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Assessing Drinking Water Quality in Jubail Industrial City, Saudi Arabia

M. Alsawalha*

Department of Chemical & Process Engineering Technology, Jubail Industrial College, Jubail Industrial City, KSA
*Corresponding author: murad_s@jic.edu.sa

Abstract The focus of this paper is not only on performing laboratory water tests, but also on correlating the obtained results for drinking water samples with the statistical quality control calculations. For this objective various physico-chemical parameters of domestic drinking water were measured, water samples that were collected from Jubail city, mainly from two different areas (Al Huwailat and Jalmudah). The revealed results were correlated with the standard specification (s) outlined by the World Health Organization (WHO). It was found that tested parameters were below the permissible limit stipulated by WHO, which indicates the high quality of water provided in Jubail Industrial City. In addition, the results from the applied research were statistically evaluated by the One-Way analysis of variance (ANOVA) to compare the means of two analysed groups. It was concluded that F_{test} for all parameters was less than $F_{critical}$, which proves that difference being analyzed is statistically significant at the confidential level 95%. Statically this leads us to fact that water quality of the studied areas is suitable for domestic purposes.

Keywords: *water quality, water physico-chemical parameters, one-way analysis variance (ANVOA)*

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1. Introduction

Laboratory analysis of water is essential for determining its quality. Therefore, the analyses made mainly consisted of physical and chemical tests. The physical tests involves suspend solids, temperature, turbidity, color, taste and the odor caused mainly by the presence of organic substances. Chemical laboratory tests related to alkalinity, fluorides, metals and organic and nutrients and hardness. The overall analytical assessments ensure obtaining healthy water [1,2,3]. Moreover, the physical and chemical tests can effectively estimate the water quality in relation to many problems in household water supplies [4].

Some statistical tools like quality index (WQI), were used mainly to provide information on the laboratory results [5,6]. The King Saud University in The Kingdom of Saudi Arabia (KSA) performed additional investigation on drinking water quality from different regions of the capital city in Riyadh [7]. The statistics results for the Riyadh network samples were found to be within the permitted limits of Saudi standard specifications [8].

In general, having a regular a variety of methods to control water quality will help in achieving an acceptable level of drinking water [9,10].

It follows that accurate statistical measurement will give correct directions before having the final decision on any laboratory results. Subsequently, statistical calculations will help in monitoring the reproducibility of analytical measurement over time and have it 'in control' [11,12,13]. An example of quality control charts is the Peareto chart. It was used for estimating variables effects on laboratory experiment or on a given system [14].

The ability to measure variation in results is significant in controlling any variation. The sources of variation are different and they can be categorized as input, materials, and output. Table 1, gives examples for each source.

Table 1. Possible sources of variation with examples

Variation sources	Examples
Input	Materials, Tools
Materials	Operation, Methods, Machine, Environment
Output	Measurement Instruments, Human Inspection performance

In this article, the alkalinity and hardness on various portable drinking water samples collected from the Jubail industrial city were investigated to identify the water drinking quality for public and household uses. Another statistical tool also is used for measuring the difference between all water parameters variables. This is called the one-way ANVOA statistical analysis [15]. This test determines if a significant difference in means results on the dependent variable exist between two or more groups. The objective of this investigation is to evaluate the analytical performance the parameters of physical chemicals of water quality analysis by one-way ANOVA analysis. The test is used mainly to evaluate the null hypothesis that there is no statistically significant difference between measurements in the two areas. In addition, also considered was a correlation between the water quality physico-chemical analysis results (obtained

from the two different areas for the domestic Jubail Industrial City) and the standard specifications.

2. Materials and Methods

2.1. Studied areas

In the present investigation, domestic water samples were collected from Jubail Industrial City, which is considered as one of the most prominent industrial cities in the Eastern province and in Kingdom of Saudi Arabia. The industrial city lies on Latitude 27° N and Longitude 49° E. The distance between Jubail Industrial City and the capital Riyadh is 471 km.

2.2. Sampling

Samples were collected from two different locations in Jubail industrial city, Al Huwailet (Al) and Jalmudah (J) in March, April, May, and July. Samples were collected according to the American Public Health Association standard method [16]. The water samples were collected from the main water source of the public network of each house. Thus, the total number of water samples in this study were 40 collected from two areas, and selected randomly.

2.3. Measuring pH, total dissolved solid and conductivity

For measuring the pH, conductivity and TDS a waterproof type instrument HI98129 was utilized. The conductivity capacity of this instrument-ranges between 0 to 3999 (µS/cm), total dissolved solid (TDS) with a range capability 0 to 2000 ppm.

2.4. Chemicals used

In this study, all chemicals were purchased from the Sigma Aldrich company. For the total alkalinity test, a Phenolphthalein indicator (≤0. 001% heavy metals) was used in addition to and sulfuric acid with a purity of 99.0%. Ammonium chloride - ammonium hydroxide buffer solution with pH 10-11 was used for total hardness test (composition: NH_4Cl, 1 wt. %) Eriochrome Black-T as indicator and Ethylene Diamine Tetra Acetic Acid, used with an assay ≥ 99% (titration).

2.5. Total Alkalinity test

For the alkalinity test, a 30 ml of water sample was selected. Then two drops of phenolphthalein indicator were added to it and it was titrated with 0.02 N sulfuric acid H_2SO_4 to pH 8.3. The color changed from pink to colorless. The total alkalinity was calculated as mg/L $CaCO_3$, as given in the literature [17].

2.6. Total Hardness test

The amount of 20 mL of collected water sample was transferred to a conical flask. Next, an amount of 5 ml ammonium chloride was added to ammonium hydroxide buffer solution (pH 10-11), purchased from Sigma Aldrich. Then, three drops of Eriochrome Black-T indicator and titrate the sample with standardized EDTA solution (Ethylene Diamine Tetra Acetic Acid) were added until the color of the sample changed to red. The total hardness of water sample was calculated in terms of mg. L^{-1} of $CaCO_3$ [16].

2.7. Chlorides and Turbidity analysis

The chlorides and turbidity were tested by following the standard procedure prescribed by the American Public Health Association (APHA) [18].

3. Results and Discussion

Table 2 shows the statistical results for pH, total dissolved solids, chlorides, alkalinity, hardness and electrical conductivity.

Table 2. Summary Descriptive statistics of water quality parameters in two different areas, sampling (n=20, for each area/group)

Analysis type and results	Areas	
	Al	J
pH		
Average	7.72	7.75
Variance	0.02	0.03
Stad. dev	013	0.17
Lowest value	7.59	7.58
Highest value	7.84	7.92
Turbidity (NTU)		
Average	2.20	2.22
Variance	0.01	0.01
Standard deviation	0.06	0.07
Lowest value	2.13	2.15
Highest value	2.26	2.28
TDS mg. L^{-1}	**Al**	J
Average	166.2	166.45
Variance	0.27	0.47
Stand. Dev.	12.89	12.90
Lowest value	153.31	153.55
Highest value	179.09	179.35
Electrical conductivity (µS cm^{-1})		
Average	262.90	262.75
Variance	0.09	0.93
Standard deviation	16.21	16.21
Lowest value	246.96	246.54
Highest value	279.11	278.96
Chlorides mg. L^{-1}		
Average	25.00	25.15
Variance	0.32	0.66
Stand. Dev.	0.56	0.81
Lowest value	24.44	24.54
Highest value	25.56	25.96
Alkalinity mg. L^{-1}		
Average	26.85	26.7
variance	0.13	0.22
Stand. Dev.	5.18	5.17
Lowest value	21.67	21.53
Highest value	32.03	31.87
Hardness mg. L^{-1}		
Average	26.85	26.7
Variance	0.13	.22
Stand. Dev.	5.18	5.17
Lowest value	21.67	21.53
Highest value	32.03	31.87

The averages of the physico-chemical characteristics parameters (Table 2) were found to be under the allowed limits, which outlined by the Saudi standard specifications (SASO 2000) [8]. The standard pH result of drinking water ranges between 6.5- 8.5 and with an ions concentration of dissolved solid particles below 700 (mg. L^{-1}). The average results (mean) for investigating samples were found to be in agreement with the allowed permitted limits [7].

Moreover, results were found to be below the maximum allowable by the World Health Organization and below 250 µS cm^{-1} for drinking water [19]. The TDS for all tested water samples were also below the WHO guidelines; 500 mgl^{-1} which is in agreement with standards in the WHO guidelines [19]. Subsequently, it shows a higher domestic water quality in Jubail Industrial City and less than was obtained by other investigators [20,21].

Table 3 presents World Health organization guidelines for drinking water.

Table 3. World Health Organization guidelines, for drinking water [18]

Water parameter	WHO specifications
pH	7- 8.5
Turbidity (NTU)	≤ 5
TDS (mg L^{-1})	≤ 1000
Chlorides (mg L^{-1})	≤ 250.00
Alkalinity (mg L^{-1})	≤ 120.00
Hardness (mg L^{-1})	≤ 200.00

Statistically, the One-Way variance (ANOVA) was calculated. The calculations were conducted with programing α =0.05, using Excel software 2013.

Table 4. One-way ANOVA analysis of Domestic water in Jubail Industrial City (twenty samples for each area)

Turbidity						
Source of variation	SS	df	MS	F	P-value	F-Critical
Between groups	0	1	0	0.98	.032	1.7
Within groups	0.15		0	-	-	-
Total	0.15					
Totals dissolved solids						
Source of variation	SS	df	MS	F	P-value	F-Critical
Between groups	0.62	1	0.62	1.67	0.2	1.7
Within groups	14.15	38	0.37			
Total	14.77	39				
Electrical conductivity						
Source of variation	SS	df	MS	F	P-value	F-Critical
Between groups	0.22	1	0.22	0.43	0.51	1.7
Within groups	19.55		38	.5		
Total	19.77	39				
Chlorides						
Source of variation	SS	df	MS	F	P-value	F-Critical
Between groups	0.22	1	.22	0.46	0.5	1.7
Within groups	18.55	38	0.48			
Total	18.77	39				
Alkalinity						
Source of variation	SS	df	MS	F	P-value	F-Critical
Between groups	0.22	1	0.22	1.26	0.26	1.7
Within groups	6.75	38	0.17			
Total	6.97	39				

Table 4 presents results from the one-way variance (ANOVA). The sum squares between groups (SS) ranged between 0-0.62 while the SS values within groups ranged between 0.18 -18.55. In addition, it was found the mean square (MS) of the physico-chemical parameters ranged between 0.0-0.48.

In addition, from Table 4, it can be observed that values of F test for all parameters were less than $F_{critical}$, which proves that difference being analyzed is statistically significant at the confidential level 95%. Moreover, a high positive correlation between all physico-chemical characteristics parameters can be observed in the results of Table 4. Subsequently, it can be said that water quality of the studied areas is fit for domestic purposes.

4. Conclusions

The one-way Anova variance was significant to accept the null hypothesis since p value is not less that α =0.05. Moreover, the results showed high quality water for domestic–purposes and more than adequately fit for consumption according to the World Health Organization (WHO) standard guidelines.

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