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Performance Evaluation of Drinking Water Treatment Plant in Iraq

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Abstract

The presence of natural or non-natural pollutants in water resulting from human activity such as the introduction of harmful agricultural and industrial pollutants into rivers that could be the main reason in forming trihalomethane compounds after chlorination step in drinking water production plants. Therefore, the objective of this paper was to assess to the efficiency of traditional drinking water treatment plants in the removal of organic and inorganic pollutants (chemical and physical parameters). The Al-Hussein city water project as traditional water treatment plant in Karbala governorate was taken with a capacity of 8000 m^3/ h as a model for this study. The physical and chemical properties of traditional plant was measured such as (Turbidity, Temperature, pH, Electric conductivity, Alkalinity, Total hardness, Calcium, Magnesium, Chloride, Aluminum, Sulphate, Total dissolved salts) was taken from four units in the plant (quick mixing unit, sedimentation unit, filtration unit and disinfection unit).

The average chemical and physical properties for both raw and drinking water was calculated for eight months during 2017-2018.The average removal percentage of turbidity was 60.7%. However, the values of the other tests ranged from 5 to -0.94%. In order to evaluate the presence of the organic substances in the plant. The samples for raw and drinking water were withdrawn in the winter and spring season from four units of the plant. The traditional plant show the removal efficiency of organic materials was 82% in the winter and 52% was in the spring season. The results showed that the physical and chemical properties were not significantly affected during

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the treatment process and their values were within the limits of the standard of drinking water. The traditional drinking water treatment plant consider unstable plant for the removal of organic compounds in the winter and spring with the possibility of forming chlorinated organic compounds. Therefore, there was the need to use additional treatment techniques to meet the challenges of new pollutants.

Introduction

Pollution may be defined as the addition of undesirable material into the environment as a result of human activities, causes instability disorder, harm or discomfort to the ecosystem or living organisms. A pollutant may be defined as a physical, chemical or biological substance released into the environment which is directly or indirectly harmful to humans and other living organisms they are considered contaminants when they exceed natural levels.[1] The commonly types of pollution are (Water pollution, Air pollution, Noise pollution, Radiation pollution, Soil pollution, Thermal pollution).[2] Water pollution is the introduction of undesirable substances or exposure to certain circumstances resulting in unacceptable it for human use.[3] There are types of water pollution sources, the most important (i) Organic pollutants (ii) inorganic pollutants, the organic pollutants like (insecticides, herbicides, organ halides) and inorganic pollutants like (heavy metals, silt, burning, chemical waste from industrial effluents.[4]

There are many treatment units used to produce drinking water such as (coagulation and flocculation, sedimentation, filtration, disinfection, reverse osmosis, adsorption and ion exchange, advanced oxidation).[5] The traditional drinking water plants involve several units and form the shape called "treatment train".[6] Generally, the traditional drinking water plants has commonly units such as (coagulation and flocculation, sedimentation, filtration, disinfection). The efficiency of these plant for the removal of organic pollutants can be evaluated by GC-MS device, and other parameters of inorganic compounds can be evaluated the traditional plant such as (Turbidity, Temperature, pH, Electric conductivity, Alkalinity, Total hardness, Calcium, Magnesium, Chloride, Aluminum, Sulphate, Total dissolve Slate). Water quality is a concept related to the chemical, and biological, physical, characteristics of water.[7] The physical and chemical properties for drinking water must be within allowed limit ,therefor, requires different processing techniques to reach these limits to the necessities of human needs or purposes.[8] As such, the purpose of this research is to evaluate the efficiency of Al-Hussein city water project as traditional water treatment plant in Karbala governorate for the removal of organic and inorganic pollutant.

Material and Equipment, Method

The materials used in this study are listed in the table (1) while table (2) provides information about the equipment used during the work.

Description of the Work Site

The water project of Al Hussein City was founded in 1985 and it was one of the most important projects in the holy city of Karbala with a capacity of 8000 m^3/ h. The project is based on traditional methods of filtering and sterilization. It is located several kilometers away from the Euphrates River and is surrounded by dense agricultural areas. The water is drawn from the Husseiniya River for the purpose of the producing drinking water. The project contains 2 quick mixing units working for mixing raw water with coagulation material, then after that the water distribution to the 8 sedimentation basins with a capacity of basins 1000 m^3/h. In this step, the removing was for the large suspended molecules while the small suspended molecules will go to the all 40 filters with capacity of 200 m^3/h per one filter. After that the water go to the for disinfection unit (have a large size) to kill the bacteria by used chlorine with period (20 - 30 min) as contact time. After that, the water becomes ready for human consumption and for the distribution. Figure (1) Aerial section of Google Maps shows the stages of treatment of water in the water project of the city of AL Hussein in Karbala.

Sampling

Water samples were withdrawn from AL-Hussein City water project for the purpose of conducting the following tests such as gas chromatography (GC-MS) and inorganic components. The sampling was repeated twice, for the first time it was for raw water and the produced water. Meanwhile, the second time includes the following locations (A) the quick mixing unit (B)the sedimentation unit (C) the filtration unit (D)the disinfection unit. Below the description of the containers used in withdrawn the samples from the river.

1. Glass container against sunlight (1 Liter) filled with water (taken from one large sample) for each time period. With a screw cap and TFE-faced silicone septum. If the sample was didn't analyze through 24 h it was retained at 4 °C until the analyzed time to ensure the organic compounds does no disintegrate to other compounds. These samples were used for the (GC - MS) test.
2. For inorganic models, the container used was glass or plastic bottles because these containers are made of stable materials and they do not give dissolved inorganic materials affecting the values of inorganic tests. In the

Table 1: The materials used during the work

Chemicals	Formula	Purity	Supplier
Hydrochloric Acid	HCl	37%	Himedia Company
Sulfuric acid	H_2SO_4	95-98%	Sigma-Aldrich
Sodium Hydroxide	NaOH	99.90%	Scharlau Company
Hexane	C_6H_{14}	99%	Lab. chemistry department/ College of Science / Al. Nahrain university
Diethyl Ether	$(C_2H5)_2O$	995%	Lab. chemistry department/ College of Science / Al. Nahrain university
Barium chloride	$BaCl_2$	99.99%	Sigma-Aldrich
Murexide	$C_8H_8N_6O_6$	99.90%	Sigma-Aldrich
Ethylene diamine tetraacetic acid	$C_{10}H_{16}N_2O_8$	99%	Sigma-Aldrich

Fig. 1: Aerial picture for water project of Al- Hussein City (Google Maps)

modeling process, models of tap water were taken after a few minutes of opening tap water, as for the other sites, to ensure that the sample contains all the components present in the water. The sample is drawn from the size of three samples each sample pulled after five minutes.

Calculations

The average chemical and physical properties was calculated for specific periods of time by using eq. (1). The removal percentage for many averages to the raw and drinking water was calculated by using eq. (2). as below.

$$\text{Average} = \sum X_i / n \quad ...(1)$$

Table 2: Equipment used in this study

Instruments	Model	Supplier
Gas Chromatography -Mass spectro - photometer (GC-MS)	GC-MS QP2010Ultra	Shimadzu Company
Turbidimeter	2100Q Portable	HACH Company
pH meter	type 3320	Jenway Company
Conductivity/TDS/ Salinity Meter	SensoDirect Con200	Lavibond Company

Where $\sum X_i$ is the total values of one parameter at different times, n the number of these parameters

$$R\% = (\text{Average raw} - \text{Average treated} / \text{Average raw})*100) \quad ...(2)$$

Where R% is the removal percentage.

Results and Discussion

Water Quality

Water quality is a concept related to the chemical biological and physical characteristics of water. The increase in the water components from the permissible limits and for the various uses causes actual health and economic damage. Table (3) represent set of instructions include the maximum permissible limits for the physical and chemical properties of organic and inorganic constituents for drinking water Issued the Central Agency for Standardization and Quality Control.[9] If their values exceed the maximum permissible limit the water becomes polluted and has health and economic damage to humans.

Evaluation of the Plant from the Presence of Organic Matter

The presence of organic materials in the water of the project was studied by the technique of gas chromatography - mass spectrometry. In order to evaluate the removal of organic materials in the water project of Al - Hussain city. The samples were withdrawn during two periods i.e. 9/1/2018, the samples were withdrawn for raw water and water produced, but on 24/4/2018, the samples

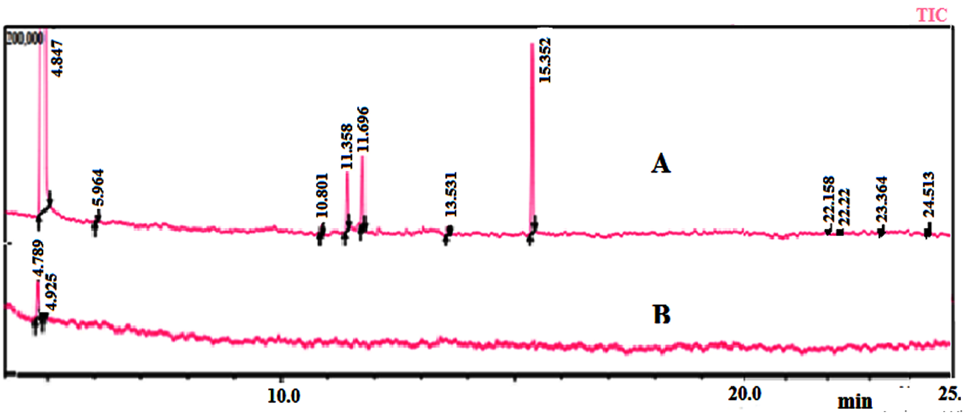

Fig. 2: Scheme for GC-MS (A) raw water and (B) drinking water

were withdrawn from the sites (quick mixing unit, sedimentation unit, filtration unit, disinfection unit). The samples withdrawn during January and April were extracted by hexane and hexane - diethyl ether. The organic layer (containing the dissolved organic matter) was withdrawn in each case and analyzed by (Shimadzu GC-MS. QP2010Ultra). Figure (2) represents the analysis from GC/MS in January and the compounds produce from chromatogram were recorded in table (4). The results show the presence of the phenol in raw water and drinking water, the maximum number of remained compounds was 11 and the minimum number of remained compounds was 2 with removal efficiency was 82%.

Table 3: The physical and chemical properties limits for drinking water

1-physical properties		**3- organic compound**	
properties	**Maximum allowed mg/L**	**Properties**	**Maximum allowed**
mg/L			
Color	10 units	Carbon tetrachloride	0.004
Turbidity	5 units	Dichloromethane	0.2
Taste	Acceptable	1,2 dichloroethane	0.03
Odor	Acceptable	Benzene	0.01
Acid function(PH)	6.5 – 8.5	Toluene	0.1
2- chemical properties	Benzo-a-Pyrine	0.0007	
Properties	**Maximum allowed mg/l**	Monochlorobenzene	0.3
As	0.01	1,2 dichlorobenzene	1.0
Cd	0.003	1,4 dichlorobenzene	0.3
Cr	0.05	Trichlorobenzene	0.02
CN	0.03	Acrylamide	0.0005
F	1.0	Phenol	0.002
Pb	0.01	4- Pesticides	
Hg	0.001	Type of pesticides	Maximum allowed mg/l
NO_3	50	Aldrin/dieldrin	0.00003
NO_2	3	Atrazine	0.002
Se	0.01	Bentazone	0.03
Al	0.2	Carbofuran	0.007
Cl	350	D.D.T	0.001
Cu	1.0	Chlordane	0.0002
$CaCO_3$	500	Hexachlorobenzene	0.001
Fe	0.3	Isoproturon	0.009
Mn	0.1	Lindane	0.002
Na	200	Mcpa(clorophenoxy)	0.002
TDS	1000	Molinate	0.006
SO_4	400	Pendimethalin	0.02
Zn	3	Permethrin	0.02
Ca	150	Propanil	0.02
Mg	100	Simazine	0.002
Ba	0.7	Trifluralin	0.02
Ni	0.03		
B	0.5		

Although Al-Hussain city project could remove some organic compounds but the plant could not remove the phenol from the water. The phenol is consider as toxic and dangerous compound.[10] Thus, it must be removed from water. The samples withdrawn during April were extracted by hexane -diethyl ether and analyzed by GC-MS as in figures (3,4,5,6) and tables (5,6,7 and 8). Generally, the result from the GC-MS analysis shows many hydrocarbon compounds remained at all treatment units. The maximum number of remained compounds was 23 and the minimum number of remained compounds

Table 4: Different compounds in raw water and drinking water

Compounds for scheme(A) raw water			
Peak	**Retention time**	**Area %**	**Name**
1	4.847	94.65	Phenol
2	5.964	0.09	Phenol, 2-methyl- (CAS)
3	10.801	0.08	Pentane, 3-bromo- (CAS)
4	11.358	0.82	Propanoic acid, 2-methyl-, 2,2-
5	11.696	1.03	Propanoic acid, 2-methyl-, 3-hy
6	13.531	0.15	Butyric acid, neopentyl ester
7	15.352	2.57	Pentanoic acid, 2,2,4-trimethyl
8	22.158	0.16	11,14-Eicosadienoic acid, meth
9	22.22	0.05	9-Octadecenoic acid (Z)-, meth
10	23.364	0.1	TRICOSANE
11	24.513	0.16	Nonadecane (CAS)

Compounds for scheme(B) drinking water			
Peak	**Retention time**	**Area %**	**Name**
1	4.789	94.58	phenol
2	4.925	5.42	Acetic acid, phenyl ester (CAS)

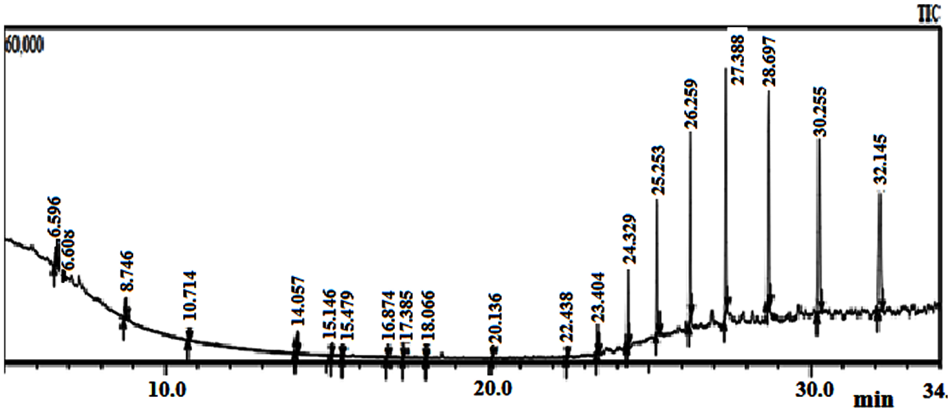

Fig. 3: Scheme for GC-MS of the quick mixing unit

was 11. Therefore, the removal efficiency of the plant was approximately 52% for all units. This means that trihalomethan compounds may be high after disinfection.[11] This problem requiring the development of new treatment technologies for the removal of organic matter.

Table 5: Different compounds of the quick mixing unit

Compounds from figure (2) the quick mixing unit

Peak	Retention time	Area %	Name
1	6.596	1.5	Tetradecane, 2,6,10-trimethyl- (CAS)
2	6.608	0.01	Tetradecane, 2,6,10-trimethyl- (CAS)
3	8.746	1.2	Dodecane (CAS)
4	10.714	0.61	Tricosane (CAS)
5	14.057	1.36	1H-1,2,3-Triazole (CAS)
6	14.057	0.69	2-Hepten-3-ol, 4,5-dimethyl- (CAS)
7	15.146	0.65	1-Pentadecanol (CAS)
8	15.479	0.04	Propanoic acid, anhydride (CAS)
9	16.874	0.07	2-Benzylidene-3-oxo-4-(octylsulfanyl)-2,3-
10	17.385	0.02	TRANS-.BETA.-IONON-5,6-EPOXIDE
11	18.066	0.04	tert-Butyl 2-hydroxypropylcarbamate
12	20.136	0.18	7,7-Dimethyl-1-trimethylsilylocta-1,3-diyn-5-
13	22.438	0.52	Pentadecane (CAS)
14	23.404	1.9	Eicosane (CAS)
15	24.329	4.71	Docosane (CAS)
16	24.329	4.88	Docosane (CAS)
17	25.253	8.51	Tetratetracontane (CAS)
18	26.259	12.02	Tetracontane
19	27.388	15.57	Tetracontane
20	28.697	13.51	Tetrapentacontane
21	28.697	13.51	Tetrapentacontane
22	30.255	11.06	Tetrapentacontane
23	32.145	7.44	Tetrapentacontane

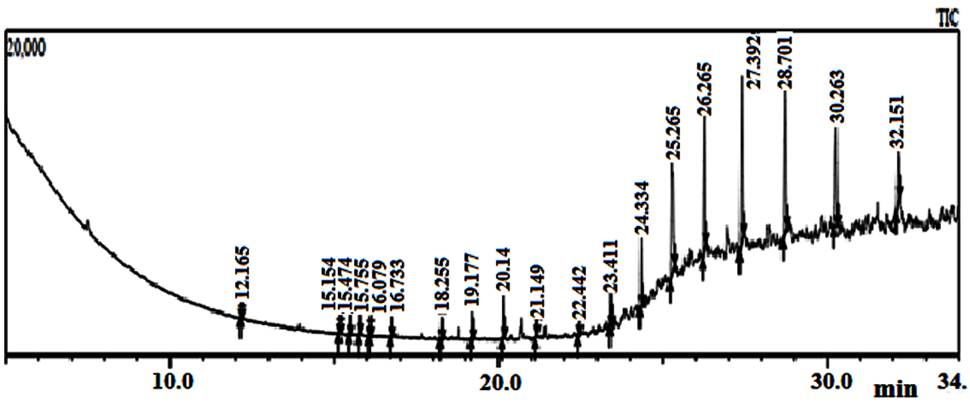

Fig. 4: Scheme for GC-MS of the sedimentation unit

Evaluation Inorganic Substances

In January / 2018 water samples were withdrawn from the Al-Hussein City project. The sampling was of four treatment units and the experiments were carried out in the quality control laboratories affiliated to the Ministry of Housing Municipalities and Public Works. The values of inorganic properties were recorded in the table (9). It was notice that the sedimentation unit do not have any effect on the treatment process due to the low turbidity level. As such, the coagulant material is not adding to the raw water except when the turbidity values rise. On the other hand, high values of (TDS, EC, CL, TH) were observed at the last treatment unit, due to the

Table 6: Different compounds of the sedimentation unit

Compounds from Figure (4) of the sedimentation unit

Peak	Retention time	Area %	Name
1	12.165	0.47	--
2	15.154	0.53	1-Pentadecanol (CAS)
3	15.474	1.35	Hexadecane, 1-iodo- (CAS)
4	15.755	1.77	2-tert-Butyl-4-(2,4,4-trimethylpent-2-yl)phenol
5	16.079	0.56	7-Oxanonadecane
6	16.733	1.64	1-Hexadecanol (CAS)
7	18.255	1.51	Nonadecane (CAS)
8	19.177	1.67	7-Hexadecene, (Z)- (CAS)
9	20.14	3.2	1,2-Benzenedicarboxylic acid, bis(2-methylprop
10	21.149	0.84	Hexadecane, 1-iodo- (CAS)
11	22.442	0.86	Pentadecane (CAS)
12	23.411	2.3	Eicosane (CAS)
13	24.334	4.53	Docosane (CAS)
14	25.263	17.94	Tetratetracontane (CAS)
15	26.265	11.96	Tetracontane
16	27.392	15.53	Tetracontane
17	28.701	15.61	Tetrapentacontane
18	30.263	12.09	Tetrapentacontane
19	32.151	5.6	Tetrapentacontane

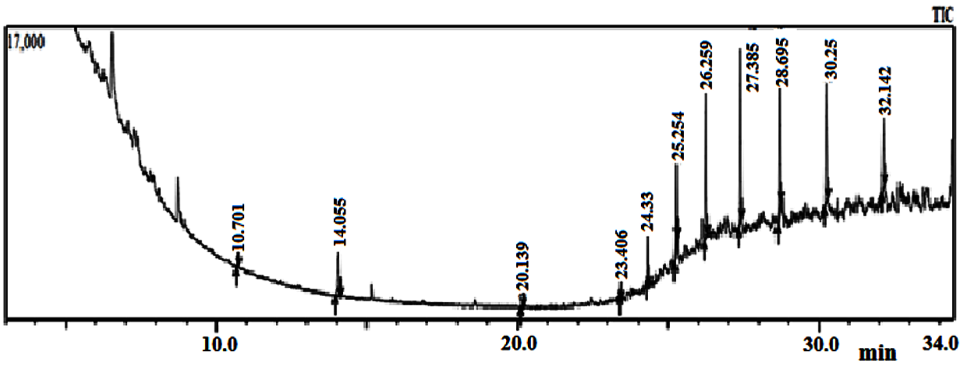

Fig. 5: Scheme for GC-MS of the filtration unit

addition of chlorine which leads to an increase of salts, while we find an increase in (turbidity, SO4, Ca) due to the media of filtration unit that is not effective or, the media of filtration unit were slightly dissolving in water. Although the changes in the physical and chemical properties values during the treatment units are few, these values fall within the limits of the Iraqi standard because the values of the components of the Euphrates River basically fall within these limits.

Evaluation the Project between 2017 - 2018

The physical and chemical tests in the water project were monitored for AL- Hussein city between 2017-2018 and the tests included, raw water and drinking water for the purpose of evaluating the efficiency of removal of inorganic materials in the project. The tests were cooperation with the Quality Control Laboratory in Karbala and the results were recorded in the tables (10 and11) respectively. The average values of all parameters were calculated using eq. (1) and the removal efficiency % were calculated for both raw and drinking water using eq. (2).

The results of removal efficiency% to the different inorganic tests resulting from the average values of

Table 7: Different compounds of filtration unit

compounds from Figure(5)of the filtration unit			
Peak	**Retention time**	**Area %**	**Name**
1	10.701	1.12	Tricosane (CAS)
2	14.055	7.48	1H-1,2,3-Triazole (CAS)
3	20.139	0.66	7,7-Dimethyl-1-trimethy-lsilylocta-1,3-diyn-5-e
4	23.408	1.02	Eicosane (CAS)
5	24.33	3.96	Docosane (CAS)
6	25.254	7.35	Tetratetracontane (CAS)
7	26.259	14.97	Tetracontane
8	27.385	18.89	Tetracontane
9	28.695	17.18	Tetrapentacontane
10	30.25	17.25	Tetrapentacontane
11	32.142	10.12	Tetrapentacontane

Table 8: Different compounds of disinfection unit

Compounds from Figure(6) of the disinfection unit			
Peak	**Retention time**	**Area %**	**name**
1	14.061	19.87	2-Hepten-3-ol, 4, 5-dimethyl- (CAS)
2	15.151	10.62	1-Dodecanol (CAS)
3	20.142	4.45	1,2-Benzenedicarboxylic acid, bis(2-methylpro
4	23.412	3.06	Eicosane (CAS)
5	24.335	5.59	Docosane (CAS)
6	25.263	4.28	Tetracontane
7	26.267	11.57	Tetracosane (CAS)
8	27.396	9.18	Tetrapentacontane
9	28.701	9.52	Tetrapentacontane
10	30.266	10.6	Tetrapentacontane
11	32.159	11.25	Tetrapentacontane

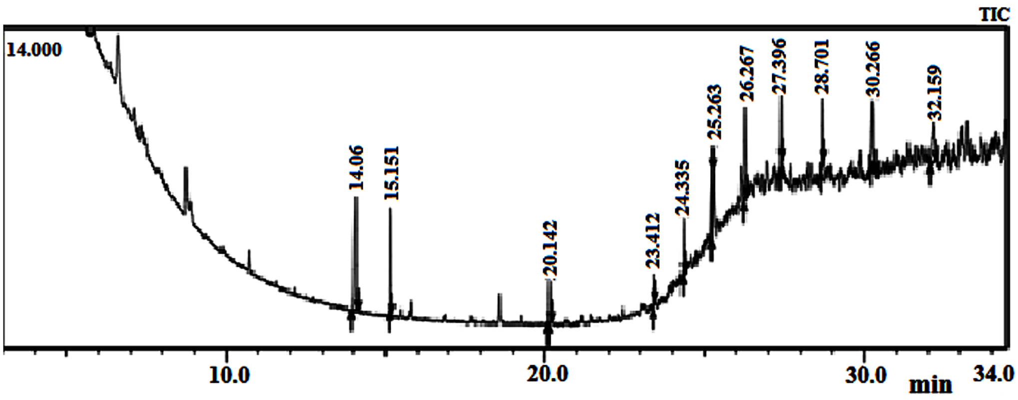

Fig. 6: Scheme for GC-MS of the disinfection unit

Table 9: Values of inorganic chemical and physical properties of treatment units

Parameter mg/L	Raw water (Assembly Unit)	Before filter (Sediment ation unit)	After filter (filter unit)	Clean water (chlorination unit)	The limits of the standard
Turbidity, NTU	1.35	1.3	1.47	1.47	5
Temperature T	20	20	20	20	25
PH	7.88	8.2	8.2	7.83	6.5- 8.5
E.C , μs/cm 25 C	1118	1118	1125	1129	----
Alkalinity(as $CaCO_3$)	132	132	132	128	125 - 200
Total hardness(as $CaCO_3$)	366	360	368	371	500
Calcium(as Ca)	84	84	87	87	150
Magnesium(as Mg)	38	38	38	37	100
Chloride(as Cl)	124	124	124	128	350
Aluminum(as Al)	0	0	0	0	0.2
Sulphate(as So_4)	255	243	255	259	400
T.D.S	698	698	705	706	1000

Table 10: Parameter value for raw water between 2017- 2018

Months	Tub	TH	Alk	T.D.S	pH	Cl	Ca	Mg	E.C	Na	K	SO_4
Oct-17	8	347	106.5	671	7.8	108	81.7	35	1050.5	83.7	4.6	260
Nov-17	8.6	364	114.6	692.6	7.7	114	83.6	38	1081	84	4.7	271
Dec-17	6.6	376	118	700	7.9	121.6	89	37	1094.6	90	4.4	284.6
Jan-18	6.5	370	124	702	8	123.5	88	36.5	1102	84	4.35	259.5
Feb-18	8.2	346	125.5	701	8	131.5	82	33.5	1102.5	96.7	4.12	236.7
Mar-18	9.6	386.6	121	686.6	7.9	115.6	100.6	32.6	1089.6	84	4.2	252
Apr-18	8.7	381	123.5	689.5	7.9	108.5	101.7	31	1093.7	79	3.9	268
May-18	8	367	128	668	7.9	121	96	30.8	1059.8	90	4.5	255
Average	8.025	367.2	120.1	688.8	7.8	117.9	90.3	34.3	1084.2	86.4	4.3	260.8

Table 11: Parameter value for drinking water between 2017- 2018

Months	Tur	TH	Alk	T.D.S	pH	Cl	Ca	Mg	E.C	Na	K	SO_4
Oct-17	3.7	343	104.5	667.5	7.5	109.7	80	34.7	1044.7	82	4.4	262
Nov-17	3.6	360	112.6	688	7.6	116	82	37.6	1075.6	83.6	4.5	273
Dec-17	1.5	372	116.6	707	7.8	123	88	37	1105	88.6	4.13	288
Jan-18	3	366	122	699	7.8	125	86	36.5	1101	83	3.7	259.5
Feb-18	3.25	341	123.5	695	7.9	134	81	33	1093	95	4	239
Mar-18	3.9	384	119	691	7.7	117	99	33	1097	84	4.13	255
Apr-18	3.5	377	121.5	690	7.8	110	100.7	30.5	1094.5	77.7	3.7	272
May-18	2.8	362	126	667.6	7.8	124.8	95	30.6	1059	88.6	4.4	258
average	3.1	363.1	118.2	688.1	7.7	119.9	88.9	34.1	1083.7	85.3	4.12	263.3

Table 12: Average values of raw water and treated water

Parameter	Average raw	Average treated	R%
Turbidity	8.03125	3.15625	60.7
Hardness	367.2	363.125	1.1
Alkalinity	120.1375	118.2125	1.6
T.D.S	688.8375	688.1375	0.1
pH	7.8875	7.7375	1.9
Ca	90.325	88.9625	1.5
Mg	34.3	34.1125	0.54
E.C	1084.2125	1083.725	0.04
Na	86.425	85.3125	1.28
K	4.34625	4.12	5.2
SO_4	260.85	263.3125	-0.94

the raw and drinking water depended on eq. (2) was recorded in the table (12). The removal efficiency % of turbidity was 60.7 % which consider the highest value comparing to other values of the removal efficiency % that was between (5.2) to (-0.94) and these values is very low. The chlorine values were ignored, since the chlorination is in the final stage of treatment process. The presence of chlorine in water is a desirable process, and the raw water does not contain chlorine until subtract from drinking water. The negative value of sulphate indicates that alum is added to the raw water, this giving an extra dose of sulfate to the water product instead the raw water. The results appear the traditional treatment plant, was not able to the remove different inorganic parameters and can use this plant only for removal turbidity %.

Conclusion

Al - Hussein Water Project is one of the traditional filter plant proved efficiency removal of organic compounds up to 82 % in winter season and 52 % in the spring season. Thus, the possibility of the formation of trihalomethan after chlorination was high. The physical and chemical properties were not significantly affected during the treatment process through calculate the efficiency removal of the average chemical and physical properties to raw and produced water for eight months' period during 2017 2018, and the removal percentage of turbidity was 60.7 %. Meanwhile the other tests values ranged from (5) to -0.94 %. The results showed that the physical and chemical properties were not significantly affected during the treatment process. The conventional drinking water treatment plant proved to be variable in the removal of organic compounds in the winter and spring with the possibility of forming chlorinated organic compounds, generally on filtration and disinfection only. Therefore, the use of additional processing techniques is required to meet the challenges of new pollutants

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