Open Access
Full Length Article

ORIGINAL ARTICLE

Chemical Characterization of Treated and Rejected Wastewater of Reverse Osmosis Treatment Plants in the Area of Allama Iqbal Town, Lahore

Naveed Aslam Dogar[1,2,*], Haroon Iftikhar[2], Noor-Ul-Ain Khalid[3], Muhammad Shahid[4], Sajjad Ahmad[2]

[1]Department of Chemistry, Government College University, Lahore, Pakistan.
[2]Department of Chemistry, Government College of Science, Wahdat Road Lahore, Pakistan.
[3]Department of Chemistry, Forman Christian College University, Lahore, Pakistan.
[4]Department of Chemistry, Lahore Garrison University, Lahore, Pakistan.

ABSTRACT

Background: Water is one of the most essential requirements of life. Life is not possible without water. Polluted water on the other hand can affect the health badly. Reverse Osmosis (RO) plants are used to remove dissolved solids including harmful and toxic materials from wastewater.

Objectives: To investigate the quality of 6 treated and rejected wastewater samples of RO plants water being consumed in the areas of College block, Hunza Block of Allama Iqbal Town, and Gulberg III Lahore, Pakistan.

Methodology: Both qualitative and quantitative analyses were done by using the parameters like Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Cl^-, pH, nitrate, nitrite, SO_4^{2-}, Na^+, K^+ and heavy metals like Cr^{3+}, Fe^{3+}, Cu^{2+}, Zn^{2+} and Mn^{2+} through Flame emission spectroscopy, UV-Vis spectroscopy, Atomic absorption spectroscopy, and volumetric analysis.

Results: The sample analysis indicated that these parameters lie within the permissible limits with reference to National Environmental Quality Standards (NEQS) values with some exceptions. The pH of treated water of college block (sample A) was 9.219, which is slightly higher than normal pH value, which is between 6.5-8.5. The value of Cr^{3+} ion in rejected water of Gulberg III was 0.06ppm, which is also higher than the normal limit.

Conclusion: All the parameters of treated and rejected wastewater indicated the suitability of water samples for population of respective areas, but the values of rejected wastewater are towards an increase, and should therefore be treated before dumping.

Keywords	*Address of Correspondence	Article info.
Biochemical Oxygen Demand, Chemical Oxygen Demand, heavy metals, pH, RO plant, Rejected Wastewater.	*naveedaslamdogar@gmail.com*	*Received: June 11, 2021* *Accepted: April 19, 2022*

Cite this article *Dogar NA, Iftikhar H, Khalid NA, Shahid M, Ahmad S. Chemical Characterisation of Treated and Rejected Wastewater of Reverse Osmosis Treatment Plants in The Area of Allama Iqbal Town, Lahore. 2022; 13(1):60-69.*

INTRODUCTION

When two moles of hydrogen and one mole of oxygen combine together, we get a colorless and odorless compound. This product is known as water. It is an essential requirement of every living cell without which life is impossible. Water is a universal solvent or solvent of life. A cell contains more than 70% of water. The human body contains almost 60% of water in which the brain and heart almost contain 73%, lungs contain 83%, skin has 64%,

muscles and kidneys contain 79% and the bones contain 31% water[1].

An average human body requires almost 2000ml to 2500ml of water but this may vary according to the temperature, pressure, and by other environmental conditions. Water is very essential for normal life, but polluted water can badly effect the human health and can cause deadly water borne diseases like vomiting, diarrhea, *E. coli* infections, typhoid, dysentery, Hepatitis A, B, C and E, etc[2].

Both natural and human activities are responsible for water pollution. Volcanic eruptions, earthquakes, tsunamis, etc. are natural sources but they are not as harmful as anthropogenic activities related to the generation of industrial domestic and commercial waste[3].

The Government of Punjab has taken some serious actions in 2013 and installed many RO plants for the purification of drinking water in different areas of Lahore, Pakistan. This study was planned for the chemical characterization of treated and rejected wastewater of reverse osmosis treatment plants in the area of Allama Iqbal Town and Gulberg III, Lahore[4]. This research has extreme benefit in gaining a better understanding of the water quality in these areas.

MATERIALS AND METHODS

All the treated and rejected water samples were collected from reverse osmosis plants of College block and Hunza Block of Allama Iqbal Town and Gulberg III, Lahore, Pakistan.

Tests for Chloride (Cl^-) Determination

Apparatus and chemicals required for the determination included 20ml to 25ml burette graduated in 0.1ml, burette support, 100ml graduated cylinder, titrating flask, beakers, pipette, silver nitrate solution and potassium chromate as an indicator.

$AgNO_3$ (0.16M) solution was prepared by adding 2.73g of $AgNO_3$ in 100ml of distilled water in a burette. Water (10ml) was pipetted out, which was to be tested in the titrating flask. Two to 3 drops of potassium chromate were added to the flask as an indicator. It was titrated against the standard solution till $AgNO_3$ turned red. The volume of $AgNO_3$ used was recorded till the end point[5].

Biological Oxygen Demand (BOD) Analysis

The apparatus required for BOD were 20ml to 25ml burette, burette support, 100ml graduated cylinder, titrating flask, beakers, pipette, reagents, silver nitrate solution, potassium chromate as an indicator, 500ml conical flask, pipette bulb, pipette with elongated tips and 250ml graduated cylinders and washed bottles. Chemicals required were calcium chloride, magnesium sulphate, ferric chloride, di-sodium hydrogen phosphate, potassium di-hydrogen phosphate di-sodium hydrogen phosphate, ammonium chloride, manganese sulphate, potassium hydroxide, potassium iodide, sodium azide, conc. sulphuric acid, starch indicator, sodium thiosulphate and distilled water.

Four (300ml) BOD bottles were taken and 10ml of sample was added in two of them while the remaining two were filled with diluted water alone for blank. Glass stoppers were placed to preserve one blank and one sample in the BOD incubator at 20˚C. The other two bottles containing one sample and one blank were investigated immediately. Then, 2ml of alkali iodide azide reagent was added. Sufficient time was required for complete reaction with oxygen. Next, 2ml of conc. H_2SO_4 was added and 10ml of the solution was pipetted out from the bottle and transferred to the Erlenmeyer flask, which was then standardized with sodium thiosulphate solution. When the solution became pale yellow, starch indicator was added to it which turned the solution blue. Titration was continued till blue color turned to colorless (endpoint). The titration process was repeated for concordant readings. After 5 days, the incubated sample and blank bottles were titrated to find Dissolved Oxygen (DO) value in mg/l. The titration process was repeated for concordant readings[6, 7].

Chemical Oxygen Demand (COD) Determination

The apparatus included COD Digester, burette and burette stand, COD vials with stand, 250ml Erlenmeyer flask, pipette & pipette bulb, tissue paper, and wash bottles. The chemicals required were potassium dichromate, Conc. sulfuric acid, ferrous ammonium sulphate (Mohar Salt), silver sulphate, ferroin indicator, and organic free distilled water.

Reagents required included 0.25N solution of potassium dichromate, 0.1N ferrous ammonium sulphate solution,

and ferroin indicator. Concentrated sulphuric acid was also required.

H_2SO_4 and the sample were taken in a reflux flask and 10ml of 0.25N $K_2Cr_2O_7$, H_2SO_4 and $AgNO_3$ were added reagent in it, mixed and refluxed for two hours. Then, 150ml distilled water was added to dilute it. The indicator was added till the color changed from green to wine red, which is the end point. The experiment was performed against blank[8].

Total Alkalinity Determination

Alkalinity is due to the presence of CO_2, HCO_3^{1-}, CO_3^{2-} , and OH^- etc. It may come in water form acid rain and earths' natural buffering system etc. It can be determined easily by using methyl-orange as an indicator and N/50 sulphuric acid solution titration[9].

pH Determination

pH meter is used for the determination of pH. Standard buffer solution was used for the calibration of glass electrode and then pH of the sample was measured[10].

Determination of Total Hardness

Buffer solution of pH 10 was used along with Erichrome Black-T indicator and EDTA as a standard solution (0.01M). Value of $CaCO_3$ in ppm expressed the total hardness of water[11].

Determination of Calcium Ions

Standard EDTA solution of 0.01M was used along with EBT and buffer of pH 10. The sample was taken and boiled to remove bicarbonates. Then, it was titrated against EDTA solution using EBT as an indicator[12].

Determination of Nitrate and Nitrite Ions in Water

Nitrate ion can be measured spectroscopically. Salicylic acid under basic conditions forms a stable complex with nitrate ion, which can be estimated by a spectrophotometer at 410nm. Chromophore absorption is directly proportional to amount of nitrate present. Blank is prepared using distilled water with simple normal reagent.

For the determination of nitrite ion, spectrometer, pipette, glass stopper flask, beaker and distilled water were required. Colored reagents were produced by adding 100ml of 85% phosphoric acid and 10ml sulphanilamide mixed in 800ml of water. N-1-naphthylethylene diamine di-hydrochloride (1g) was added and diluted up to 1000ml by distilled water. This coloring agent was then stored in the dark. Further, 0.05N sodium oxalate was prepared, followed by the preparation of a stock nitrite solution of 0.018N. This solution required 1ml of $CHCl_3$ for its preservation. Standard 0.05N $KMnO_4$ was also used in this analysis.

Further, 50ml of sample was taken and 2ml of coloring reagent was added to it as a chromophoric reagent. The absorbance was measured at 543nm, followed by a waiting period of 10min to 120min after addition of the coloring agent. Standard curve was used to estimate the sample nitrite concentration[13].

Measurement of Total Dissolved Solids (TDS)

First, 100ml of filtered water was taken using the Whatmann filter paper. The water was evaporated in an electric oven at 110˚C. The amount of solid residue in the sample was then weighed[14]. Formula used was:

TDS (mg/L) = [(A-B)*1000*1000] / Sample volume (ml)

Where, A = Weight of dried residue + dish (g)

B = Weight of dish (g)

Determination of Heavy Metals

Atomic Absorption Spectroscopy (AAS) is used for the determination of heavy metals. Standard solution (5ppm, 10ppm, 15ppm and 20ppm) of Fe, Cr, Pb, Cd and Mn were prepared and tested by AAS. Comparison was used between the standard and unknown sample to determine heavy metals in water[15].

Estimation of Na^+ and K^+ Ion by the Help of Flame Photometric Method

After calibration of the instrument with the help of standard and adjusting the reading between 0-10mg/l and 0-100mg/l, distilled water was aspirated to bring zero mark reading and the sample was applied to the flame-photometer. The readings were accordingly noted[16].

Determination of Sulphate Concentration in Water Sample

For this determination, magnetic stirrer, physical balance, measuring cylinder along with spectrophotometer etc. were used. Then, 50ml of the sample was taken along with buffer and 2ml conditioning agent. A pinch of $BaCl_2$ was added and stirred for 1min at a defined speed. Its absorbance was measured at 420nm. Afterwards, 5mg to 40mg of standard curve was used for the determination of sulphate ions[17].

Iron Determination

Porcelain dish, measuring cylinder, glass rod, wash bottles, iron wire and spectrometer etc. were the apparatus used for iron determination. Glacial acetic acid, HCl, ammonium acetate buffer, hydroxyl amine hydrochloride solution 1,10-phenenthroline solution, ammonium ferrous sulphate solution and 0.1N $KMnO_4$ were the reagents required for this estimation.

Water sample (50ml) was taken and 2ml HCl was added in it. The solution was heated till its volume reached to 20ml. 10ml of ammonium acetate buffer and 4ml of 1,10-phenenthroline were added in it. The solution was then incubated in the dark for 20min and then absorbance was measured at 510nm. The sample value was compared with the calibration curve obtained from known concentration[18].

RESULTS

Samples A and A* represent the treated and rejected water of College block, respectively. Samples B and B* represent the treated and rejected water of Hunza block, respectively. Similarly, samples C and C* represent the treated and rejected water of Gulberg III block, respectively.

The parameters like pH, TDS, total hardness, Ca^{2+} ions, Cl^{1-} ions, total alkalinity, BOD, COD[19] values are given in Table **1**. All these values were compared with National Environmental Quality Standards.

Table **1** shows that the treated sample A (collected from the college block RO plant) has a pH value greater than NEQS, therefore it is not much suitable for drinking. All other parameters of all the samples lie within the permissible limits.

Table 1. Sample Parameters Measured for Treated Sample A (Collected from the College Block RO Plant).

PARAMETERS	A	A*	B	B*	C	C*	NEQS
pH	9.239	7.965	8.262	7.940	7.715	7.619	6.5-8.5
TDS	120	180	100	110	200	230	<1000
Total Hardness	25	93	26	37	33	86	<500
Ca^{2+}	40	65	18	88	40	93	<500
Total Alkalinity	80	130	94	128	102	288	<300
Cl^{1-}	13	20	15	25	30	85	<250
COD	56	74	33	55	10	69	150mg/l
BOD	26	58	12	18	28	60	80mg/l

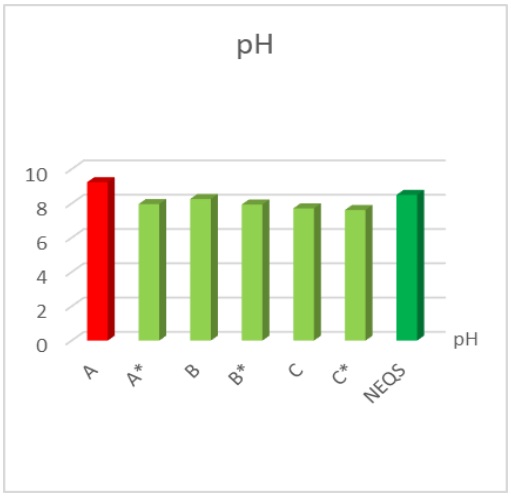

Figure 1. pH values of all the samples.

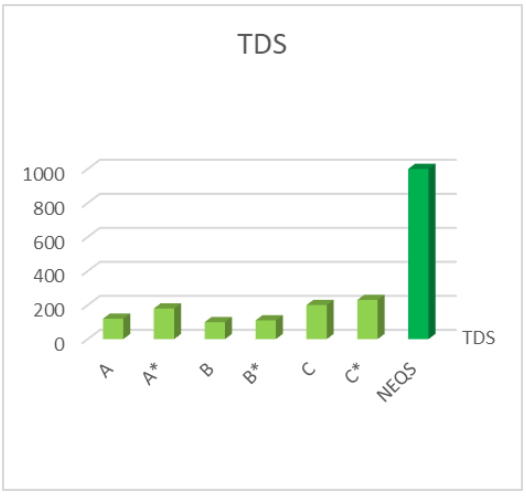

Figure 2. TDS values of all the samples.

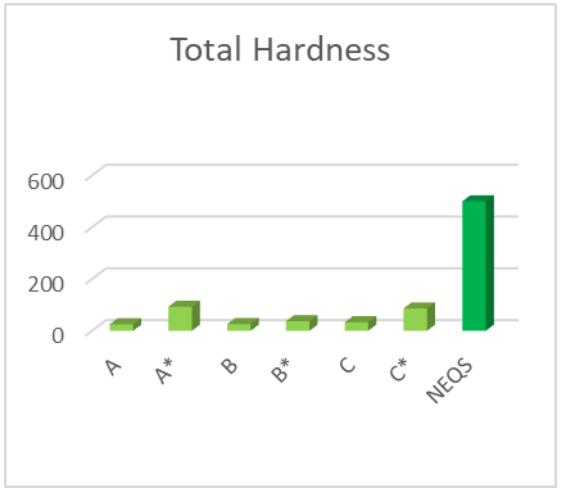

Figure 3. Total Hardness of all the samples.

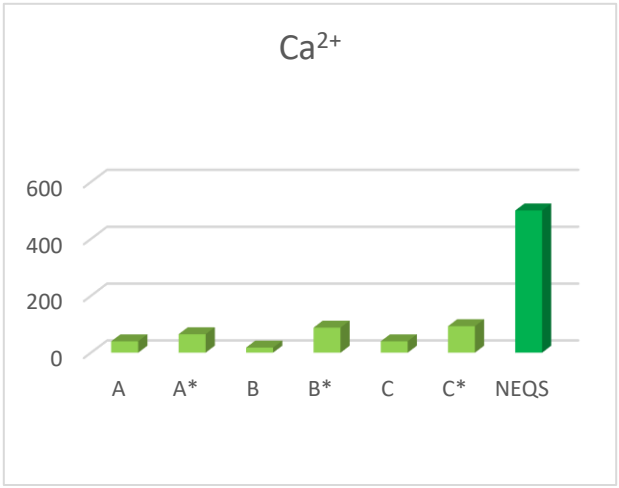

Figure 4. Total Ca^{+2} ions in all the samples

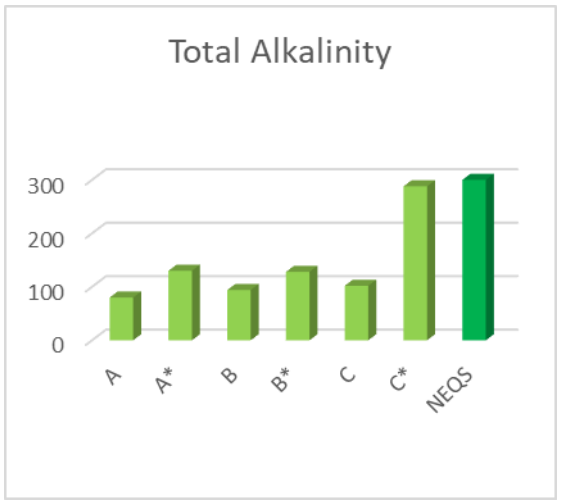

Figure 5. Total alkalinity of all the samples.

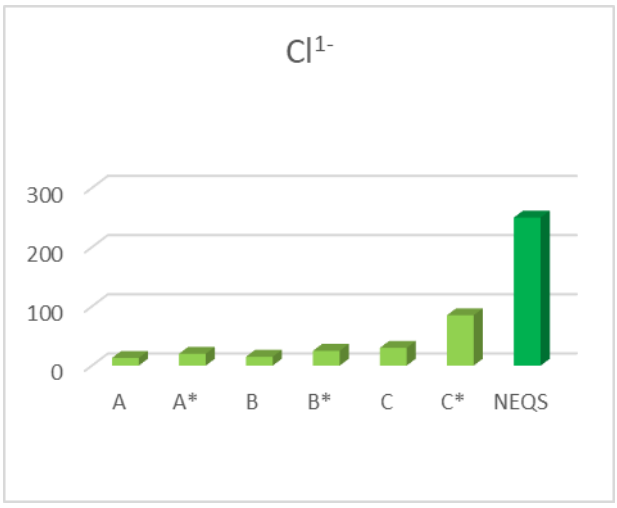

Figure 6. Total Cl^{-1} ions in all the samples.

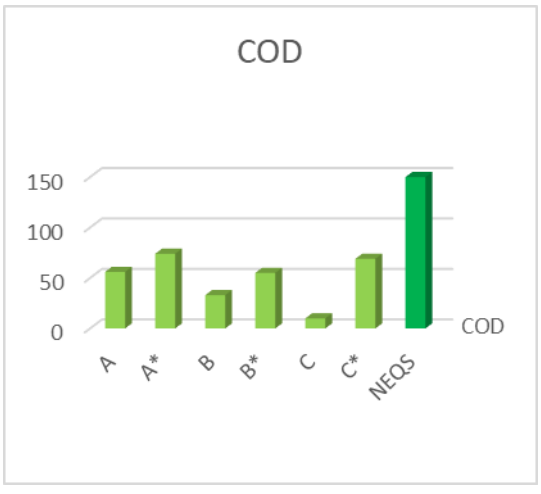

Figure 7. COD values of all the samples.

Figure 8. BOD values of all the samples.

Table 2. Measurement of Ions in all the RO Plant Samples.

METAL	A	A*	B	B*	C	C*	NEQS (ppm)
Fe^{3+}	0.00	0.00	0.00	0.00	0.00	0.00	2.0
Zn^{2+}	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cu^{2+}	0.00	0.00	0.00	0.00	0.00	0.00	<0.05
Mn^{2+}	0.00	0.00	0.00	0.00	0.00	0.00	<0.05
K^{+}	1.4567	3.5674	1.05	2.7768	1.4612	3.4013	12
Na^{+}	0.00	0.00	0.00	0.00	0.00	0.00	250

Table 3. Measurement of Na^{+} / K^{+} Levels in all the RO Plant Samples.

PARAMETERS (ppm)	A	A*	B	B*	C	C*	NEQS (mg/l)
Na^{+}	30	65	40	88	21	22	250mg/l
K^{+}	2	5	4	7	5	6	12mg/l

Figure **1** represented that the pH value of treated water from the college block is not within the NEQS permissible limit, while Fig. **2** to Fig. **8** showed that all other parameters such as total alkalinity, total hardness, TDS, Ca^{+2} and Cl^{-1} ions concentration, BOD and COD values are within the permissible limits, and the treated water sample can be used and is safe for drinking purposes.

By using atomic absorption spectroscopy, the metals like Fe^{3+}, Zn^{2+}, Cu^{2+}, $Mn2^{+}$, K^{+} and Na^{+} were estimated and their values are given in Table **2**. It shows that only K^{+} ions are present in all the RO plant samples. The concentration of K^{+} ions lies within the safety limit of NEQS values.

Na^{+} and K^{+} ions were estimated by flame photometric method (Table **3**). The values lie within the safety limits.

UV-Visible spectrophotometer studies were conducted to find the ppm percentage of NO_2^{1-}, NO_3^{1-}, Fe^{3+}, Cr^{3+}, and SO_4^{1-}. From the data in Table **4**, it can be concluded that the rejected water of Gulberg III contained 0.06ppm of Cr^{3+}, which exceeds the safety limits of NEQS. The sample of rejected water (sample B*) of Hunza block had 42.20ppm of NO_2^{1-} which is very high as compared to NEQS, which is 12ppm only.

Variations of different parameters like pH, TDS, total Hardness, Ca^{2+}, total alkalinity, and Cl^{-} ion for the treated and rejected water of Hunza block, College block and Gulberg III were investigated for seven days as shown in Tables **5-10**.

Table 4. Measurement of Specific Cations and Anions Level in all the RO Plant Samples.

PARAMETERS (ppm)	A	A*	B	B*	C	C*	NEQS (ppm)
NO_3^{1-}	0.000	0.085	0.004	0.000	0.000	0.000	12
NO_2^{2-}	0.00	0.002	5.747	42.20	0.044	0.110	12
SO_4^{2-}	1.321	92.62	23.34	27.46	29.62	27.26	1000
Fe^{3+}	0.151	0.108	0.744	0.02	0.173	0.220	2.0
Cr^{3+}	0.00	0.001	0.010	0.00	0.003	0.06	<0.05

Table 5. Measurement of Different Parameters in Hunza Block (Treated Water) Sample.

Sample HunzaBlock	Parameters (ppm)	1st Day (ppm)	2nd Day (ppm)	3rd Day (ppm)	4th Day (ppm)	5th Day (ppm)	6th Day (ppm)	7th Day (ppm)
01	pH	6.9	7.2	7.95	7.75	7.8	7.95	7.81
02	TDS	1.5	2.0	8.0	4.01	3.04	1.80	2.00
03	Total Hardness	50	56	33	76	31	53	61
04	Ca^{2+}	85	88	88	90	85	89	86
05	Total Alkalinity	92	101	79	83	105	36	45
06	Cl^{1-}	25	28	21	18	17	24	19

Table 6. Measurement of Different Parameters in Hunza Block (Rejected Water) Sample.

Sample HunzaBlock	Parameters (ppm)	1st Day (ppm)	2nd Day (ppm)	3rd Day (ppm)	4th Day (ppm)	5th Day (ppm)	6th Day (ppm)	7th Day (ppm)
01	pH	6.95	7.26	7.05	7.65	7.88	7.95	8.01
02	TDS	257	230	150	311	324	180	200
03	Total Hardness	101	177	303	116	201	153	101
04	Ca^{2+}	115	168	88	260	115	275	111
05	Total Alkalinity	92	110	119	88	155	163	155
06	Cl^{1-}	115	98	141	37	111	204	19

Table 7. Measurement of Different Parameters in College Block (Treated Waste Water) Sample.

Sample College Block	Parameters (ppm)	1st Day (ppm)	2nd Day (ppm)	3rd Day (ppm)	4th Day (ppm)	5th Day (ppm)	6th Day (ppm)	7th Day (ppm)
01	pH	7.5	7.35	7.45	7.25	7.86	7.68	7.50
02	TDS	125	126	110	120	118	125	127
03	Total Hardness	98	102	92	97	90	97	91
04	Ca^{2+}	60	65	70	65	70	68	72
05	Total Alkalinity	88	81	94	87	80	85	88
06	Cl^{1-}	14	22	29	36	31	20	13

Table 8. Measurement of Different Parameters in College Block (Rejected Waste Water) Sample.

Sample College Block	Parameters (ppm)	1st Day (ppm)	2nd Day (ppm)	3rd Day (ppm)	4th Day (ppm)	5th Day (ppm)	6th Day (ppm)	7th Day (ppm)
01	pH	6.5	7.15	7.45	6.25	8.86	7.08	7.04
02	TDS	448	156	350	430	128	445	527
03	Total Hardness	228	132	302	207	210	307	411
04	Ca^{2+}	104	225	110	215	118	182	372
05	Total Alkalinity	266	319	401	213	120	115	88
06	Cl^{1-}	133	221	194	200	103	119	103

Table 9. Measurement of Different Parameters in Gulberg III (Rejected Water) Sample.

Sample Gulberg III	Parameters (ppm)	1st Day (ppm)	2nd Day (ppm)	3rd Day (ppm)	4th Day (ppm)	5th Day (ppm)	6th Day (ppm)	7th Day (ppm)
01	**pH**	7.65	6.28	7.05	7.51	7.11	8.00	7.65
02	**TDS**	100	103	110	204	107	309	102
03	**Total Hardness**	304	302	166	117	136	66	133
04	**Ca^{2+}**	270	282	168	76	117	101	109
05	**Total Alkalinity**	119	104	137	198	165	274	196
06	**Cl^{1-}**	111	135	121	119	112	106	105

Table 10. Measurement of Different Parameters in Gulberg III (Treated Water) Sample.

Sample Gulberg III	Parameters (ppm)	1st Day (ppm)	2nd Day (ppm)	3rd Day (ppm)	4th Day (ppm)	5th Day (ppm)	6th Day (ppm)	7th Day (ppm)
01	**pH**	7.1	6.13	6.0	7.11	7.9	6.95	8.0
02	**TDS**	1.00	1.03	1.10	2.04	1.07	3.09	1.02
03	**Total Hardness**	30	32	66	47	36	49	34
04	**Ca^{2+}**	70	82	68	76	67	60	86
05	**Total Alkalinity**	99	104	107	98	96.5	97.4	96
06	**Cl^{1-}**	15	11	18	19	12	16	15

DISCUSSION

This work was planned to evaluate the quality of treated and rejected wastewater used in the vicinity of Allama Iqbal Town and Gulberg III in Lahore, Pakistan. Table **1** shows the parameters like pH, TDS, hardness, chloride ion, alkalinity, COD, and BOD are within the permissible limits of treated wastewater samples. As reported by Elorm and Sudesh, the parameters are very important for understanding how to make it re-useable, as the improvement in waste can make it re-useable for this growing population[20]. Tables **2** and **3** revealed that the heavy metals like Zn^{2+}, Cu^{2+} and Mn^{2+} are not detected in the treated or rejected wastewater of all the samples, and the concentration of Na^{+} and K^{+} was within acceptable limits in all samples. If these metals are present, then removal of these heavy metals is very important because heavy metals are carcinogenic and even in rejected water, they must be removed before disposal[21]. The presence of sulphate, phosphate and other nitrate ions does not make the water safe for drinking because they can precipitate the calcium and magnesium present in the human body, resulting in the weakening of bones and loss of minerals in the human body. The kidney stones are composed of oxides and phosphates of calcium, and their presence can be a dangerous threat to humans as well as animals[22]. These acidic radicals can also create boiler scales in industry and can be very harmful to machine life[23]. Table **4** showed that the concentrations of nitrite, nitrate, sulphate, ferric, and chromium lie within safe limits, which are considered to be safe for domestic life. The pH of all the treated wastewater samples increased because the concentrations of sulphates, nitrates and other acidic radicals decreased in these, while they increased in rejected wastewater samples. Chromium is very harmful and has many side effects, such as irregular heartbeats, sleep disturbances, headaches, mood changes, and allergic reactions. Chromium may also increase the risk of kidney or liver damage[24]. The value of chromium in rejected wastewater from Gulberg III (sample C*) exceeded the safety limit and should be treated properly before dumping. Tables **5-10** showed the collection of treated and rejected wastewater for consecutive seven days, and study of their parameters reveals that the water

meets standard drinking values with some variations among each other during consecutive 7-day studies.

CONCLUSION

Conclusively, the RO plants seem to be efficient in treating water and enabling it suitable for the population of these areas. This treated and rejected wastewater is within permissible limits but in rejected wastewater, values of some parameters increased, which can be threatening to human health due to the accumulation of the elements in the environment.

CONFLICT OF INTEREST

No conflicts of interest have been declared by the authors.

FUNDING SOURCE

There was no funding source and all research was done by self-support.

ACKNOWLEDGEMENTS

By the grace of Almighty, I, Naveed Aslam Dogar, acknowledge the motivation and moral support provided by my respected colleagues and seniors. I am really thankful to Dr. Nawaz Chaudhary, Dr. Dildar Ahmed, Dr. Muhammad Pervaiz and Dr. Mushtaq for their encouragement and valuable suggestions during the entire work.

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
EBT	Erichrome Black-T
EDTA	Ethylenediaminetetraacetic acid
M	Molar Solution
N	Normal Solution
NEQS	National Environmental Quality Standards
pH	Potential of Hydrogen
RO	Reverse Osmosis
TDS	Total Dissolved solids

REFERENCES

1. Westall F, Brack A. The importance of water for life. Space Sci Rev. 2018; 214(2):1-23.
2. Jackson S. How much water does a culture need? Environmental water management's cultural challenge and indigenous responses. Water Environ Res. Elsevier. 2017; 173-88.
3. D'Inverno G, Carosi L, Romano G, Guerrini. Water pollution in wastewater treatment plants: An efficiency analysis with undesirable output. Eur J Oper Res. 2018; 269(1):24-34.
4. Patil P, Sawant D, Deshmukh R. Physico-chemical parameters for testing of water-a review. IJEST. 2012; 3(3):1194-8.
5. Pontes C, Réus G, Araújo E, Medeiros M. Silver nitrate colorimetric method to detect chloride penetration in carbonated concrete: how to prevent false positives. JOBE 2021; 34:101860-9.
6. Jouanneau S, Recoules L, Durand M, Boukabache A, Picot V, Primault Y, *et al*. Methods for assessing biochemical oxygen demand (BOD): A review. Water Res. 2014; 49:62-82.
7. Kim M, Youn SM, Shin SH, Jang JG, Han SH, Hyun MS, *et al*. Practical field application of a novel BOD monitoring system. Environ Monit Assess. 2003; 5(4):640-3.
8. Linares RV, Li Z, Abu-Ghdaib M, Wei C-H, Amy G, Vrouwenvelder JS. Water harvesting from municipal wastewater via osmotic gradient: An evaluation of process performance. J Membr Sci. 2013; 447:50-6.
9. Millero FJ, Graham TB, Huang F, Bustos-Serrano H, Pierrot D. Dissociation constants of carbonic acid in seawater as a function of salinity and temperature. Mar Chem. 2006; 100(1-2):80-94.
10. Covington AK, Paabo M, Robinson RA, Bates RG. Use of the glass electrode in deuterium oxide and the relation between the standardized pD (paD) scale and the operational pH in heavy water. Anal Chem. 1968; 40(4):700-6.
11. Diskant EMA. Stable indicator solutions for complexometric determination of total hardness in water. Anal Chem 1952; 24(11):1856-7.
12. Hansen S, Selman L, Palaniyar N, Ziegler K, Brandt J, Kliem A, *et al*. Collectin 11 (CL-11, CL-K1) is a MASP-1/3 - associated plasma collectin with microbial-binding activity. J Immunol. 2010; 185(10):6096-104.
13. Fang T, Li H, Bo G, Lin K, Yuan D, Ma J. On-site detection of nitrate plus nitrite in natural water samples using smartphone-based detection. Microchem J 2021; 165:106117-27.
14. Patey MD, Rijkenberg MJ, Statham PJ, Stinchcombe MC, Achterberg EP, Mowlem MJTTiAC. Determination

of nitrate and phosphate in seawater at nanomolar concentrations. 2008; 27(2):169-82.

15. Willis J. Determination of Lead and Other Heavy Metals in Urine by Atomic Absorption Spectroscopy. Anal Chem. 1962; 34(6):614-7.
16. Chen M-J, Hsieh Y-T, Weng Y-M, Chiou RY-Y. Flame photometric determination of salinity in processed foods. Food Chem. 2005; 91(4):765-70.
17. Esterby SR. Review of methods for the detection and estimation of trends with emphasis on water quality applications. Hydrol Process. 1996; 10(2):127-49.
18. Harvey Jr AE, Smart JA, Amis E. Simultaneous spectrophotometric determination of iron (II) and total iron with 1, 10-phenanthroline. Anal Chem. 1955; 27(1):26-9.
19. Adams SA, Matthews CE, Ebbeling CB, Moore CG, Cunningham JE, Fulton J, *et al*: The effect of social desirability and social approval on self-reports of physical activity. Am J Epidemiol. 2005; 161(4):389-98.
20. Obotey Ezugbe E, Rathilal S. Membrane technologies in wastewater treatment: A review. Membranes. 2020; 10(5):89-97.
21. Klaassen CD. Heavy metals and heavy-metal antagonists. Pharmacol. 1996; 12:1851-75.
22. Ali I. New generation adsorbents for water treatment. Chem Rev. 2012; 112(10):5073-91.
23. Hall RE. A system of boiler water treatment based on chemical equilibrium. Ind Eng Chem Res. 1925; 17(3):283-90.
24. Levina A, Lay PA. Chemical properties and toxicity of chromium (III) nutritional supplements. Chem Res Toxicol. 2008; 21(3):563-71.