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Assessment and statistical study of physico-chemical properties of water quality in some local water treatment plants in Jeddah, Kingdom of Saudi Arabia

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ABSTRACT

The work aimed to assess the quality of drinking water in some of local commercial water treatment plants in Jeddah city, five samples were taken from different water plants subjected to physical, chemical and biological analysis. The parameters such as pH, electrical conductivity (EC),total dissolved solids (TDS),salinity (Sal.), total hardness (TH),calcium (Ca),magnesium(Mg), sodium(Na), potassium (K), iron (Fe), chloride (Cl), fluoride (F), nitrate (NO_3), bicarbonate (HCO_3), sulphate (SO_4) and microbial examinations were done for all samples. These results were compared with the maximum level of the World Health Organization (WHO), Saudi Specification and Standardization organization (SASO) and Gulf Countries Standards for drinking water (GCS). The results showed a compliance with the water quality standards regarding the physical, chemical and biological characteristics. Statistical tools such as average, standard deviation and the correlation coefficient (r), were also calculated for these water quality characteristics.

Key words: physico-chemical properties; drinking water; water quality; biological examinations; drinking water standard; Jeddah.

INTRODUCTION

The importance of water and its role as essential for our daily life and all supporting activities requirements [1], and a really a wander of nature, to check the quality of water sampling to be safe, acceptable and attainable a number of examinations of water samples will be done according to water quality standards to identify the concentration of component properties from available sources. The standards of the concentration of various parameters for water quality were controlled throughout the world by legislation [2-4]. These parameters will be different to some extent from one country to other. Most of people over the world using freshwater which forms the main sources for drinking water and some places using ground water for both drinking agricultural, industrial, household, recreational and environmental activities. In Saudi Arabia as we know it is arid and some scarcity of rainfall for this reason the water treatment becoming expensive commodity [5-8], Jeddah city so depending on desalination of water from the Red Sea and treatment of saline water from different ground water sources to meet their daily need of drinking water. Achievements related to infrastructure to provide residents throughout the city with dependable water supply [9], many large desalinization of seawater plants and small plants from natural sources facilities were made to supply of fresh water in Jeddah [10]. The literature scanning shows that many studies related to the physical, chemical and biological analysis were reported [11-20]. The present work was undertaken to assess the water quality of some water treatment plants, which were selected from different localities at the southern and northern side of Jeddah city.

Study area and Geographical description of Jeddah city:
Jeddah city is the second largest populated one and situated in the western area in Kingdom of Saudi Arabia on the bank of the Red Sea, its Map Coordinates Latitude: N 21° 32' 36.5485" Longitude: E 39° 10' 22.7611" Latitude: N 21° 32.609142' Longitude: E 39° 10.379352' Latitude:21.543486° Longitude:39.172989° . Many industries and industrial estates beside that large population are residing in it so their need of water will be much more; the geographical description of Jeddah map is given in Fig.-1.

Fig.1, The map of sample locations in Jeddah, Kingdom of Saudi Arabia

MATERIALS AND METHODS

Water samples from different water treatment plants in Jeddah, were collected based on standard procedure [21] and reserved in pre-cleaned polyethylene bottles of five liters capacity without any air bubbles, for chemical and biological analysis. The chemical and biological analyses of the samples were carried out in the Rabigh Arabian Water & Electricity Company (RAWEC).

Analysis was carried out for various water quality parameters such as pH using Hanna pH meter**,** electrical conductivity (EC) using Veriner Lab. Quest, total dissolved solids (TDS), total hardness (TH), the calcium (Ca) and magnesium (Mg) determined with EDTA, sodium (Na) and potassium (K) using a flame photometer, while the titration with mercury nitrated are used to determine chloride (Cl). For bicarbonate, a titration with 0.01N sulfuric acid is used. Other parameters such as nitrate (NO_3), sulphate (SO_4),fluoride (F), were determine using standard method [22- 24]. All The reagents used for the analysis were AR grade and double distilled water was used for preparation of solutions.

The microbial analysis such as total colonies of coliform in S#1, S#2, S#3, S#4 and S#5 samples are determined by membrane filtration method in which 100 ml of the sample was filtered slowly through the membrane filtration unit upon which a sterile membrane filter was placed. The water was pumped down using a pump. After all the water was filtered, the membrane was placed in a Petri dish containing absorbent pad soaked in Lauryl broth. Then Petri dish was then incubated at 44.5 ºC. After 24 h, yellow colored colonies were counted as CFU/100 mL as expressed below:

$$\frac{\text{count}}{100\ \text{ml}} = \frac{\text{count on Filter}}{\text{Volume of water filtered}} \times 100$$

Statistical analysis were applied for water characteristics, mean and standard deviation can be calculated using SPSS 18.0 application program and to detect the significant differences for physico-chemicals characteristics. In order to find the relationship between two parameters x and y, the Karl Pearson’s correlation coefficient, r is used and it is determined as follows:

$$r = \frac{n\Sigma xy - \Sigma x \Sigma y}{\sqrt{([n\Sigma x^2) - (\Sigma x)^2][n\,\Sigma y^2 - (\Sigma y)^2]}}$$

Where, n = number of data points; x = values of x–variable; y = values of y–variable.

RESULTS AND DISCUSSION

The results of analysis of various physical ,chemical and biological characteristics of examined samples, shown that there were no considerable variations in the water quality in local treatment plants in Jeddah, the data was summarized in Table -1 and Table-2. A comparison of physico-chemical characteristics of the studied water samples has also been made with WHO standards (1993) and SASO standards (1984).These parameters are discussed below: All water sampling plants were found to be a very clear in appearance, free from apparent turbidity, colorless, odorless and from any un-objectionable taste, which is a compliance with the water quality standards.

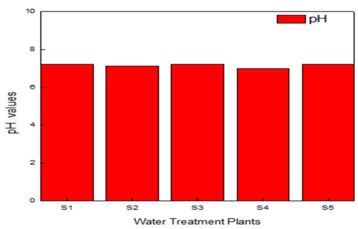
pH analysis:
The experimental results for pH analyses of S#1,S#2, S#3,S#4and S#5 samples are depicted in (Table -1,Fig.- 2) .As well-known pH is a measure of acidity or alkalinity of a solution. In the case of water samples S#1, S#2, S#3, S#4 and S#5, the mean value of pH was found to be 7.14 which is in a compliance with the guideline range of pH values for drinking water (6.5- 8.5) prescribed by WHO, SASO and GCS, as a result there is no significant change in the pH values of water sampling plants.

Table-1: Physico-chemical parameters of some water treatment plants in Jeddah

S. No.	Parameters	WHO	SASO	GCS	EEC	CGL	S#1	S#2	S#3	S#4	S#5
1	pH	6.0-8.5	6.5-8.5	6.5 – 8.5	6.5-8.5	6.5-8.5	7.20	7.20	7.10	7.00	7.20
2	Electrical Conductance EC **	--	800-2300	160-1600	400		216	236	352	231	167.0
3	T.D.S.*	1000	1500	100-1000	1500	<500	120	127	235	125	110.0
4	Salinity *	--	--	--	--	---	141	155	229	150	108.0
5	Total Hardness *	500	500	500	---	--	40	--	110	25	38.0
6	Bicarbonate *	--	--	--	---	--	24	26	42	35	28.0
7	Calcium *	--	200	200	100	--	14.40	8.00	36.0	10.0	12.0
8	Magnesium *	--	30-150	150	30(50)	--	3.00	3.00	4.70	2.00	1.50
9	Sodium *	200	200	200	20-175	--	12.3	22	18	20	13.0
10	Potassium *		150	150	--	--	1.50	1.00	0.20	1.20	0.20
11	Iron *	0.3	1.0	0.3	0.05(0.2)	<0.3	0.00	0.00	0.02	0.02	0.00
12	Sulphate *	400	400	400	25(500)	--	28.0	32.0	22.0	5.00	7.00
13	Chloride *	250	600	250	25	<250	17.50	40.00	63.00	40.00	26.00
14	Fluoride *	1.5	0.6-1.0	0.6-1.70	0.7	--	0.90	1.00	0.90	0.85	1.00
15	Nitrate *	10	45	25(50)	0.1	1.0 as N	2.00	3.00	<1	5.72	0.04

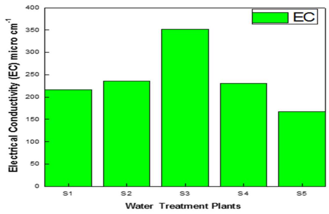
** Units in Milligram per liter* *** Units in Micro Siemens*
WHO: World Health Organization (1993) *SASO: Saudi Arabia Standard Organization (1984/409)*
GCS: Gulf Countries Standard ((1993/149)) *EEC: European Economic Community standard*
CGL: Canadian Guideline (1987)

Fig.2, Graphical Representation of pH Values



Electrical conductivity analysis:
The experimental analysis for electrical conductivity (EC) were carried out for the S#1,S#2, S#3,S#4 and S#5 samples, the electrical conductivity (EC) can be defined as it is a numerical expression that shown the ability of water to hold electrical current and it is related to ionic forces of the solution and the amount of salts dissolved in water[25].The EC values were found to be in the range of 167µS/cm to 352 µS/cm (Table-1, Fig.-3). The mean value of electrical conductivity is found to be 240 µS/cm .Conductivity values of all samples were in agreement with conductivity range 160-1600 µS/cm of the guideline range for drinking water as indicated by WHO, SASO and GCS. It was evident from the (Fig.-3), there was no significant change in conductivity.

Fig.3, Graphical Representation of EC Values

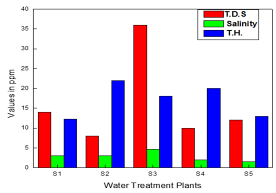


Total dissolved solids:

Total Dissolved Solids (TDS) analysis, can considered as the summation of all dissolves solids in the water, such as non-organic materials, carbonate, bicarbonate, nitrate, sodium, potassium, chloride, and magnesium. TDS affects the other characteristics of drinking water such as taste and hardness. It has been reported that, the amount of TDS more than 500 mg/l of TDS is not considered desirable for drinking water supplies, in some cases will be allowed up to 1500 mg/l [26].The TDS values varied from 110 mg/l to 235 mg/l(Table-1, Fig.-4). All water sampling plants showed a compliance of TDS values with the prescribed limit (100 -1000 mg/l) given by WHO, SASO and GCS.

Hardness can be considered one of the property of water, it can be known by its lather formation with soap and elevation of boiling point of water [27]. The hardness of water mainly depends upon the amount of calcium or magnesium salts or both. The analysis of total hardness (TH) of water under the study, shown values in the range from 40 mg/l to 110 mg/l (Table-1, Fig.-4). All samples values were lesser than the prescribed limit (500 mg/l) by WHO, SASO and GCS.

Fig.4, Graphical Representation of TDS, Salinity& TH Values



Calcium analysis:

The values of concentration of calcium varied from 8.00 mg/l to 36.00 mg/l (Table-1, Fig.-5). The presence of calcium related to hardness. This higher value of calcium related to the S#3 compare to other samples and all found to be below permissible limit of WHO, SASO and GCS.

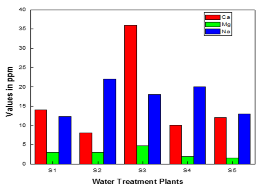
Magnesium analysis:

The increase amount of magnesium is related to hardness. Magnesium content in the investigated water samples was ranging from 1.70 mg/l to 4.00 mg/l. (Table-1, Fig.-5). Which were found to be within WHO, SASO and GCS limits. .

Sodium analysis:

The concentrations of sodium concentrations were varied from 12.30 mg/l to 18.00 mg/l. (Table-1, Fig.-5). All Sampling plants shown a low concentration of sodium when compared to the prescribed limit by WHO, SASO and GCS.

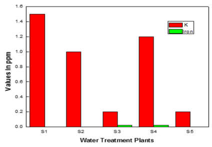
Fig.5, Graphical Representation of Ca, Mg & Na Values



Potassium analysis:
The concentration of potassium varied from 0.20 mg/l to 1.50 mg/l, (Table-1, Fig.-6). All water sampling plants showed a low content of potassium than the prescribed limit by WHO, SASO and GCS.

Iron analysis:
The concentration of iron varied from 0.00 mg/l to 0.02 mg/l. (Table-1, Fig.-6). All water sampling plants showed lower iron concentration than the prescribed limit by WHO, SASO and GCS.

Fig.6, Graphical Representation of K& Fe Values



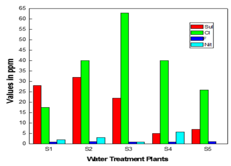
Nitrate analysis:
The amount of nitrate in the water sampling plants varied from 0.04 mg/l to 5.70 mg/l. (Table-1, Fig.-7) and found within the prescribed limit by WHO, SASO and GCS.

Sulphate analysis:
The concentration of sulphate varied from 32.0 mg/l and 5.0 mg/l, (Table-1, Fig.-7). It is well known that its occurrence from common minerals and gypsum [22], and discharge of industrial wastes and domestic sewage tends to increase sulphate concentration. The result of analysis shows the values found within the prescribed limit by WHO, SASO and GCS.

Chloride analysis:
The chloride content in the study area varied from 63.00 mg/l to 17.50 mg/l.(Table-1,Fig.-7) and found to be within the prescribed limit by WHO, SASO and GCS.

Fluoride analysis:
The amount of fluoride content in all water sampling plants ranging from 1.00 mg/l to 0.85 mg/l. (Table-1, Fig.-7) and found to be within the prescribed limit by WHO**.**

Fig.7, Graphical Representation of Sul., Cl, F and Nit



Biological analysis:
Biological analysis were carried out beside the investigation of physical and chemical parameters, the importance of microbiological analysis of water quality to make sure about the safety of water for drinking purposes. Results of fecal coliform analyses are shown in Table-2. The observable results is that the water sampling plants shows a zero value of coliform per 100 ml of the water sampling plants. This indicates that after treatment it was totally removed in order to be microbiologically safe for human consumption similar report have been given [28].

Table-2: Biological analysis of some water treatment plants in Jeddah

Biological Parameters	Units	WHO	GCS (1993/149) SAS (1993/701	S#1	S#2	S#3	S#4	S#5
Coliform Bacteria	No. of count /100 ml	--	--	0.0	0.0	0.0	0.0	0.0
Fecal Coliform	No. of count /100 ml	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coliform MPN/100 ml	No. of count ./100 ml	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Statistical analysis:

The values of the statistical tools such as mean and standard deviation were given in Table-3, which shown a clear picture of interrelationship between different variables to help in developing research [29-32] and opening new era of knowledge which reduces the range of uncertainty associated with decision-making, and also helps in putting possible causal or mechanistic relationships [33-35]. The values of correlation coefficients (r) were calculated and Pearson correlation matrix is obtained[37-42]. The values of correlation coefficients (r) ranging from -1.0 to +1.0 and it is a dimensionless index, the values are listed in Table-4.

Table -3: Statistical tools for water quality characteristics

Parameters	Mean	Std. Deviation
pH	7.1400	0.08944
EC	240.4000	68.09038
TDS	143.4000	51.62654
Salinity	156.6000	44.42184
Total Hardness	40.6000	41.43429
Bicarbonate	31.0000	7.41620
Calcium	16.0800	11.38560
Magnesium	2.8400	1.22597
Sodium	17.0600	4.27411
Potassium	0.8200	0.59330
Iron	0.0080	0.01095
Sulphate	18.8000	12.23520
Chloride	37.3000	17.28294
Fluoride	0.9300	0.06708
Nitrate	2.3320	2.19880

Table -4: Pearson correlation matrix for water quality characteristics

Par.	pH	EC	TDS	Sal.	TH	HCO_3	Ca	Mg	Na	K	Fe	SO_4	Cl	F
pH	1													
EC	-.381	1												
TDS*	-.297	.959**	1											
Sal.	-.372	1. 00**	.956*	1										
TH	-.258	.798	.905*	.790	1									
HCO_3^-	-.716	.794	.836	.784	.770	1								
Ca	-.191	.857	.955*	.850	.984**	.767	1							
Mg	-.041	.926*	.886*	.930*	.750	.528	.825	1						
Na	-.446	.403	.224	.411	-.180	.338	-.075	.227	1					
K	-.066	-.276	-.506	-.267	-.497	-.517	-.545	-.173	.069	1				
Fe	-.919*	.685	.647	.676	.593	.923*	.555	.380	.414	-.185	1			
SO_4^{2-}	.557	.321	.202	.337	.022	-.317	.132	.616	.152	.300	-.395	1		
Cl.	-.503	.880*	.869	.878	.624	.883*	.703	.684	.628	-.509	.750	.038	1	
F	.792	-.400	-.293	-.393	-.408	-.503	-.299	-.231	-.051	-.396	-.748	.253	-.215	1

*Par. Parameter; *. Correlation is significant at the 0.05 level (2-tailed);*
***. Correlation is significant at the 0.01 level (2-tailed).*

From the Pearson correlation matrix, the values of (r) can be classified into a positive correlation values for the parameters of EC. and TDS, Sal., TH, HCO_3, Ca, Mg, Cl ; TDS and Sal., TH, HCO_3 , Ca, Mg, Cl, Fe; Sal and TH, HCO_3, Ca, Mg, Cl, Fe; HCO_3 and Ca, Mg, Cl; Ca and Mg, Cl; Mg and SO_4 ,Na and Cl ; Fe and Cl. , which indicates the strong relation between these variables. A low positive correlation values was observed for the parameters EC and Na, SO_4; TDS and Na ,SO_4; Sal and Na, SO_4, ; TH and SO_4,; HCO_3 and Na ,NO_3; Ca and SO_4,; Mg and Na, Fe; Na and EC,TDS, Sal , HCO3 , Mg, K, Fe, SO_4, ; K and Na , SO_4,;Fe and Na ,NO_3; $SO_4^-$and EC,TDS, Sal., TH, Ca, Mg, Cl ; Ca ,Na, K,F, Cl and SO_4, ,NO_3,; Fe and SO_4,; NO_3 and HCO_3, Fe, Cl. The second type of correlation values which is highly negative correlation observed for the parameters pH and HCO_3, Fe, Cl,NO_3;TDS and K;HCO_3 and SO_4 , pH, K,F; Ca and K; K and TDS, HCO_3, Ca, Cl ; Fe and pH, F; Cl and pH, K; F and HCO_3,Fe,NO_3; NO_3 and pH, F, which indicates the strong relation between these variables, also the low negative correlation for pH and E.C. TDS, Sal.TH, Ca, Mg, Na, K; EC. and pH, K ; F, NO_3;TDS and pH, F, NO_3; Sal., and pH, Na,K,F,NO_3;TH and pH ,Na,K,F,NO_3; HCO_3 and SO_4, Ca and pH, Na, K,F,NO_3; Mg and pH,K,Fe,F,NO_3; Na and pH, TH, Ca ,F; K and pH, EC, Sal., TH, Mg, Fe, F ; Fe and K,SO_4, SO_4 ; and HCO_3, Fe,NO_3 ; Cl and F;F and TDS , EC, ,Sal., TH, Ca, Mg ,Na,K;SO_4, Cl; NO_3 and NO_3 and EC,TDS ,Sal., TH, Ca, Mg, Na, SO_4, were obtained.

CONCLUSION

The present study assessment and statistical study of physico-chemical and microbial properties of water quality in some water treatment plants in Jeddah, Kingdom of Saudi Arabia, and the results of physico-chemical and antimicrobial evaluations for the samples collected from different water treatment plants shown that all the parameters are well in a compliance and agreement within water quality standards given by SASO GCS and WHO. Therefore, we can say that it is fit for drinking purpose. As the importance of water quality for human purposes it should be monitored and cheeked continuously. Further investigations should be done for comparative study of quality water analysis for untreated and treated water that used in water treatment plants.

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