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RESEARCH ARTICLE

An Assessment of Inorganic Contaminants Levels in the Wastewater of Lifting and Treatment Sewage Stations in Karbala, Iraq

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ABSTRACT

The investigation in this study includes examining the impact of wastewater at ten different stations. Eight lifting stations and two treatment stations in the center and district of Al-Hurr in the Karbala city. The study's goal is to determine the operational effectiveness of the main treatment unit project in Karbala and the Al-Hurr treatment unit and its impact on wastewater quality, disclosing the qualitative features of wastewater in the study area, controlling waste water from treatment plants, and utilizing its service in other fields. More than 70 trace elements were examined in this study by using inductively coupled plasma mass technology, in wastewater samples. Arsenic (As) concentrations were shown to be higher than permitted levels in some sites reaching 11.300 ng/mL, and lead (Pb) concentrations were found to be higher than permissible limits at several lifting stations, where the concentration value reached 15.500 ng/mL. according to Iraqi standards and the World Health Organization. The findings of the investigation were provided on several indicators and classifications to take advantage of the water departure from the treatment plants in several places, as the indicators revealed that the water is contaminated, salty, and unsuitable for agricultural irrigation. It is suitable for crops that survive high salinity and for animal consumption. The correlation coefficient was also evaluated for the elements measured at the stations under study, and there was a perfect correlation for some elements, with correlation coefficient values ranging between (0.996–1.000) for each of elements (Ni, Re, W and As, Li).

Keywords: Chemical pollutants, ICP-MS, Toxic materials, Wastewater treatment, Water quality

Introduction

Wastewater which is discharged from homes, businesses, and industrial facilities, is a complicated mixture of water carrying waste.[1] Municipal and industrial water outlets may contain pollutants, medicinal products, and also other industrial waste, heavy metals, oils, pesticide residues, sludge, by products.[2–4] Environmental issues are caused by the over usage of these contaminants and their untreated discharge.[5] Other extremely dangerous substances, and poisonous Additionally, metal ions have a tendency to bio-accumulate and might gradually leach into rivers, endangering aquatic life.[6] Heavy metals present at higher concentrations have a number of detrimental consequences on the health of humans and other creatures.[7,8] Heavy metals can exist naturally in the environment, ecosystem and soils.[9] Wastewater pollution is frequently caused by mining, recovery, and other economic activities that use several harmful metal ions.[10,11] Numerous varieties of waste-water have been produced as a result of the population boom, urbanization, and industrialization.[12,13] Black water, which contains pathogens, yellow water, which is nutrient-rich urine, and gray water, which comes from shower drains and laundry facilities, make up domestic wastewater.[14] Environmental issues are brought on by the over usage of these contaminants and their untreated discharge.[15] Given the large number of organic and inorganic

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contaminants present, wastewater discharge has the potential to damage soil, groundwater, and surface waters.[16,17] One of the most important challenges on a global scale is heavy metal contamination.[16,18,19] Metal ion concentrations in some industrial wastes are typically substantially higher than allowed limits. Cd, lead, Hg, Cr, Ni, Cu, Zn, Co, and other metals are among them. Due to their toxicity even at very low concentrations, heavy metals can harm the environment and subsequently cause a variety of ailments in humans.[20,21] Heavy metals cannot decompose because of their limited solubility in wastewater, which causes them to accumulate. One of the most crucial aspects of water treatment is the elimination of toxic heavy metals from wastewaters.[22] Additionally, wastewater is a good screening target for determining the sources and potential environmental impacts of human trace element consumption.[23] Despite advancements in treatment technology, wastewater treatment plants (WWTPs) are still unable to completely eliminate chemical pollutants, such pharmaceuticals, trace metals (TMs), and metalloids, which are regularly detected in environmental samples.[21] Human health and the sustainability of the socioeconomic system are directly related to water quality. As anthropogenic activities become more intense, contaminants, particularly trace elements, infiltrate the water system and endanger people.[24] Water supplies and water quality are critical for human survival, the ecological environment, and economic and regional sustainability.[25] Pollutants in bodies of water, particularly trace elements, rich aquatic ecosystems and, ultimately, the human body via the drinking water pathway.[26] Some of the metals are poisonous, persistent, and non-degradable.[27]

The study's goal is to determine the operational effectiveness of the main treatment unit project in Karbala and the Al-Hurr treatment unit and its impact on wastewater quality, disclosing the qualitative features of wastewater in the study area; as well as evaluating the possibility of using wastewater after treatment for agricultural and industrial purposes.

Materials and methods

An ICP-MS analyzer (inductively coupled plasma (ICP-MS) made in USA) was used and the chemical reagents of analytical reagent grade were used, nitric acid HNO_3 (1 M) (70%) (B.D.H) and deionized water was used throughout the experiments.

Sampling

Wastewater samples were taken from ten different stations: eight lifting stations and two treatment stations in the center and district Al-Hurr in the Karbala city. Samples were taken from each station at a depth of 1–3 m. Wastewater samples were collected in pre-washed 1L polyethylene containers. Wastewater samples were filtered using filter paper (Huathman 42, 44). Vials and examination equipment were washed with deionized water before use. All samples were kept in the refrigerator after receipt to ensure that the samples were not damaged during laboratory examination. Table 1 shows nformation on lifting and treatment stations and Figs. 1 and 2 show the sequence of lifting and treatment stations, the information system data for sewage systems was provided by the Directorate of Karbala Sewage.

Table 1. Type of the lifting and treatment stations for sewage.

Station symbol	Station name	Station type
Z-1	The main processing unit project	Wastewater treatment plant
Z-2	AL- Hur processing unit project	Wastewater treatment plant
Z-3	Messila lift station	Sewage lifting station
Z-4	Oasis station	Sewage lifting station
Z-5	Ghadeer station	Sewage lifting station
Z-6	Staff district station	Sewage lifting station
Z-7	Ready lift station	Sewage lifting station
Z-8	Al-Bahadliya Station	Sewage lifting station
Z-9	Industrial district lift station	Sewage lifting station
Z-10	Poultry lift station	Sewage lifting station

Inductively coupled plasma-mass procedure

The most often used and recommended techniques are inductively coupled plasma-mass spectrometry (ICP-MS) and inductively coupled plasma-optoelectronic spectroscopy (ICP-OES) because of their well-known advantages of sensitivity, selectivity, and multi-element analytical capabilities.[28–30] Inductively coupled plasma mass spectrometer (ICP-MS) technology currently allows for the simultaneous identification of several trace elements.[31] In tests ranging from 1 ng. L^{-1} to high mg. L^{-1} ranges, ICP-MS shown to be more accurate than other methods at detecting components of biological or clinical origin at the lowest concentrations with good linearity, the exceptional sensitivity of.[32] The concentration of trace elements was measured in wastewater samples, where 10 mL was taken from the sample and a digestion process was carried out by using 1M HNO_3. After the samples were entered and injected into the device, the concentration reading was taken directly.

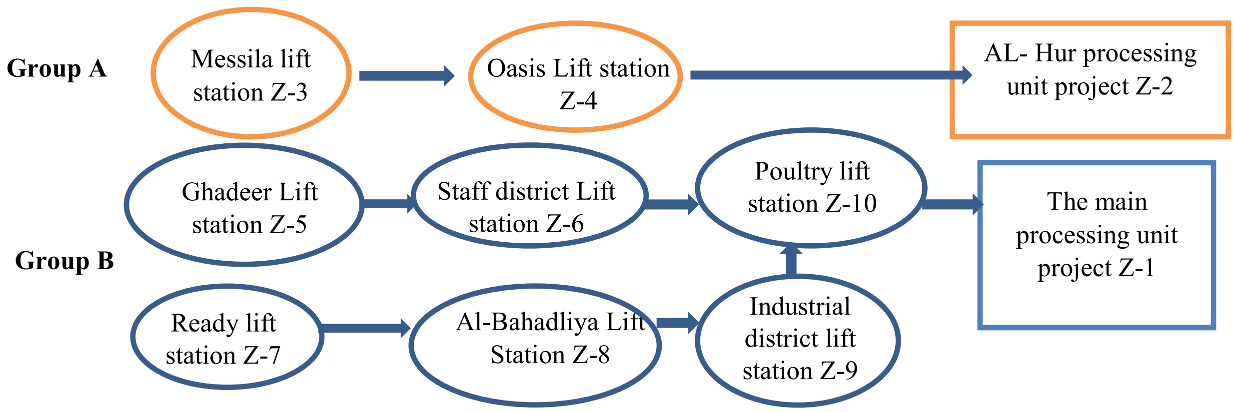

Fig. 1. The lifting and treatment stations A: Lifting and treatment stations for Al-Hur District B: Lifting and treatment stations in the center of Karbala city.

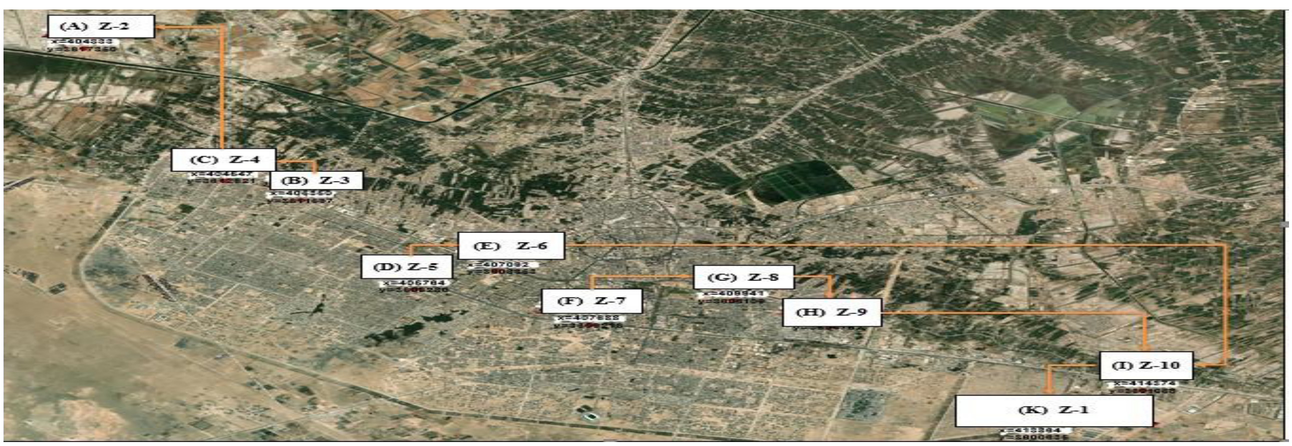

Fig. 2. Map of the locations of wastewater sampling (A): AL- Hurr processing unit project Z-2 (B): Msaylila lift station Z-3 (C): Oasis Lift station Z-4 (D): Ghadeer lift station Z-5 (E): Staff district Lift station Z-6 (F): Ready lift station Z-7 (G): Al-Bahadliya Lift Station Z-8 (H): Industrial district lift station Z-9 (I): Poultry lift station Z-10 (K): The main processing unit project Z-1.

Results and discussion

Trace elements level in wastewater

The analysis of trace elements for the wastewater of the lifting and treatment stations in Karbala city using ICP-MS techniques was presented. Where more than 70 elements were estimated in the stations under study, where the elements that showed concentration values were 28 elements, while for the rest of the elements, the concentration of the elements was equal to zero. The items were divided according to the concentration values into three sections (Ultra Micro Elements Concentration, Micro Elements Concentration, and Macro Elements Concentration) according to the results shown in Tables 2 to 4.

Ultra micro elements concentration

According to the analysis presented in Table 2, the concentration of As levels ranged between 0.000–11.300 ng. mL^{-1} with a Mean and Standard Deviation of 2.075 ± 4.163 for lifting stations. The maximum concentration in station (Z-10) was 11.300 ng. mL^{-1}. The results showed that the concentration of arsenic is outside the permissible limits in the final lifting station (Z-10) because the station is considered the final complex for all lifting stations where all chemical pollutants are concentrated in this station. The Pb concentration ranged between 0.000–15.500 ng. mL^{-1} with a Mean and Standard Deviation of 7.913 ± 6.803 for lifting stations. The maximum concentration in station (Z-9) was 15.500 ng. mL^{-1}. It was found that the concentration of lead was outside the permissible limits in the lifting station (Z-9) compared to the World Health Organization. The reason for the increase in the concentration of (Pb, As) in the study area is that the industrial zone lift station (Z-9) contains industrial waste from factories and oil waste present in the area, which are discharged directly into the sewer without any treatment being carried out, which causes an increase in the concentration of the elements. (Pb, As). The

Table 2. The concentration of ultra micro elements in the lifting and treatment stations in the range (0–25 ng. mL^{-1}).

	Station symbol	Concentration of trace elements ng. mL^{-1}												
		Ag	As	Ga	Li	Mo	Nb	Ni	Pb	Re	Se	V	W	Rb
Before treatment	Z-3	0	0	0	0	0	0	0	0	0	0	0	0	10.1
	Z-4	5.0	0	0	0	0	0	0	0	0	10.5	0	0	7.50
	Z-5	0	0	0	0	0	0	0	13.0	0	0	5.4	0	13.5
	Z-6	0	5.3	5.8	9.4	0	0	0	0	0	6.0	5.6	0	13.2
	Z-7	0	0	6.3	0	0	0	0	8.8	0	0	6.2	0	11.2
	Z-8	5.0	0	6.9	0	0	16.0	0	13.3	0	0	5.8	0	11.5
	Z-9	0	0	5.2	0	0	0	0	15.5	0	0	8.5	0	10.5
	Z-10	5.0	11.3	5.9	16.4	11.4	0	0	12.7	0	6.0	6.7	0	25.4
	μ	1.9	2.7	3.7	3.2	1.4	2.0	0	7.9	0	2.8	4.8	0	12.9
	SD	2.59	4.16	3.15	6.25	4.03	5.65		6.80		4.12	3.10		5.40
After treatment	Z-1	0	0	0	0	0	0.0	11.6	0.0	6.3	0	0	6.0	8.5
	Z-2	0	0	0	0	0	0	0	0	0	0	0	0	7.9
	μ	0	0	0	0	0	0	5.8	0.0	3.150	0	0	3.04	8.2
	SD							8.20		4.45			0.24	0.42
WHO 2011		10.0	10.0	-	-	70.0	-	70.0	10.0	-	10.0	-	-	-
IME 2012		10.0	50.0	-	-	-	-	100.0	50.0	-	10.0	-	-	-

IME, WHO, 2011 Iraqi standards for treated wastewater in irrigation (IME, 2012) (ng. mL^{-1}).[33,34] World Health Organization (ng. mL^{-1}).[35] Respectively.

Ni and Re concentration ranged between (0.000–11.600 ng. mL^{-1}) and (0.000–6.300 ng. mL^{-1}) with a Mean and Standard Deviation of (5.800 ± 8.202 and 3.150 ± 4.455) respectively for treatment stations, and the maximum concentration in station (Z-1) was 11.600 ng. mL^{-1} and 6.300 ng. mL^{-1}. The results showed that the nickel concentration was within the permissible limits for all stations. The presence of (Ni and Re) in the treatment station (Z-1) is caused by the deposition of some trace elements in the sedimentation ponds during prolonged processing. For the rest of the elements (V and Rb), the values of the Mean and Standard Deviation (4.775 ± 3.101, and 12.863 ± 5.402) respectively for lifting stations. As for the rest of the elements, their effect was very little. Fig. 3 shows the concentration of trace elements in the lifting stations (Before treatment) and treatment stations (After treatment).

The results in Fig. 4. showed the concentration and distribution of some elements (Ga, Pb, V, Rb). It was found that the concentration of Ga is normally distributed and that the concentration of the element ranges between 0.0–6.9 ng. mL^{-1} and in the low concentration range in most lifting stations. As for lead, it was found that the concentration of the element ranges between 0.0–15.5 ng. mL^{-1} and is within the high concentration limits of most lifting stations. The concentration distribution of Vanadium was in the range 0.0–8.5 ng. mL^{-1} and within the low concentration limits for most stations. As for the Rb element, the distribution of concentration values was in the range (7.5–25.4 ng. mL^{-1}) and the values were within the high limits for most stations. A significant increase in the concentration of the element was

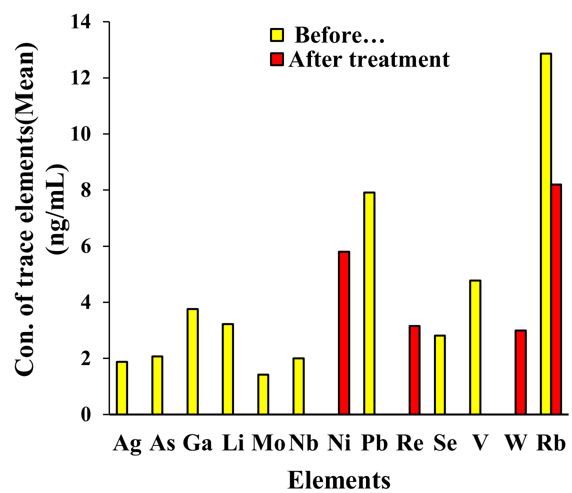

Fig. 3. The concentration of Trace elements in the lifting and treatment stations in the range (0–30 ng. mL^{-1}).

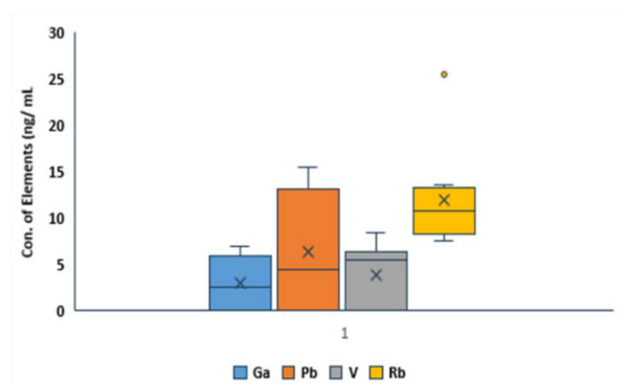

Fig. 4. The concentration of some elements (Ga, Pb, V and Rb) in the lifting and treatment stations.

Table 3. The concentration of micro elements concentration in the lifting and treatment stations in the range (10–180 ng. mL^{-1}).

	Station symbol	Concentration of trace elements ng. mL^{-1} Al	Ba	Fe	Mn
Before treatment	Z-3	89.700	69.000	170.000	58.000
	Z-4	66.200	62.000	30.000	33.200
	Z-5	10.000	57.000	16.300	40.300
	Z-6	20.000	50.000	107.100	50.400
	Z-7	10.000	56.000	93.600	38.800
	Z-8	20.000	51.000	83.500	51.600
	Z-9	30.000	52.000	107.800	12.100
	Z-10	60.000	47.000	99.600	76.900
	Mean ± SD	38.238 ± 29.837	55.500 ± 7.191	88.488 ± 48.062	45.163 ± 19.054
After treatment	Z-1	130.300	60.000	10.000	0.000
	Z-2	75.400	50.000	10.000	0.000
	Mean ± SD	102.850 ± 38.820	55.000 ± 7.071	10.000 ± 0.00	0.000
WHO 2011		100	700	300	100
IME 2012		100	1000	300	100

IME, WHO, 2011 Iraqi standards for treated wastewater in irrigation (IME, 2012) (ng. mL^{-1}), World Health Organization (ng. mL^{-1}) respectively.

observed at the final lift station (Z-10) because most of the chemical pollutants were discharged from all lift stations and collected at this station. The symbol X in the figure represents the Mean concentrations of the elements.

Micro elements concentration

The results of trace elements analysis are represented in Table 3. The concentration of the Al element ranged between 10.000–130.300 ng. mL^{-1}. The value of Mean and Standard Deviation 38.238 ± 29.837, for lifting stations, and 102.850 ± 38.820 for treatment stations. it was found that the concentration of Al in the treatment station (Z-1) was outside the permissible limits compared to the World Health Organization. And the reason for the appearance of Al in the treatment station (Z-1) is the deposition of some trace elements in the sedimentation basins during prolonged treatment. The concentration of the barium element in the lifting and treatment stations ranged between 47.0–69.0 ng. mL^{-1}, and the value of the Mean and Standard Deviation 55.500 ± 7.191 for lifting stations and 55.000 ± 7.071 for treatment stations. The concentration of iron and manganese elements in the stations under study were between 10.000–170.000 and 0.000–76.900 ng. mL^{-1} and the value of the Mean and Standard Deviation 88.488 ± 48.062 and 45.163 ± 19.054 respectively for lifting stations. The concentration of the barium, iron and manganese concentration were within the permissible limits in all lifting and treatment stations. Fig. 5. shows the concentration of trace elements at the lifting and treatment stations.

The results in Fig. 6. showed the concentration and distribution of some elements (Al, Ba, Fe, Mn). The concentration of Al and Mn elements. It was found

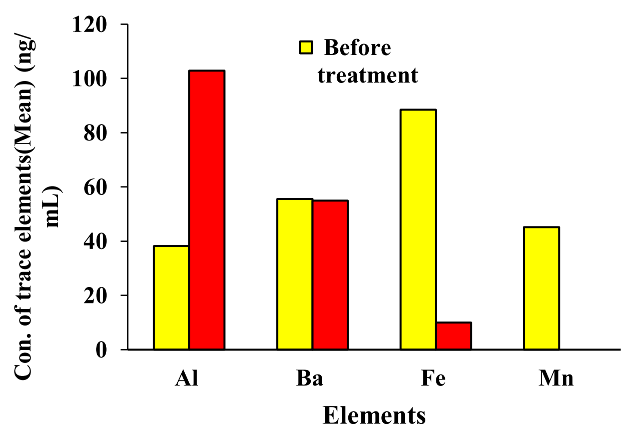

Fig. 5. The concentration of micro elements concentration in the lifting and treatment stations in the range (10–180 ng. mL^{-1}).

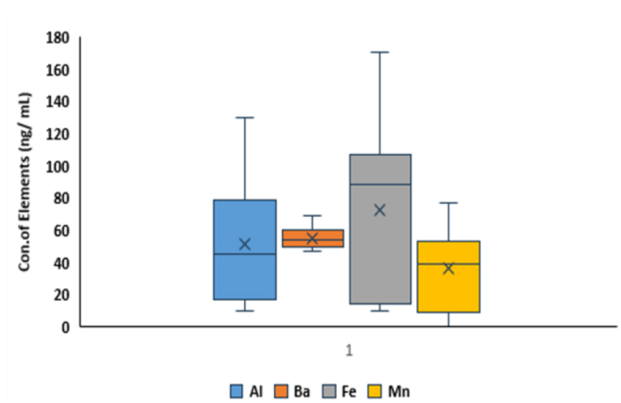

Fig. 6. The concentration of some elements (Al, Ba, Fe and Mn) in the lifting and treatment stations.

that the concentration of the elements is normally distributed and that the concentration of the element is within the middle limit of concentration in most stations. A significant increase in the concentration

Table 4. The concentration of macro elements concentration in the lifting and treatment stations in the range (0.01–500 mg. L^{-1}).

	Station symbol	concentration of trace elements mg. L^{-1}										
		B	P	Cu	Si	Sr	K	Mg	Na	S	Ca	Cl
Before treatment	Z-3	0.531	1.170	0.000	9.280	5.950	45.500	80.100	294.000	368.000	393.600	533.600
	Z-4	0.538	1.870	0.000	11.000	8.480	47.000	79.900	254.000	454.000	540.600	490.800
	Z-5	0.475	2.380	0.000	9.230	5.580	34.200	66.300	210.000	305.000	360.000	398.000
	Z-6	0.588	1.100	0.000	9.890	7.460	42.300	75.000	256.000	394.000	465.000	445.000
	Z-7	0.443	2.210	0.000	9.030	5.970	34.300	63.300	214.000	304.000	369.000	472.000
	Z-8	0.582	1.940	0.0062	9.670	7.040	38.200	72.100	244.000	375.000	444.000	515.400
	Z-9	0.5700	1.310	0.570	8.880	6.810	35.100	74.800	251.000	372.000	438.000	496.800
	Z-10	0.665	2.610	0.0081	26.700	7.500	93.700	89.300	275.000	422.000	425.000	506.900
	Mean± SD	0.549± 0.0693	1.824± 0.574	0.073± 0.201	11.710± 6.094	6.849± 0.977	46.288± 19.242	75.100± 8.242	249.750± 28.146	374.250± 51.831	429.400± 58.169	482.310± 43.456
After treatment	Z-1	0.427	1.820	0.000	8.420	6.080	35.600	76.400	256.000	340.000	372.600	412.600
	Z-2	0.535	1.900	0.000	9.640	6.300	41.500	82.600	286.000	364.000	385.600	495.000
	Mean± SD	0.481± 0.076	1.860± 0.057	0.000	9.030 ± 0.863	6.190 ± 0.156	38.550 ± 4.172	79.500± 4.384	271.000± 21.213	352.000± 16.971	379.100± 9.192	453.800± 58.266
WHO 2011		0.5	10	2	———	———	———	150	200	250	200	250
IME 2012		1.0	———	0.05	———	———	———	———		More than 200	-	More than 200

IQS, WHO, 2011 Iraqi standards for treated wastewater in irrigation (IME, 2012) (mg. L^{-1}), World Health Organization (mg. L^{-1}) respectively.

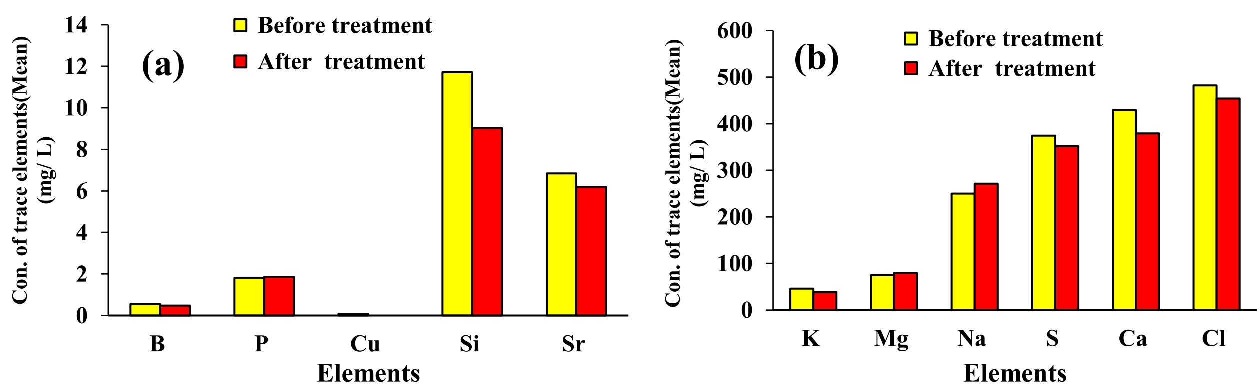

Fig. 7. The concentration of macro elements concentration in the lifting and treatment stations in the range (a) (0–30 mg. L^{-1}) (b) (0–500 mg. L^{-1}).

of the element (Al) was observed at the lift station (Z-1). As for the element Ba that the concentration of the element is within the low limit of concentration in most stations. As for the element Fe that the concentration of the element is within the high limit of concentration in most stations.

Macro elements concentration

The results of trace elements analysis (high concentration) are represented in Table 4. The boron concentration value ranges between 0.427–0.665 mg. L^{-1}, where the value of the Mean and Standard deviation 0.549 ± 0.0693 for lifting stations, and 0.481 ± 0.076 for treatment. The concentration of boron was within the permissible limits in stations (Z-1, Z-5, and Z-7) and outside the permissible limits in the rest of the stations compared to the limits of the World Health Organization. The concentration of phosphorus in the lifting and treatment stations ranged between 1.100–2.610 mg. L^{-1}, and the value of the Mean and Standard deviation for lifting stations were 1.824 ± 0.574 and 1.860 ± 0.057 for treatment stations. The concentration of phosphorus was within the permissible limits in all stations. The results of the rest of the trace elements with a high concentration (Cu, Si, Sr, K, Mg, Na, S, Ca, and Cl) that the copper concentration was within acceptable limits compared to the World Health Organization. As for the rest of the elements (Mg, Na, S, Ca and Cl), the concentration values were higher than the acceptable limits and require further treatment. The reason for the increase in the concentration of some elements is the addition of chemicals in the treatment stages, such as alum, gypsum, and chlorine, to the wastewater, which causes an increase in the concentration of chlorine and sulfur. In addition to the deposition of some

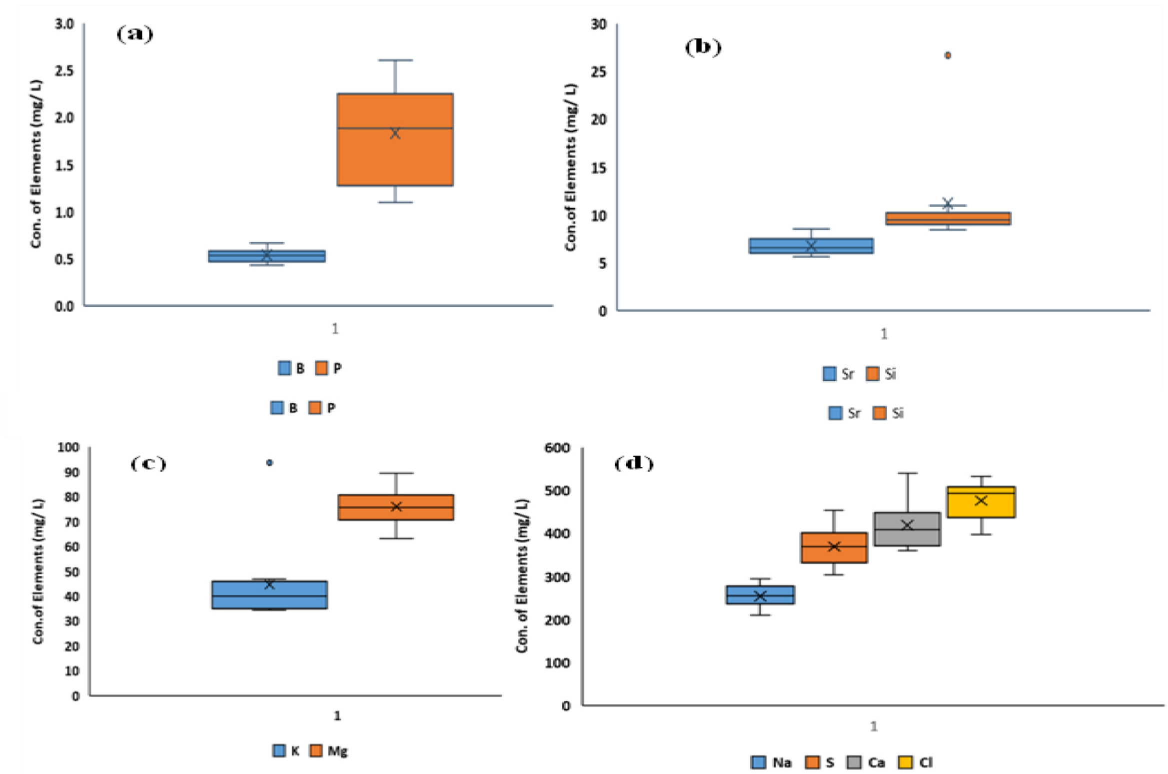

Fig. 8. The concentration of some elements in the lifting and treatment stations (a) Con. of (B, P) (mg. L^{-1}) (b) Con. of (Sr, Si) (mg. L^{-1}) (c) Con. of (K, Mg) (mg. L^{-1}) (d) Con. of (Na, S, Ca, Cl) (mg. L^{-1}).

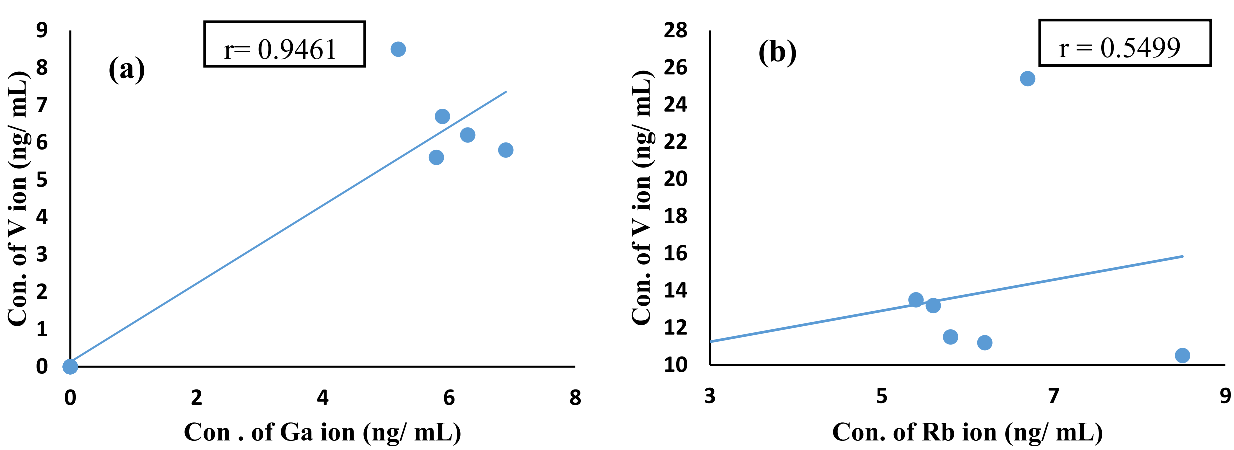

Fig. 9. Correlation coefficient (R) determination coefficient of the Lifting and treatment stations between (a) Con. of Ga ion (ng. mL^{-1}) and Con. of V ion (ng. mL^{-1}) (b) Con. of V ion (ng. mL^{-1}) and Con. of Rb ion (ng. mL^{-1}).

elements inside the final sedimentation tanks in treatment plants during prolonged treatment, this leads to an increase in the concentration of some elements.

The results in Fig. 8, showed the concentration and distribution of some elements (B, P, Sr, Si, K, Mg, Na, S, Ca and Cl). It was found that the concentration of (B, P) is normally distributed and that the concentration of the elements within the low limit of concentration in most lifting stations. As for (Sr, Si and K) elements, it was found that the concentration of the elements is within the middle limit of concentration limits of most lifting stations. And A significant increase in the concentration of the elements (Si and K) was observed at the final lift station (Z-10). As for the (Mg, Na, S, Ca, Cl) elements, the distribution of concentration was within the high limits for most stations.

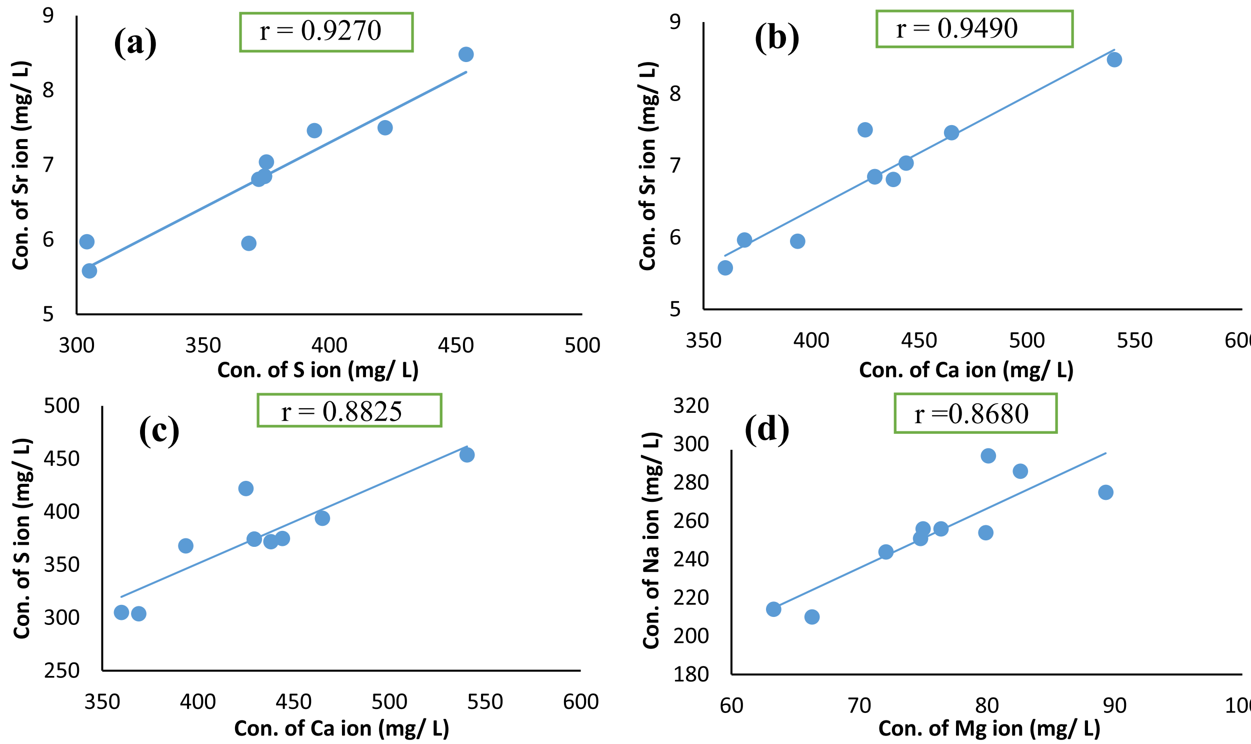

Fig. 10. Correlation coefficient (R) determination coefficient of the Lifting and treatment stations between (a) Con. of S ion (mg. L^{-1}) and Con. of S ion (mg. L^{-1}) (b) Con. of Sr ion (mg. L^{-1}) and Con. of Ca ion (mg. L^{-1}) (c) Con. of S ion (mg. L^{-1}) and Con. of Ca ion (mg. L^{-1}) (d) Con. of Na ion (mg. L^{-1}) and Con. of Mg ion (mg. L^{-1}).

Table 5. Statically data t-test and F-test for Lifting and treatment stations.

Elements	Mean ± SD Before treatment	Mean ± SD After treatment	t-calculated T-test = $\frac{(\bar{X}1+\bar{X}2)}{Spooled\sqrt{\frac{N1+N2}{N1N2}}}$	F-test = $(SD1)^2/(SD2)^2$
Rb	12.863 ± 5.402	8.200 ± 0.424	1.166	162.322
Al	38.238 ± 29.837	102.850 ± 38.820	2.626	1.693
Ba	55.500 ± 7.191	55.000 ± 7.071	0.0880	1.017
B	0.549 ± 0.0693	0.481 ± 0.076	1.214	1.203
P	1.824 ± 0.574	1.860 ± 0.057	0.085	10.07
Si	11.710 ± 6.094	9.030 ± 0.863	0.594	49.864
Sr	6.849 ± 0.977	6.190 ± 0.156	1.00	39.223
K	46.288 ± 19.242	38.550 ± 4.172	0.542	21.272
Mg	75.100 ± 8.242	79.500 ± 4.384	0.707	3.534
Na	249.750 ± 28.146	271.000 ± 21.213	1.00	1.76
S	374.250 ± 51.831	352.000 ± 16.971	0.576	9.327
Ca	429.400 ± 58.169	379.100 ± 9.192	1.166	40.046
Cl	482.310 ± 43.456	453.800 ± 58.266	0.800	1.798

Value t0.05 (N1 + N2 – 2) = (8 + 2 – 2 = 8) = 2.31, F0.05 (8,2) = 19.35, P-value < 0.05 sig. difference, p-value > 0.05 non sig. difference.

Statistical analysis of data

To find out if there are statistically significant differences between the concentration of trace elements in wastewater samples in the pumping stations (before treatment) and the concentration of the same elements in the treatment plants (after treatment) in the city of Karbala, which were estimated using the standard method ICP-MS. T-test and F-test were performed with a confidence limit of 95% as shown in Table 5. The obtained results indicated that there is a significant difference between them. Where the p value of the T test and the F test was p > 0.05 significant difference, the null hypothesis was rejected and we note that there is a difference in the concentrations of trace elements in the wastewater samples in the lifting stations (before treatment) and the concentrations of elements in the treatment plants (after treatment) and that the treatment plants are effective in disposing of

Table 6A. Correlationcoefficient (R) determination coefficient of the Lifting and treatment stations.

	Correlation coefficient R												
	Ag	As	Ga	Li	Mo	Nb	Ni	Pb	Re	Se	V	W	Rb
Ag	1.00												
As	0.38	1.00											
Ga	0.27	0.43	1.00										
Li	0.35	0.99	0.44	1.00									
Mo	0.50	0.89	0.31	0.85	1.00								
Nb	0.50	−0.15	0.42	−0.15	−0.11	1.00							
Ni	−0.21	−0.15	−0.33	−0.15	−0.11	−0.11	1.00						
Pb	0.23	0.16	0.56	0.12	0.32	0.35	−0.32	1.00					
Re	−0.21	−0.15	−0.33	−0.15	−0.11	−0.11	1.000	−0.32	1.00				
Se	0.58	0.47	0.02	0.49	0.34	−0.20	−0.20	−0.28	−0.20	1.00			
V	0.07	0.36	0.82	0.36	0.297	0.20	−0.39	0.84	−0.39	−0.10	1.00		
W	−0.21	−0.15	−0.33	−0.15	−0.11	−0.11	1.00	−0.32	1.00	−0.20	−0.39	1.00	
Rb	0.38	0.90	0.483	0.883	0.918	−0.02	−0.23	0.49	−0.23	0.23	0.549	−0.23	1.00

Table 6B. Correlation coefficient (R) determination coefficient of the lifting and treatment stations.

	Correlation coefficient R							
	Al	Ba	Fe	Mn	B	P	Cu	Si
Al	1.0000							
Ba	0.4384	1.0000						
Fe	−0.1975	0.1329	1.000					
Mn	−0.3581	−0.0586	0.6115	1.000				
B	−0.1964	−0.5427	0.4228	0.5608	1.000			
P	−0.1368	−0.3029	−0.4645	0.1913	−0.0439	1.0000		
Cu	−0.1881	−0.1857	0.2326	−0.3230	0.1803	−0.3536	1.0000	
Si	0.0556	−0.4321	0.1629	0.5941	0.6770	0.5323	−0.1339	1.0000
Sr	−0.0437	−0.2546	0.0412	0.2638	0.6340	−0.0724	0.0418	0.3977
K	0.1622	−0.3306	0.2265	0.6081	0.7060	0.4176	−0.1782	0.9820
Mg	0.5906	−0.1300	0.0850	0.1417	0.6350	−0.0274	−0.0476	0.6420
Na	0.6530	0.0919	0.2894	0.0253	0.4623	−0.3867	−0.0362	0.2857
S	0.2110	−0.1108	0.1368	0.2844	0.7140	−0.1572	0.0225	0.4785
Ca	−0.0852	−0.0513	0.0856	0.1907	0.5170	−0.2670	0.1205	0.1384
Cl	0.0518	0.0086	0.6017	0.3346	0.5748	−0.1947	0.1662	0.2747

Table 6C. Correlation coefficient (R) determination coefficient of the lifting and treatment stations.

	Correlation coefficient R						
	Sr	K	Mg	Na	S	Ca	Cl
Sr	1.0000						
K	0.4390	1.0000					
Mg	0.4735	0.7440	1.0000				
Na	0.2198	0.4353	0.8680	1.0000			
S	0.9270	0.5692	0.7370	0.5409	1.0000		
Ca	0.9490	0.1981	0.3274	0.17 04	0.8825	1.0000	
Cl	0.3346	0.3618	0.4773	0.5932	0.4955	0.3399	1.0000

most of the chemical pollutants, as well as we notice some elements need more treatment processes.

Correlation coefficient (R)

Knowing the correlation between the studied parameters in wastewater stations can facilitate rapid monitoring of the wastewater treatment process. The coefficient of determination (R) was used to determine the strength of the relationship between each two of the studied parameters. Through the results shown in the Table 6(A, B), it was found that the (Ag) has a moderate correlation with Mo, Nb and Se (R = 0.5092, 0.5092, 0.5864) and a weak correlation with all elements. (As) has a very strong correlation with Li and Rb (R = 0.9960, 0.9070) and a strong correlation with Mo (R = 0.8970) and a weak correlation with all elements. (Ga) has a strong correlation with V (R = 0.8210) and a moderate correlation with Pb (R = 0.5674). and a weak correlation with all elements. (Li) has a strong correlation with Mo and Rb (R = 0.8540,0.8830) and a weak correlation with all elements. (Mo) has a very strong correlation with Rb (R = 0.9180) and a weak correlation with Ga, Nb, Ni, Pb, Re, Se, V and W. (Ni) has a perfect correlation with Re and W (R = 1.000,1.000) and a weak correlation with all elements. Pb has a strong correlation with V (R = 0.8430). (Re) has a erfect correlation with W (R = 1.000). (V) has a moderate correlation with Rb (R = 0.5499), Fig. 9 (a) and (b). The correlation coefficient is displayed between the items of the perfect, strong, and very strong correlation type.

Results in Table 6B and C show the correlation coefficient results for trace elements (middle and high concentrations). (Al) was discovered to have a moderate association with Mg and Na (R = 0.5906 and 0.6530). (Fe) has a moderate correlation with Mn and Cl (R = 0.6115, 0.6017). (Mn) has a moderate correlation with B, Si and K (R = 0.5608, 0.5941 and 0.6081). (B) has a moderate correlation with Si, Sr, K, Mg, S, Ca and Cl. (P) has a moderate correlation with Si (R = 0.5323). (Si) has a very strong correlation with K (R = 0.9820). (Sr) has a very strong correlation with S and Ca (R = 0.9270 and 0.9490). (K) has a very strong correlation with Si (R = 0.9820) and a moderate correlation with Mn, B, Mg and S (R = 0.6081, 0.7060, 0.7440 and 0.5692). (Mg) has a strong correlation with Na (R = 0.8680). (Na) has a moderate correlation with Al, S and Cl (R = 0.6530, 0.5409, and 0.5932). (S) has a very strong correlation with Sr (R = 0.9270) and a strong correlation with Ca (R = 0.8825). (Ca) has a very strong correlation with Sr (R = 0.9490) and a strong correlation with S (R = 0.8750), Fig. 10. (a), (b), (c), and (d). The correlation coefficient is displayed between the items of the perfect, strong, and very strong correlation type.

Conclusion

According to the findings of this study, the majority of trace element concentrations of untreated wastewater samples in pumping stations that were examined with using inductively coupled plasma mass technology were higher than the concentrations of the same elements in treated wastewater samples. And the values for some trace elements, such as As, Pb, Al, B, Mg, Na, S, Ca, and Cl, were outside the permissible limits according to Iraqi quality standards 2012, and WHO 2011. The source of these elements from manufacturing, agricultural processes and natural factors. And the correlation coefficient was also evaluated for the elements measured at the stations under study, and there was a perfect correlation for some elements, with correlation coefficient values ranging between 0.996–1.000 for each of elements (Ni, Re, W and As, Li) which indicates that there is a direct proportionality between these elements. As the concentration of one element increases the concentration of the other element increases for the stations under study. Furthermore, although WWTPs are usually successful, they fall short in some areas of treatment for some components, where levels were outside of permitted levels and required additional treatment, therefore treated wastewater cannot be used for irrigation, it can be used in some fields of restricted agriculture.

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Author's declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for republication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at University of Karbala.

Author's contribution statement

M. N. H., A. F. K. and H. J. A. designed the study. The overall number of experiments was determined.by M. N. H. Every experiment was carried out by M. N. H. All of the results were analyzed and discussed primarily by M. N. H. and A. F. K. The paper was written by M. N. H. under direct supervision of A. F. K. and H. J. A.

References

1. Ibrahem S, Hassan M, Ibraheem Q, Arif K. Genotoxic effect of lead and cadmium on workers at wastewater plant in Iraq. J Environ Public Health. 2020;9–20. https://doi.org/10.1155/2020/9171027.

2. Azimi A, Azari A, Rezakazemi M, Ansarpour M. Removal of heavy metals from industrial wastewaters: A review. Chem Bio Eng Rev. 2017;4(1):37–59. https://doi.org/10.1002/cben.201600010.
3. Fu F, Wang Q. Removal of heavy metal ions from wastewaters: A review. J Environ Manage. 2011;92(3):407–418. https://doi.org/10.1016/j.jenvman.2010.11.011.
4. Ursino C, Castro-Muñoz R, Drioli E, Gzara L, Albeirutty MH, Figoli A. Progress of nanocomposite membranes for water treatment. Membranes (Basel). 2018;8(2):1–40. https://doi.org/10.3390/membranes8020018.
5. Yang X, Liu Y, Hu S, Yu F, He Z, Zeng G, *et al.* Construction of Fe3O4@MXene composite nanofiltration membrane for heavy metal ions removal from wastewater. Polym Adv Technol. 2021;32(3):1000–1010. https://doi.org/10.1002/pat.5148.
6. Castro-Muñoz R, Barragán-Huerta BE, Fíla V, Denis PC, Ruby-Figueroa R. Current role of membrane technology: From the treatment of agro-industrial by-products up to the valorization of valuable compounds. Waste Biomass Valorization. 2018;9(4):513–529. https://doi.org/10.1007/s12649-017-0003-1.
7. Bhuyan MM, Okabe H, Hidaka Y, Hara K. Pectin-[(3-acrylamidopropyl) trimethylammonium chloride-co-acrylic acid] hydrogel prepared by gamma radiation and selectively silver (Ag) metal adsorption. J Appl Polym Sci. 2018;135(8):2–9. https://doi.org/10.1002/app.45906.
8. Bhuyan MM, Adala OB, Okabe H, Hidaka Y, Hara K. Selective adsorption of trivalent metal ions from multielement solution by using gamma radiation-induced pectin-acrylamide-(2-Acrylamido-2-methyl-1-propanesulfonic acid) hydrogel. J Environ Chem Eng. 2019;7(1):5–6. https://doi.org/10.1016/j.jece.2018.102844.
9. Journal BS, Ali RJ, Sadee BA. Determination of essential and trace elements in various vegetables using ICP-MS. Baghdad Sci J. 2022;20:715–725. https://doi.org/10.21123/bsj.2022.7253.
10. Youni AM, Darwesh DA. An evaluation of waste and well water quality for agriculture production around erbil city, Iraq. Baghdad Sci J 2023;20:1242-page? https://doi.org/10.21123/bsj.2023.7576.
11. Castro-Muñoz R, Gontarek E, Figoli A. Membranes for toxic- and heavy-metal removal. Current Trends and Future Developments on (Bio-) Membranes. 2019;125–149. https://doi.org/10.1016/B978-0-12-816778-6.00007-2.
12. Heydari Moghaddam M, Nabizadeh R, Dehghani MH, Akbarpour B, Azari A, Yousefi M. Performance investigation of Zeolitic Imidazolate Framework—8 (ZIF-8) in the removal of trichloroethylene from aqueous solutions. Microchem J. 2019;150:104–185. https://doi.org/10.1016/j.microc.2019.104185.
13. Yousefi M, Nabizadeh R, Alimohammadi Mohammadi AA, Mahvi AH. Removal of phosphate from aqueous solutions using granular ferric hydroxide process optimization by response surface methodology. Desalin Water Treat. 2019;158:290–300. https://doi.org/10.5004/dwt.2019.24281.
14. Werkneh AA, Gebru SB. Development of ecological sanitation approaches for integrated recovery of biogas, nutrients and clean water from domestic wastewater. Resour Environ Sustain. 2023;11:1–15. https://doi.org/10.1016/j.resenv.2022.100095.
15. Janjhi FA, Ihsanullah I, Bilal M, Castro-Muñoz R, Boczkaj G, Gallucci F. MXene-based materials for removal of antibiotics and heavy metals from wastewater- a review. Water Resour Ind. 2023;29:1–20. https://doi.org/10.1016/j.wri.2023.100202.
16. Dehghani MH, Kamalian S, Shayeghi M, Yousefi M, Heidarinejad Z, Agarwal S, *et al.* High-performance removal of diazinon pesticide from water using multi-walled carbon nanotubes. Microchem J. 2019;145:486–491. https://doi.org/10.1016/j.microc.2018.10.053.
17. Khan NA, Khan SU, Islam DT, Ahmed S, Farooqi IH, Isa MH, *et al.* Performance evaluation of column-SBR in paper and pulp wastewater treatment: Optimization and bio-kinetics. Desalin Water Treat. 2019;156:204–219. https://doi.org/10.5004/dwt.2019.23775.
18. Shamsollahi HR, Alimohammadi M, Momeni S, Naddafi K, Nabizadeh R, Khorasgani FC, *et al.* Assessment of the health risk induced by accumulated heavy metals from anaerobic digestion of biological sludge of the lettuce. Biol Trace Elem Res. 2019;188(2):514–520. https://doi.org/10.1007/s12011-018-1422-y.
19. Czikkely M, Neubauer E, Fekete I, Ymeri P, Fogarassy C. Review of heavy metal adsorption processes by several organic matters from wastewaters. Water (Switzerland). 2018;10(10):1–15. https://doi.org/10.3390/w10101377.
20. Ihsanullah Abbas A, Al-Amer AM, Laoui T, Al-Marri MJ, Nasser MS, *et al.* Heavy metal removal from aqueous solution by advanced carbon nanotubes: Critical review of adsorption applications. Sep Purif Technol. 2016;157:141–161. https://doi.org/10.1016/j.seppur.2015.11.039.
21. De Santiago-Martín A, Meffe R, Teijón G, Martínez Hernández V, López-Heras I, Alonso Alonso C, *et al.* Pharmaceuticals and trace metals in the surface water used for crop irrigation: Risk to health or natural attenuation? Sci Total Environ. 2020;705:1–15. https://doi.org/10.1016/j.scitotenv.2019.135825.
22. Pillai HPS, Tharayil M. Treatment of heavy metals from water by electro-phytoremediation technique. J Ecol Eng. 2017;18(5):17–26. https://doi.org/10.12911/22998993/76208.
23. Pinter J, Jones BS, Vriens B. Loads and elimination of trace elements in wastewater in the Great Lakes basin. Water Res. 2022;209:1–11. https://doi.org/10.1016/j.watres.2021.117949.
24. Tong S, Li H, Tudi M, Yuan X, Yang L. Comparison of characteristics, water quality and health risk assessment of trace elements in surface water and groundwater in China. Ecotoxicol Environ Saf. 2021;219:112283. https://doi.org/10.1016/j.ecoenv.2021.112283.
25. Long J, Luo K. Elements in surface and well water from the central North China Plain: Enrichment patterns, origins, and health risk assessment. Environ Pollut. 2020;258:113725. https://doi.org/10.1016/j.envpol.2019.113725.
26. Fazaa NA, Dunn JC, Whittingham MJ. Pollution threatens water quality in the central marshes of southern Iraq. Baghdad Sci J. 2021;18:1501–page? https://doi.org/10.21123/bsj.2021.18.4(Suppl.).1501.
27. Hammadi AH, Ramadan AA, Ali AY, Atia AF, Hassan RK, Mahdy ZM. Effect of waste water bacteria and some chemical properties on drinking water in AL-Mada,in treatment plan station. Baghdad Sci J. 2011;8:35–38. https://doi.org/10.21123/bsj.2011.8.1.35-38.
28. Boudias M, Gourgiotis A, Montavon G, Cazala C, Pichon V, Delaunay N. 226Ra and 137Cs determination by inductively coupled plasma mass spectrometry: State of the art and perspectives including sample pretreatment and separation steps. J Environ Radioact. 2022;244:106812. https://doi.org/10.1016/j.jenvrad.2022.106812.
29. Hong YS, Choi JY, Nho EY, Hwang IM, Khan N, Jamila N, *et al.* Determination of macro, micro and trace elements in citrus fruits by inductively coupled plasma–optical emission

spectrometry (ICP- OES), ICP–mass spectrometry and direct mercury analyzer. J Sci Food Agric. 2019;99(4):1–9. https://doi.org/10.1002/jsfa.9382.
30. AL-Nuaimi S A. Study the effects of the polluted waste water on the environment. Baghdad Sci J 2021;3(1):94–100. https://doi.org/10.21123/bsj.2006.681.
31. Mohammed Nawi A, Chin SF, Jamal R. Simultaneous analysis of 25 trace elements in micro volume of human serum by inductively coupled plasma mass spectrometry (ICP-MS). Pract Lab Med 2020;18:2–9. https://doi.org/10.1016/j.plabm.2019.e00142.
32. Michalke B. Review about powerful combinations of advanced and hyphenated sample introduction techniques with inductively coupled plasma-mass spectrometry (ICP-MS) for elucidating trace element species in pathologic conditions on a molecular level. Int J Mol Sci. 2022;23(11):2–22. https://doi.org/10.3390/ijms23116109.
33. Aziz A M, Aws A. Waste water production treatment and use in Iraq country report. In Second Regional Workshop of the Project ‘Safe Use of Wastewater in Agriculture, 2012, p. 16–18.
34. Noor T, Alanisi EMA. Critical assessment of treated wastewater and their reuse for irrigation in Iraq. South Asian Res J Biol Appl Biosci. 2022;12;4(2):50–62. https://doi.org/10.36346/sarjbab.2022.v04i02.003.
35. Herschy RW. Water quality for drinking: WHO guidelines. In: Encyclopedia of Earth Sciences Series. 2012:876–883. https://doi.org/10.1007/978-1-4020-4410-6_184.

تقييم مستويات الملوثات اللاعضوية في المياه الصرف الصحي في محطات الرفع والمعالجة للمجاري في كربلاء، العراق

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الخلاصة

يتضمن البحث دراسة تأثير مياه الصرف الصحي في عشر محطات مختلفة. ثماني محطات رفع ومحطتي معالجة في مركز وناحية الحر في مدينة كربلاء. هدف الدراسة هو تحديد الفعالية التشغيلية لمشروع وحدة المعالجة الرئيسية في كربلاء ووحدة معالجة الحر. وتأثيرها على جودة مياه الصرف الصحي، والكشف عن الخصائص النوعية للمياه العادمة في منطقة الدراسة، والتحكم في مياه الصرف الصحي من محطات المعالجة، والاستفادة من خدمتها في مجالات أخرى. تم فحص أكثر من 70 عنصراً نزراً في هذه الدراسة باستخدام تقنية كتلة البلازما المقترنة حثيًا في عينات مياه الصرف الصحي. تبين أن تراكيز الزرنيخ (As) أعلى من المستويات المسموح بها في بعض المواقع، كما وجد أن تراكيز الرصاص (Pb) أعلى من الحدود المسموح بها في العديد من محطات الرفع. حسب المعايير العراقية ومنظمة الصحة العالمية. وقدمت نتائج التحقيق على عدة مؤشرات وتصنيفات للاستفادة من خروج المياه من محطات المعالجة في عدة أماكن، إذ كشفت المؤشرات أن المياه ملوثة ومالحة وغير صالحة للري الزراعي. وهي مناسبة للمحاصيل التي تتحمل الملوحة العالية وللاستهلاك الحيواني. كما تم تقييم معامل الارتباط للعناصر المقاسة في المحطات محل الدراسة، وكان هناك ارتباط تام لبعض العناصر، حيث تراوحت قيم معامل الارتباط بين (0.996 -1.000) لكل من العناصر (Ni، Re، W، As، Li).

الكلمات المفتاحية: الملوثات الكيميائية، البلازما المقترنة بالحث، المواد السامة, معالجة مياه الصرف الصحي ، جودة المياه.