialysis units at Assiut University Hospitals and several devices in each unit

Wastewater Physicochemical Analyses and Quality Criteria

The physical and chemical parameters of wastewater produced by hemodialysis units at Assiut University Hospitals were investigated. These analyses were conducted in accredited laboratories of the Faculty of Science and the Faculty of Agriculture, Assiut University, and Abu Qurqas Sugar Factory in Minya and focused on evaluating each of the following: (COD), (BOD), (TDS), (EC) and (pH), (Na+), (K+), (Ca2+), (Mg2+), (Cl−), By The pH meter, EC meter, Jenway 9500 dissolved oxygen meter, flame photometer, and spectrophotometer were also used for analysis. Spectro photo meter. ASTM D3921-96a is an this test method involves the determination and estimation of the combined oil and grease and the petroleum hydrocarbon contents of a sample of waste water and ASTM D1783-01 (2020) Standard Test Methods for Phenolic Compounds in Wastewater. Also the heavy metal concentrations such as Pb, Hg, Fe, Co, Ag, Ni, Cd, and Mn by using inductive atomic absorption at 210 volts, and the rest of the tests were quantified according to standard methods. The obtained results of the chemical and physical characteristics of reverse osmosis wastewater from hemodialysis were compared to those of the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) Pescod 1992; Carr et al. 2004). And Egyptian standards (Tables 3, 4). The bacteriological parameters monitored include Escherichia coli, fecal Escherichia coli counts, Streptococci counts, and Pseudomonas aeruginosa counts. The isolation and identification of bacterial isolates were carried out according to Bergey's Manual of Determinative Bacteriology. Krieg and Wood 1989; Bergey 1994). The physiochemical parameters were studied using the standard methods of APHA (Association 1926).

Table 1. Physiochemical Characteristics of RO reject water in Assiut University Hospitals.

Parameters	Unit	RO reject water		
		Mean ± SD	Max	Min
pH		7.68±0.22	7.92	7.3
Electrical conductivity (EC)	ds/m	0.342±0.185	0.568	0.105
Biological oxygen demand (BOD)		58.56±9.03	74.3	50.2
Chemical oxygen demand (COD)		69.72±8.61	80	53
Total Suspended Solid (TSS)		4.55±1.02	5.5	2.3
Dissolved Oxygen (DO)		1.77 ± 0.021	2	1.5
Total dissolved solids (TDS)		234.19±145.92	417.48	131.2
Bicarbonate, (HCO_3)	mg/L	597.95±12.6	610	570
Phosphorus (P)		22.94 ±1.9	24. 75	20.05
Nitrogen (N)		40.73±10.58	56. 0	30
Chloride (Cl^-)		155.10 ±19.4	177.5	125.29
Magnesium (Mg^{2+})		166.7±12.7	180	140.2
Potassium (K^+)		12.24 ±1.05	13.65	10.82
Sodium (Na^+)		23.01±5.7	29.9	16.12
Calcium (Ca^{2+})		276.19 ±3.9	280	269.2
Silver (Ag)		Nil	Nil	Nil
Cadmium (Cd)		Nil	Nil	Nil
Cupper (Cu)		0.003 ± 0.001	0.0056	0.0017
Lead (Pb)		0.00184 ± 0.0001	0.003	0.0017
Mercury (Hg)		Nil	Nil	Nil
Nickel (Ni)		0.00174±0.0005	O.0026	0.0013
Cobalt (Co)		Nil	Nil	Nil
Manganese (Mn)		0.000248± 0.0002	0.00047	0
Zinc (Zn)		0.0145±0.009	0.0281	0.005
Iron (Fe)		2.68 ±0.07	2.751	2.569

Table 2. Physiochemical Characteristics of Hemodialysis Wastewater in Assiut University Hospitals.

Parameters	Unit	Hemodialysis Wastewater		
		Mean ± SD	Max	Min
pH		7.96±0.34	8.4	7.5
Electrical conductivity (EC)	ds/m	5.73 ±4.20	13.4	2.21
Biological oxygen demand (BOD)		116.6 ±1.3	118	115
Chemical oxygen demand (COD)		168.83±5.55	178	162.71
Total Suspended Solid (TSS)		23.22 ±7.43	35	10
Dissolved Oxygen (DO)		2.4 ±0.156	2.6	2,2
Total dissolved solids (TDS)		3674.7 ±2694.5	8576	1112
Bicarbonate, (HCO_3)		3583.78±71.33	3673	3470
Phosphorus (P)		22.53±2.29	24.5	18.2
Nitrogen (N)		146.2±7.1	154	136.5
Chloride (Cl^-)		4101.67±85.04	4207	3978
Magnesium (Mg^{2+})		510.22±16.63	528	490
Potassium (K^+)		147.98 ±8.65	156.78	131.18
Sodium (Na^+)	mg/L	2771.55 ±131.15	2920.40	2540.20
Calcium (Ca^{2+})		314 ±6.21	320	301. 90
Oil & grease		412.5± 400	1073.33	120
Total phenol		103±0.08	0.171	0.01
Anionic Surfactants		2.484±2.1	6.195	0.805
Silver (Ag)		0.00112±0.001	0.002	Nil
Cadmium (Cd)		0.0134±0.013	0.030	Nil
Cupper (Cu)		0.0702±0.012	0.087	0.,061
Lead (Pb)		0.00412±0.003	0.0090	Nil
Mercury (Hg)		0.00816±-0.013	0.030	Nil
Nickel (N)		0.233±0.03	0.258	0.178
Cobalt (Co)		0.243±02	0.259	0.210
Manganese (Mn)		0.0087±0.0007	0.,0093	0.0078
Zinc (Zn)		0.1336 ±0.036	0.156	0.070
Iron (Fe)		2.40±٠.٠9	2.521	2.267

Table 3. Comparison of RO reject water with HEG, ECP, FAO, and WHO.

Parameter	RO reject water	Agreed to standards √ = yes , × = no	Healthcare wastewater management in Egypt	ECP 501/2015	FAO/WHO Standards
pH	7.68±0.22	√	6-9,5	NM	6.5 - 8.41
EC	0.342±0.185	√	NM	NM	3[1]
BOD	58.56±9.03	√	600	350	300[2]
COD	69.72±8.61	√	1100	NM	NM
TSS	4.55±1.02	√	800	300	350
DO	1.77 ± 0.021	×	NM	NM	> ٥
TDS	234.19±145.92	√	NM	٢٠٠٠	٢٠٠٠
HCO_3	597.95±12.6	(× (Egypt (√ (FAO/WHO	NM	400	600[2]
P	22.94 ±1.9	√	25	NM	NM
N	40.73±10.58	√	100	NM	101
Cl-	155.10 ±19.4	√	NM	NM	1100[2]
Mg	166.7	×	NM	100	601
K	12.24	√	NM	NM	21
Na	23.01±5.7	√	100	230	900[2]
SAR	1.5	√	NM	9	152
Ca	276.19 ±3.9	(× (Egypt (√ (FAO/WHO	NM	230	400[2]
Ag	Nil	√	0.5	NM	NM
Cd	Nil	√	0.2	0.2	0.2
Cu	0.003 ± 0.001	√	1. 5	0.2	0.2
Pb	0.00184 ± 0.0001	√	1	5	5
Hg	Nil	√	0.2	NM	NM
Ni	0.00174±0.0005	√	1	0.2	0.2
Co	Nil	√	NM	0.05	0.05
Mn	0.000248± 0.0002	√	NM	0.2	0.2
Zn	0.0145±0.009	√	NM	5	5
Fe	2.68 ±0.07	√	NM	5	5

Table 4. Comparison of wastewater from Hemodialysis with HEG, ECP, FAO and WHO.

Parameter	Hemodialysis Wastewater (this study)	Agreed to standards √=yes , × = no	Healthcare wastewater management in Egypt	ECP 501/2015	FAO/WHO Standards
pH	7.96±0.34	√	6-9,5	NM	6.5 - 8.41
EC	5.73 ±4.20	×	NM	NM	3[1]
BOD	116.6 ±1.3	√	600	350	300[2]
COD	168.83±5.55	√	1100	NM	NM
TSS	23.22 ±7.43	√	800	300	350
DO	2.4 ±0.156	×	NM	NM	> ٥
TDS	3674.7 ±2694.5	×	NM	2000	٢٠٠٠
HCO3	3583.78±71.33	×	NM	400	600[2]
P	22.53±2.29	√	25	NM	NM
N	146.2±7.1	×	100	NM	101
Cl-	4101.67±85.04	×	NM	NM	1100[2]
Mg	510.22±16.6	×	NM	100	601
K	147.98 ±8.65	×	NM	NM	21
Na	2771.55 ±131.15	×	100	230	900[2]
SAR	54.3	×	NM	9	152
Ca	314 ±6.21	(× (Egypt (√ (	NM	230	400[2]
Oil & grease	412.5± 400	FAO/WHO	100	2	2
Total phenol	103±0.08	×	0,05	NM	NM
Anionic Surfactants	2.484±2.1	×	1	0, 2	0, 2
Ag	0.00112±0.001	×	0.5	NM	NM
Cd	0.0134±0.013	√	0.2	0.2	0.2
Cu	0.0702±0.012	√	1.5	0.2	0.2
Pb	0.00412±0.003	√	1	5	5
Hg	0.00816±-0.013	√	0.2	NM	NM
Ni	0.233±0.03	√	1	0.2	0.2
Co	0.243±02	√	NM	0.05	0.05
Mn	0.0087±0.0007	√	NM	0.2	0.2
Zn	0.1336 ±0.0361	√	NM	5	5
Fe	2.40±٠.٠9	√	NM	5	5
Escherichia coli	855.5±2515	√	NM	< 5000 (advised	2–10 10^4
Pseudomonas aeruginosa	240±0		NM	NM	< 5000 (advised)
Streptococci sp.	168±46.5		NM	NM	NM

Food and Agriculture Organization of the United Nations, FAO; World Health Organization, WHO; colony-forming unit, CFU; Egyptian standards and specifications for disposed in public sewage networks, NM, not mentioned - Healthcare waste management in Egypt, guide 2015, ECP 1. FAO 29 guideline (Ayers & Westcot 1985). 2. FAO 47 guidelines (Pescod 1992). 3.ECP Egyptian code of practice (501/2015)

Table 5. Comparison of the composition of reverse osmosis water in dialysis units at Assiut University Hospitals with many dialysis centers around the world and with the US EPA standards for potable water (Hmida et al. 2023).

Parameters	Assiut University Hospitals	Iran, Ali-Taleshi and Nejadkoork		France, Ponson et al.16	Morocco, Berrada et al.42	Australia, Agar		US EPA
		Sat 1	Sat 2			Sat 1	Sat 2	
Cadmium	–	–	–	–	–	0.002	0.0002	0.005
Copper	0.003	–	–	–	–	0.009	0.01	1.3
Iron	2.68	–	–	0.3	–	0.02	0.002	0.3
Lead	0.00184	–	–	–	–	0.001	0.002	0.015
Manganese	0.000248	–	–	–	–	0.01	0.002	0.05
Mercury	–	–	–	–	–	0.0001	0.0001	0.002
Zinc	0.0145	0.0667	0.0867	–	–	0.002	0.008	5
Calcium	276.19	–	–	–	–	0.1	0.1	No standard
Magnesium	166.7	–	–	–	–	0.1	0.1	No standard
Sodium	23.01	–	–	–	–	140	68	200
Total hardness	40.73	–	–	–	–	0.01	0.01	No standard
Chloride	١٥٥.١٠	25.93	27.39	45.7	542.96	150	٧٤	٢٥٠
Conductivity	٣٤٠	854.25	774.92	–	3460	680	٣٤٠	2500
pH	7.68	7.84	7.93	8	7.85	7.5	7.5	7.5 ± 1.0
Dissolved solids	234.19	–	–	–	–	320	200	500

Sat; satellite, US EPA; United States Environmental Protection Agency.

Table 6. Comparison of the composition of hemodialysis wastewater at Assiut University Hospitals and dialysis facilities in several dialysis centers around the world (Hmida et al. 2023).

Parameters	Units	Assiut University Hospitals	Iran, Ali-Taleshi and Nejadkoorki12		Morocco, Tarrass et al.17	Tunisia, Jallouli et al.18	Brazil, Machado et al.46
			Sat 1	Sat 2			
pH		7.96	7.84	7.93	7.84	7.46	7.49
Conductivity	µS/cm	٥٧٣٠	854	774	13,200	13,530	4080
COD	mg/l	168.83	16.10	17.73	289	262.033	832
Cl	mg/l	3674.7	25.93	27.39	–	3976	–
Total nitrogen	mg/l	146.2	–	–	–	13.88	126.7
Mg	mg/l	510.22	–	–	–	21.091	–
Ca	mg/l	314	–	–	–	3757	–
Na							

Table 7. Comparison of Costs of Hemodialysis Wastewater Treatment Versus Desalination (Tarrass et al. 2008).

Parameters	Multistage Flash (US $/m^3)	Multiple-Effect Distillation (US $/m^3)	Vapor Compression (US $/m^3)	Reverse Osmosis (US $/m^3)	Nano filtration (us$/m^3)	Reverse Osmosis (US $/m)^3
Capital cost	0.301	0.520	0.548	0.301	0.358	0.39
Energy Fuel	0.62	0.55	0	0	—	—
Electricity	0.18-0.19	0.08-0.09	0.60-0.66	0.26-0.32	0.118	0.161
Labor	0.038-0.043	0.036-0.048	0.064-0.096	0.021-0.097	0.312	0.338
Chemicals	0.033-0.047	0.028-0.038	0.022-0.038	0.019-0.056	0.009	—
Membran replacement	0	0	0	0.001-0.043	0.227	0.195
Maintenance	0.021-0.038	0.021-0.038	0.019-0.032	0.021-0.038	0.037	0.047
Payback costs	0.40-0.42	0.40-0.42	0.43-0.45	0.18-0.26	—	—
Total costs	1.32-1.38	1.15-1.21	1.15-1.29	0.54-0.85	0.70	0.74

Table 8. Composition of concentrated Hemodialysis solution.

Composition Before Dilution (A)			Concentration After Dilution (A)		
Sodium chloride	214.80	gm/L	K	2.00	mmol /l
Potassium chloride	5.22	gm/L	Ca	2.50	mmol /l
Calcium chloride, $2H_2O$	7.72	gm/L	Mg	0.50	mmol /l
Magnesium chloride, $6H_2O$	3.56	gm/L	CL-	111.00	mmol /l
Glacial acetic acid	4.21	gm/L	CH_3COO	2.00	mmol /l
Purified water to	1000	gm/L	Na	140.00	mmol /l
			Hco3	33.00	mmol /l
+1.000 L (A) + 32.775 L purified + 1.225 L $NaHCO_3$ SOL. (B)					

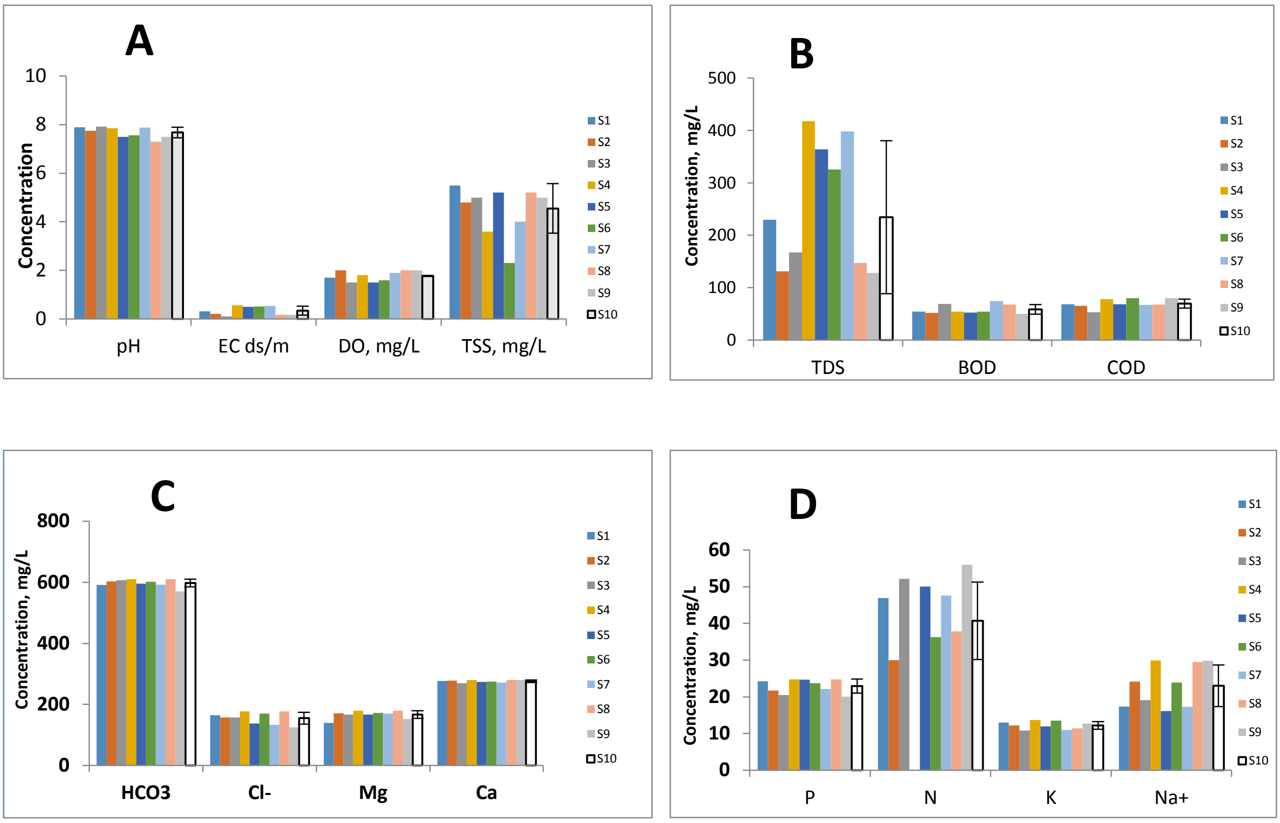

Figure 4. Results of the physicochemical parameters of (RO) reject samples analyzed S 10.

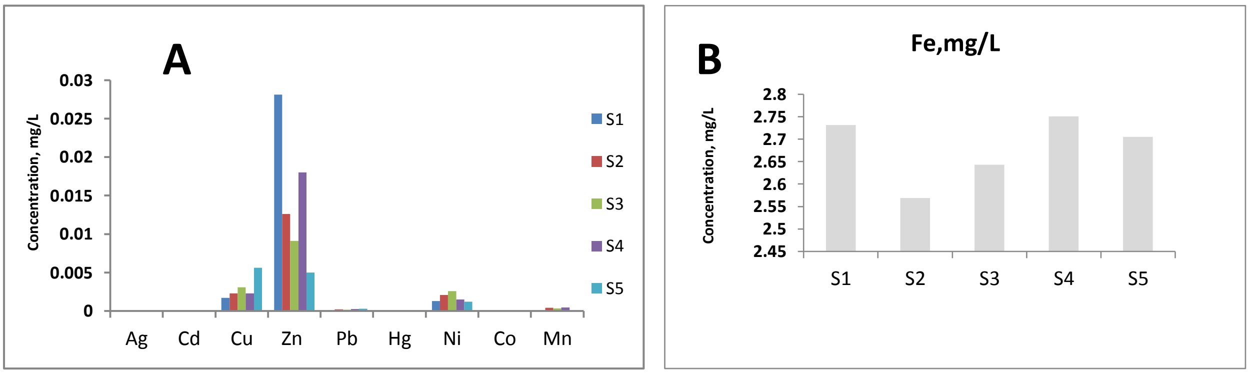

Figure 5. Heavy Metal Concentrations in the RO reject water samples analyzed.

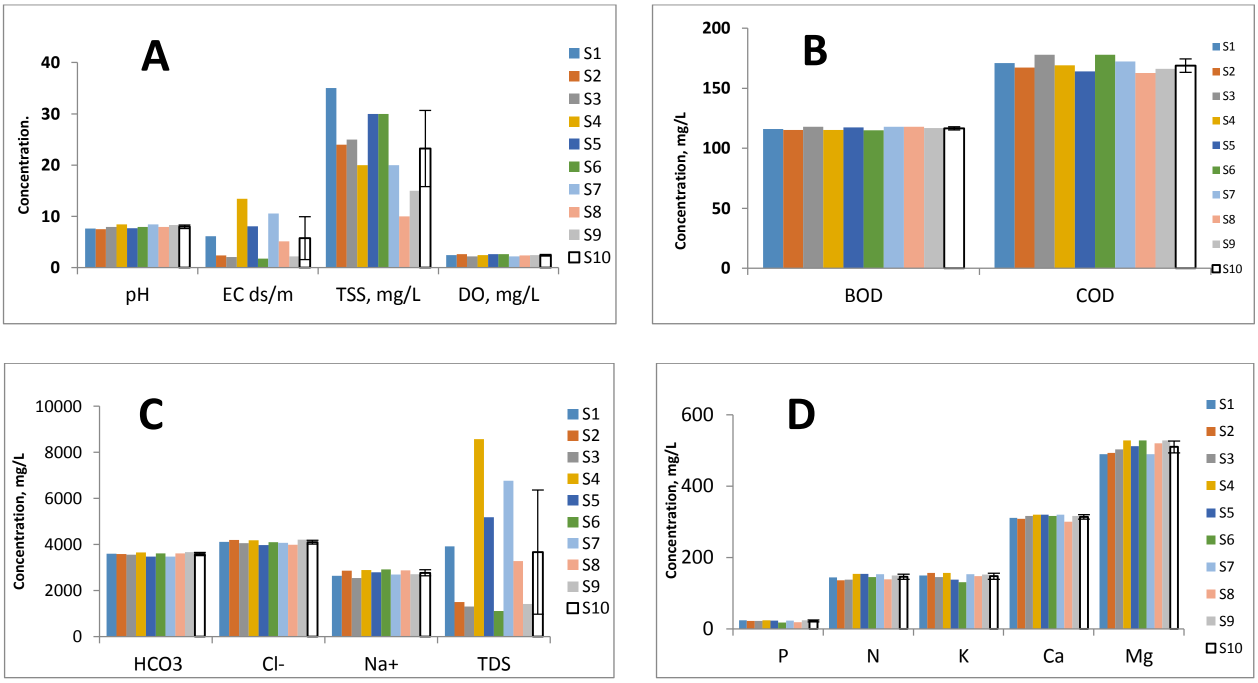

Figure 6. Results of the physicochemical parameters of the Hemodialysis Wastewater samples analyzed

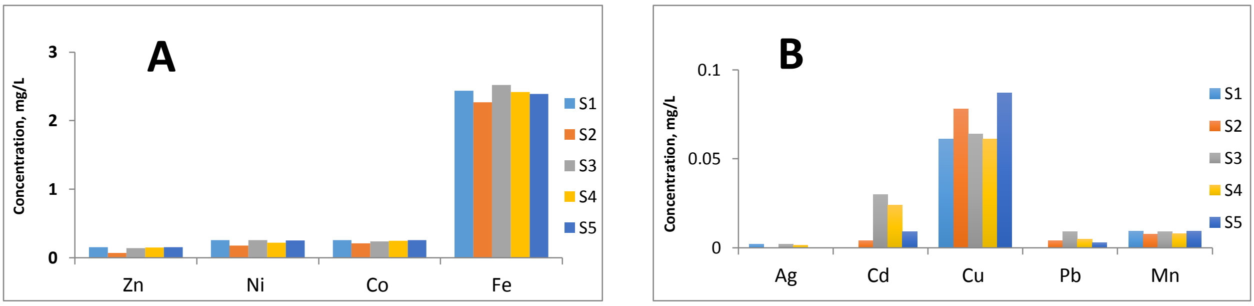

Figure 7. Heavy Metal Concentrations in Samples from Hemodialysis Wastewater

Results and discussion

Excessive water consumption in the hemodialysis process has been classified as an environmental issue. We must carefully consider researching the characteristics of this water and the possibility of reusing it because we depend on every drop of it (Tables 3 and 4). Compare hospital wastewater data on physico-chemical indicators for hemodialysis wastewater and RO-rejected water. These findings support the evidence of the vast variety of these effluents' properties due to the numerous variables at play. The physicochemical and microbiological parameters of our rejected concentrate Were within WHO and FAO standards for agricultural use The concentrations of some parameters were below discharge emission standards this is due to the huge amounts of water used in dialysis. While the physicochemical parameters of the samples taken from the dialysate rejected at its output from the generator were above the WHO standards for agricultural use (Table 2), Wastewater from dialysis units contains high levels of nutritional salts, including nitrogenous compounds, calcium, magnesium, sodium, and bicarbonate. These results are explained by the fact that hemodialysis consumes large quantities of concentrated solutions rich in the nutritional salts shown in (Table 8).

The results also showed that there are very strong fluctuations in physical and chemical parameters. The results showed no significant difference in parameter values between the summer and winter seasons. Our findings are consistent with numerous other studies that show that hemodialysis has a considerable influence on raising EC Due to this highly conductive wastewater, membrane separation techniques have been developed. According to previous research, membrane separation technology is the most effective way to address high electrical conductivity. Researchers in Portugal found that using wastewater for irrigation may have negative effects related to the impact on the physical, chemical, and biological properties of the soil, as well as the amount of chemical and biological pollution that will accumulate in the soil. (Karyabwite, 2000). These effects can be remedied and reduce the drug burden and risks to wastewater treatment plants through separate treatment of wastewater in hospitals (Verlicchi et al. 2012 ; Orias and Perrodin 2013). The study was based on FA / WHO standards and the Egyptian Code of Practice (ECP 501/2015) for wastewater use in agriculture and irrigation Pescod, 1992; Carr et al. 2004; Abbas et al. 2020). It is important to remember that sophisticated reverse osmosis systems reduce losses, which aids in the elimination of water waste.

pH hemodialysis wastewater the pH values varied from 7.5 to 8.4. These values were within the permissible limits of Egyptian standards, FAO, and WHO. Similar results were obtained in RO reject water, whose pH varied between 7.3 and 7.9. These levels show hemodialysis wastewater and RO reject water are generally alkaline (Mesdaghinia et al. 2009). (Figs. 4A and 6A).

(EC) is a perfect indicator of salinity and is an important factor in determining whether water is suitable for irrigation or not. The most significant negative environmental impact of using wastewater in irrigation is increasing soil salinity; which might reduce productivity in the long run. The EC values (Figs. 4A and 6A) of the hemolysis wastewater effluent ranged between 13.4 and 2.21 dS m^{-1}. These values are much greater when compared to RO reject water 0.568 to 0.105 ds m^{-1}, which complies with international and local standards. Similarly, the average EC value of the hemodialysis wastewater 5.73 dS m^{-1} is significantly high when compared to the FAO / WHO standard of 3 dS m^{-1} (Machado et al. 2014; El-Ogri et al. 2016).

COD and BOD are both are crucial factors that determine the amount of organic compounds in water. The BOD assesses the amount of oxygen the microbes require to decompose the organic matter under aerobic conditions. COD is the total amount of oxygen required to break down organic matter during chemical oxidation. The data shows that the average concentrations of COD and BOD in hemodialysis wastewater are about 168.83–116.6 mg L^{-1} and RO reject water 69.72–58.56, respectively (Fig. 4B and 6B). Those values are comparable to FAO / WHO standards and the ECP Egyptian code of practice. But relatively low compared with that of municipal wastewater (Boillot 2008)(Figs. 4B and 6B).

TSS The average concentration of TSS in hemodialysis wastewater and RO reject water was 23.22 mg L−1 and 4.55 mg L^{-1} respectively. Which were not above the maximum permitted values of 300 mg L^{-1} according to ECP 501/2015 recommendations or 350 mg L^{-1} according to FAO 47 criteria or the European Commission.

DO is a measure of the degree of organic matter contamination, organic substance degradation, and wastewater self-purification capacity. (Ibeh et al. 2011). The mean values of DO concentrations obtained from hemodialysis wastewater during the sampling period and RO reject water are not compatible with the WHO and ECP 501/2015 norms (Tables 3 and 4). There was no significant difference in the dissolved oxygen values recorded during hemodialysis wastewater and RO reject water, which ranged between 2.40 and 1.77 mg L^{-1}, respectively (Figs.4 A and 6A).

TDS The TDS of the hemodialysis wastewater has a maximum and a minimum of 8576 to 1112 mg L^{-1}. According to the results of this study, the average total dissolved solids content 3674.7 mg L^{-1} obtained also exceeded the limit value of the WHO standards of 2000 mg L^{-1} for discharges of waste water. While the average total dissolved solids content from RO reject water was234.19 mg L^{-1} did not exceed the limit value for these standards (Figs. 4B and 6C).

The highest value for HCO_3 was at S9 hemodialysis wastewater was 3673 mg L^{-1}, and the lowest was 3470 mg L^{-1} at S5. This is almost eight times greater than Egyptian standards. While the average value of carbonate in RO reject water is 597.95 mg L^{-1}, which is greater than the Egyptian standards of 400 mg L−1 and these values are comparable to those of FAO / WHO (Figs. 4C and 6C). The total nitrogen concentrations (Fig. 4D and 6D) measured in the hemodialysis wastewater is from different sampling ranges between 136.5 and 154 25 mg L^{-1}. These values are very high compared to those of Egyptian standards and FAO/WHO standards. These values are well beyond the nitrogen measured in the RO reject water range of 30–56. These values are comparable to those of Egyptian standards and FAO / WHO standards. The total phosphorus in hemodialysis wastewater and RO reject water ranged between 18.2 - 24.5 mg L^{-1} and 20.05 - 24.75 mg L^{-1} respectively, which corresponds mainly to Egypt standards that set the amount of total released phosphorus for direct and indirect rejection at 25 L^{-1}. However, hemodialysis wastewater contains high concentrations of phosphorus and nitrogen. These elements are beneficial to the soil, and the recovery of these elements provides a long-term supply of fertilizer to the soil; however, due to the presence of other as shown above, it may not be suitable for usage.

(Cl-) in irrigation water is the most frequent toxin. Since Cl-is neither adsorbable nor retained by soils, it moves easily with soil water, is absorbed by the crop, travels in the transpiration stream, and accumulates in the leaves (Pescod 1992). The chloride concentrations Cl- in hemodialysis wastewater vary considerably from one sampling to another these values range from 3978 mg L−1 measured at sample S6 to 4207 mg L−1 recorded at sample S4. While e the values of Chloride content from RO reject water ranged between 125.29 -177.5 mg L^{-1} did not exceed the limit FAO/WHO standards (Figs. 4C and 6C). The Mg and K concentrations obtained for the hemodialysis wastewater were in the range of 490 to 528 mg L^{-1} and 131.18 to 156.78 mg L^{-1}, respectively. These values are very high compared to those of Egypt and FAO/WHO standards. The average concentration of magnesium obtained for the RO reject water is 166.7 mg L^{-1}, exceeding the limit values cited in Egyptian standards and FAO / WHO standards. While the average concentration of potassium of 12.24 mg L^{-1} and these values are comparable to those of FAO/WHO Figs. 4(C, D) and 6D. The average concentration of calcium obtained for the hemodialysis wastewater and RO reject water was 314, 276.19 mg L^{-1} respectively. This value is comparable to that of FAO / WHO standards but relatively high compared with that of Egyptian standards (Figs. 4C and 6D).

Sodium concentration: An abundance of sodium promotes the development of an alkaline soil, which can cause physical issues with the soil and reduce soil permeability (Gerhart et al. 2006). The sodium concentrations vary considerably from one sampling to another. Indeed, these values range from 2540.20 mg L^{-1} measured at S3 to 2920.40 mg L^{-1}, recorded at S6. In (Fig. 4D,6C), the average sodium content of 2771.55 mg L^{-1} obtained also exceeded the limit value of the WHO standards for discharges of waste water. While the average sodium content of RO reject water (923.01 mg L^{-1}) did not exceed the limit value for these standards the ratio of sodium to calcium and magnesium can be used to compute the sodium adsorption ratio using equation 1. SAR. is a crucial factor in determining if irrigation water is suitable for irrigation. Assobhei and Chedad 2007). The allowed limit of the treated wastewater's Sodium Adsorption Ratio (SAR) for irrigation is around 9 mg L^{-1}. (Abbas et al. 2020) The recorded results obtained for the hemodialysis wastewater were significantly greater than the acceptable limits in the FAO / WHO guidelines (Figs. 4D and 6C). Phenol and phenolic compounds are the most common contaminants in hospital wastewater. The U.S. Environmental Protection Agency considers them to be highly hazardous chemicals, it is crucial to remove phenol from polluted water before it is discharged into natural water sources (Salah et al., 2020). The average concentration of total phenol measured in different samples is around 103 mg L^{-1}. These values are very high compared to those of municipal wastewater (0.05 mg L^{-1})

$$(1)\quad SAR = \frac{Na}{\left(\frac{Ca+Mg}{2}\right)^{\frac{1}{2}}}$$

The results of heavy metal concentration samples are presented and compared with FAO/WHO standards in Tables 3 and 4. Heavy metals pose significant risk due to their damaging effects and require special care in water treatment to avoid their toxic effects. The average concentrations of heavy metals in hemodialysis wastewater (Fe ،Pb, Hg, Zn, Co, Ag, Ni, Cd, and Mn) were2.40, 0.00412, 0.00816, 0.1336, 0.243, 0.00112, 0.233, 0.0702, and 0.0087 mg L^{-1}, respectively. While the average concentration of heavy metals detected in RO reject water (Fe، Zn, Cu, Pb, Ni, and Mn) wase 2.68, 0.0.0145, 0.003, 0.00184, 0.00174, and 0.000248, the evaluation of heavy metals in the hemodialysis wastewater and RO reject showed that these values were within the permissible limits of FAO / WHO. The order of the presence of the heavy metals studied was as follows: Fe> Co > Ni > Zn > Cu > Cd > Pb> Hg > Mn > Ag, It was noted that the concentration of iron is higher than the rest of the elements present.as shown in Figs. 5(A,B) and 7(A,B).

Microbiological characterization

On the bacteriological level, we observed polymorphic microbial proliferation at the level of the dialysate thrown into the sewers. Escherichia coli was found to be more prevalent among the bacterial species. Bacterial counts were found to be high at samplings 2, 4, and 5, in (S 2) indicating the extent of pollution caused by human activities. These bacteria are prevalent in the environment and can quickly colonize a sampling site. The bacteriological parameters studied are Escherichia coli (E. coli) and fecal Escherichia, Pseudomonas aeruginosa, and streptococci, in the hemodialysis. (Daneman et al. 2005). E. coli levels varied between 22× 102 and 11 × 102 cfu/ml in hemodialysis wastewater. Whereas the concentration of fecal coliform bacteria is zero within all samples these values are within the limits of recommendations (Table 2).

Pathogens: Hospitals, where many people are infected with viruses, are one of the sites most sensitive to infection spread. Some of the most frequent bacteria found in hemolysis wastewater have been studied and researched. Pseudomonas aeruginosa: It is one of the most common pathogens in hospitals and has a high level of antibiotic resistance and a high mortality rate due to these bacteria (Rio et al. 2002). The greatest concentration was 240 CFU/100 mL at S2 and S4 while the minimum concentration was zero at points S1, S3, and S5 (Table 9).

Streptococci sp: The hospital aids in the transmission of many invasive streptococcal infections, and numerous studies have shown the danger of transmission in hospitals. Analyses revealed that the greatest concentration was 240 CFU/100 mL at S2, while the minimum concentration was 120.

(Table 9) .In addition, we found no harmful germs (Pseudomonas aeruginosa and Streptococci sp.) in any of the samples or composites tested from RO reject water. This demonstrates bacteriological conformance in relation to standards.

Ecotoxicological characterization

The characterization of the ecotoxicity of hospital effluents was reviewed in many studies, and the findings indicated that effluent ecotoxicity must be considered (SDU 2009). The waste generated is classified as high-risk because of the high rates of hepatitis C. The current study did not look into this issue. Monitoring the effluents of each of the specialist departments of the Assiut University Hospitals is also required; however, this issue was also not looked into because of the project's high cost. With the goal of creating practical environmental management rules for the substitution of less polluting items for harmful ones (Machado et al. 2014). The simulations in some Moroccan studies revealed that nan filtration and resorted osmosis technologies outperformed seawater desalination, which led to a 25% reduction in costs (Tarrass et al. 2008). Due to the absence of such data to compare with FAO standards, several Moroccan studies were relied upon, which showed the possibility of reusing wastewater in irrigation and that it was an effective approach to watering halophytes (Gerhart et al. 2006). Researchers in the field of sustainable water management in the Eastern Mediterranean and North Africa region have indicated an integrated approach to wastewater management in these areas using renewable water. In this context, the appearance of pharmaceutical concentrations in hospital wastewater has led to major environmental risks, especially if they are disposed of directly into the municipal sewer line. This wastewater has posed a major environmental risk that must be dealt with. Pharmaceuticals and personal care products (PPCPs) were discovered.

Table 9. Microbiological Concentrations of our samples

Parameters	Unit	Hemodialysis Wastewater			RO reject water		
		Mean ± SD	Max	Min	Mean ± SD	Max	Min
Escherichia coli		855.5±2515	2200	1100	-	- ve	- ve
fecal coliform bacteria	UFC/100	-	-	-	-	- ve	- ve
Pseudomonas aeruginosa		240±0	240	0	-	- ve	- ve
Streptococci sp		168 ±46.5	240	120	-	- ve	- ve

Conclusions

This study aimed to assess the physicochemical and bacteriological characteristics of effluent from the Assiut University hospital artificial kidney unit (hemodialysis wastewater and RO reject water) for the possibility of recycling it for other purposes. Samples were taken for each phase of the artificial kidney unit. The water produced by RO rejection is similar to drinking water, has no contact with patients, and its physical, chemical, and microbiological properties agree with local and international standards. This water should not be squandered, and it should be reused. While hemodialysis wastewater characteristics were found to be non-compliant with the currently in place regulations, the study concluded that hemodialysis wastewater cannot be used for irrigation without first being treated. During an evaluation of physicochemical properties for heavy metals using the inductively atomic absorption technique, the effluents analyzed showed conformity with the irrigation outcome requirements. The compliance of most of the results of the microbiological parameters of the effluents obtained with the regulations in force was observed. E. coli concentration was studied. The maximum average value is 22 × 102 CFU/100, while the average minimum concentration is 11 × 102 CFU/100 m. These values are within the limits of recommendations. Whereas the concentration of fecal coliform bacteria is zero within all samples. With a few levels of Streptococci sp. and Pseudomonas aeruginosa sp. As part of this study, liquid effluents in hospitals, particularly those from RO reject water, can be recycled. Thus, it would also be interesting to study the potential for recycling effluents from other services in Assiut University hospitals.

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