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Water Quality Index and Life Cycle Assessment of Al-Hashimiyah Water Treatment Plant

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ABSTRACT

Drinking water treatment reduces or eliminates certain health risks and ensures appropriate water quality by removing physical, chemical, and biological pollutants. The treatment process's increased need for energy, chemicals, and technological inputs raises the expense of producing water as well as its secondary environmental effects. The goal of this research is to use the water quality index (WQI) and life cycle assessment (LCA) to determine and assess the environmental effects of the Al-Hashimiyah water treatment plant (WTP) in Babylon City, Iraq. The water quality index was employed as a criterion for categorizing and treating water in accordance with fundamental water characterization variables using a weighted arithmetic index technique. The LCA was supported by the Eco-Indicator 99 database and SimaPro 7.0 software. What makes this study unusual is the identification of two extra functional units related to decontamination, beyond the usual one cubic meter treated water. Samples of treated and raw water were gathered during a 25-month period, from March 2022 to March 2023, and were regularly tested. The results demonstrated that all chemical and physical characteristics (for both raw and processed water) met Iraqi criteria, with the exception of total suspended particles and electrical conductivity. According to LCA studies, certain environmental consequences grow as pollutant concentrations drop. Due to this, a more thorough analysis of the environmental performance of water treatment facilities is now required.

Keywords: water quality index, life cycle assessment, water treatment plant, weighted arithmetic method, eco-indicator.

INTRODUCTION

Water resources are essential for ecosystems and humans alike, but because of problems like industrialization, climate change, inadequate storage, and inadequate treatment of water prior to release, water treatment processes need to be improved qualitatively to reduce risks to public health and ensure sufficient water supplies (Bhatt et al., 2023). High-quality water supply that is free of different contaminants, suitable for use in manufacturing, consumption, and other commercial operations (Garfí et al., 2016; Al-Jumeily et al., 2019; Alnaimi et al., 2020; Farhan et al., 2021; Al-Kariem and ALKizwini, 2022). Because of this, in order to achieve water quality standards, additional energy, chemicals, and technical inputs are required, which will increase the cost of producing water and have a detrimental effect on the environment (WHO, 2023).

The water quality index (WQI) led the categorization of surface waters based on fundamental water characterisation parameters (Sener et al. 2017; Chiu et al., 2023). For a WQI system to show water quality properly, a wide range of water quality measurements are required, however computing these values is time- and money-consuming. As one of the best ways to inform the public and decision-makers about trends in water quality, WQI technology has recently become more and more popular in aquatic environments (Ponsadailakshmi et al. 2018). A water quality index may be used to identify both organic and inorganic pollutants in the water and effectively regulate the quality of the water.

Over the past ten years, life cycle assessment (LCA) has gained increasing popularity as a tool for evaluating environmental performance in the water sector because it offers a standardized platform for analyzing treatment processes using an input-output approach and thereby identifying and measuring the associated environmental impacts (Miri et al., 2014; Loubet et al., 2016a; Pargovino et al., 2019; Al-Saati et al., 2021; Chiu et al., 2023).

In the water industry, life cycle assessment is used to evaluate the environmental performance of wastewater and water treatment systems (Corominas et al., 2013; Bhatt et al., 2023) as well as to do evaluations throughout the course of the whole water usage cycle (Loubet et al., 2016; Ruji et al., 2022). A popular method that makes use of life cycle assessment is the comparison of the environmental effects of various water/wastewater treatment processes (usually advanced versus conventional), technologies, and development scenarios, as well as multi-criteria assessment on issues like costs (Capitanescu et al., 2016) and energy (Vakiliverd et al., 2018).

The majority of life cycle evaluation studies (Friedrich and Buckley, 2002; Igos et al., 2014) solely covered the operating phase of water production; very few examined the building and decommissioning stages of water production facilities (Barrios et al., 2008). In terms of environmental effects, the bulk of life cycle analyses have demonstrated that energy usage, and hence carbon emissions (Amores et al., 2013; Othman et al., 2021), and chemical use are the primary impact generators in the water production business (Lokesh et al., 2020). On the other hand, it is important to note that there is a lot of variance in LCA research on water treatment concerning study design, system limits, included or excluded processes, effect definitions, and interpretation.

Comparing several research projects might therefore be challenging. Few LCA studies in this sector do not concentrate their goals on other critical factors, including raw water quality and pollutant removal efficiency, that are connected to the operational analysis performance of the water treatment facility. Rather, it concentrates nearly solely on the primary output, which is treated water (which is why 1 m^3 of treated water is the most often used functional unit). The purpose of this study is to assess the Al-Hashimiyah water treatment plant's environmental performance using WQI and LCA in light of the aforementioned factors.

METHODOLOGY

Description of the study area

With a surface area of 101 km^2, the Shatt al-Hilla is one of the most notable rivers in Iraq and the primary water supply for the city of A-Hilla (AbdUlameer and Al-Sulttani 2023). The river's principal source, the Euphrates River, runs from the northern boundary of the Babylon Governorate to the Diwaniyah Governorate. Owing to its advantageous position, one of Iraq's principal irrigation systems is the Euphrates River. After flowing through bombs, the Shatt al-Hilla drains into the Euphrates River (Salman et al. 2013; Al-Dalimy and Al-Zubaidi 2023). Shatt Al-Hilla is utilized for drinking and farming. Though it has been neglected lately, it is still regarded as an important draw. The river's steadily rising salinity made the issue worse (Saud et al. 2019). This river serves as a tourist destination in addition to being utilized for municipal, industrial, and agricultural purposes. Water quantities need to be routinely confirmed in order to fulfill the demands of agriculture, municipalities, and industry. In Shatt Al-Hillah, the water levels have dropped due to climate change and a lack of upstream earnings. One of the study locations was the Shatt Al-Hilla station, which is connected to the city of Al-Hashimiyah in the Babil Governorate. The chosen station is located at latitude 32°22'24" and longitude 44°39'87". The research area's geographical makeup is shown in Figure 1.

Al-Hashimiyah water treatment plant was selected as a case during the present inquiry. This strategically significant plant, which has a 6,000 cubic meter per hour production capability, provides 250,000 people and territories in the southern Babil Governorate.

Al-Hashimiyah water treatment plant consist of six units as following:

- Low pumping unit,
- Sedimentation basins,
- Chemical processing unit,
- Filtration unit,
- Water storage unit,
- High pumping unit.

This project would feed large sections and areas of the governorate with water shares, including: Al-Hashimiyah district, Al-Qasim district, Al-Tali'ah district, Al-Shomali district, and the dependencies of these districts.

Figure 1. Al-Hashimiyah water treatment plant overview

Samples collection and preservation

For the Al-Hashimiyah water treatment plant, raw and processed water samples were taken from the Shatt Al-Hilla River in the Al-Hashimiyah Water Town in order to analyze the chemical and physical components and compare them with Iraqi standard criteria. The index was computed using a weighted arithmetic water quality index (Table 1). Water samples were taken every month from March 2021 to March 2023, and fifteen characteristics of both raw and processed water were assessed. These parameters included: biological oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), hydrotimetric (T.H), potential hydrogen (pH), electrical conductivity (EC), temperature, Turbidity, potassium (K), sodium (Na^{+1}), chlorine (Cl^{-1}), magnesium (Mg^{+2}), calcium (Ca^{+2}), sulfate (So_4^{-2}) and alkaline (Alk), then calculating the efficiency of the project based on the mathematical method. Then, the results were analyzed graphically using a statistical analysis program (SPSS).

Table 1. Specifications of studied indicator in current study with Iraqi treated standards (Farhan et al., 2021)

Indicator	Unit	Iraqi standards for water quality
Biological oxygen demand (BOD)	mg/l	<40
Total dissolved solids (TDS)	mg/l	1000
Total suspended solids (TSS)	mg/l	60
Hydrotimetric (T.H)	mg/l	500
Potential hydrogen (pH)	–	6.5–8.5
Electrical conductivity (EC)	μS/cm	1000
Temperature	(°C)	<35
Turbidity	(NTU)	5
Potassium (K)	mg/l	10
Sodium (Na^{+1})	mg/l	200
Chlorine (Cl^{-1})	mg/l	250
Magnesium (Mg^{+2})	mg/l	30
Calcium (Ca^{+2})	mg/l	150
Sulfate (So_4^{-2})	mg/l	250
Alkaline (Alk)	mg/l	200–125

Water quality index calculations

Using a weighted arithmetic index technique, a single water level quality figure is generated from a tremendous quantity of water quality knowledge. Basic water measures were used to classify surface waters, with the water quality index (WQI) serving as a guide. A water quality index system has to contain a lot of different water quality variables, which may be costly and time-consuming to calculate.

The water quality state can be very poor (the index value of between 0 and 25), poor (25–30), medium (50–70), good (70–90), and very good (90–100) (Nada et al., 2016; Patang et al., 2018; Egbueri, 2022; Patel et al., 2023). According to Iraqi water quality standard limits and using the prior equation, the monthly treated WQI was calculated using weighted arithmetic water quality index method (WAWQI).

Weighting variables for various criteria are incorporated into the WQI according to their respective significance in assessing the quality of the water. A more accurate depiction of the importance of each criterion in the whole evaluation is made possible by this weighting. The WQI can provide a more nuanced evaluation by capturing the various influences of different criteria on water quality through the right assignment of weights (Uddin et al., 2022; Alfaleh et al., 2023).

The methodology in calculating WQI using WAWQI method:

- Step 1: Collect data of various physico-chemical water quality parameters.
- Step 2: Calculate proportionality constant k value using formula:

$$k = (1/(1/ \sum_{i=1}^{n} si)) \tag{1}$$

where: si – is standard permissible for n^{th} parameter.

- Step 3: calculate quality rating for n^{th} parameter q_n, where there are n parameters. This is calculated using formula:

$$q_n = 100 \{ (v_n - v_{io})/(s_n - v_{io})\} \tag{2}$$

where: v_n – estimated value of the parameter of the given sampling station, v_{io} – ideal value of nth parameter in pure water, means that pH and dissolved oxygen 7.0 and 14.6 mg/L respectively and 0 for all other parameters (Alfatlawi et al., 2018; Călmuc et al. 2018; Alsultani et al., 2022 a, b), s_n – standard permissible value of the n^{th} parameter.

- Step 4: Calculate unit weight for the n^{th} parameters.

$$W_n = (k/s_n) \tag{3}$$

- Step 5: Calculate water quality index using formula:

$$WQI = ((\Sigma w_n \cdot q_n)/\Sigma\, w_n) \tag{4}$$

The mean efficiency (E%) of Al-Hashimyah water treatment plant was calculated using Equation (5) (Alfatlawi and Alsultani, 2019; Abed Al-Ridah et al., 2020):

$$E\% = \frac{Raw\ water - Treated\ water}{Raw\ water} \cdot 100 \tag{5}$$

Life cycle assessment approaches

All „inputs" are defined as resources consumed, and all „outputs" are defined as emissions and waste produced. This method is called life cycle assessment, and it is systematic and standardized. Furthermore, it characterizes and quantifies the effects on the environment and human health, as well as the depletion of resources linked to the full life cycle of any item or service (ISO 14040, 2006). The life cycle assessment (LCA) technique takes into account four primary input parameters. Define the objective and its requirements – it is the first and most crucial step in LCA research. When establishing the scope, it's common to include a description of the system, its limits, the amount of data used, the original hypothesis, and any current restrictions. The study's objective should guide the selection of the system boundaries (Thair et al., 2018; Alsultani et al., 2023).

The technical data collecting process known as inventory analysis, which is the second stage, verifies that the system's inputs and outputs match the parameters stated in the scope. At this phase, the energy and raw materials utilized, as well as the system's emissions to air, water, land, and solid waste, are calculated for the whole life cycle of the good or service. The primary result of inventory analysis is the inventory table, which lists quantitative environmental inputs and outputs connected to functional units such as kilograms of carbon dioxide, cubic meters of natural gas, kilograms of iron ore, etc. Impact assessment, the third phase, is the process of determining and describing any possible environmental effects that might arise to the system.

Currently, based on the anticipated effects on the environment, the data used for inventory analysis is divided into a number of groups (impact categories). Fourth, comprehension In this last phase of the LCA study, the findings are shown together with an explanation of the main causes of effect and mitigation strategies. Reducing the vast amount of data gathered from extended life cycle assessment research to a manageable number of crucial issues that are helpful for making decisions is the main objective of interpretation. At the moment, the data utilized for stock analysis is separated into many groups (impact categories) according to the anticipated effects on the environment. Fourth, understanding The results of the life cycle research are given in this last phase along with an explanation of the impact's primary sources and mitigation techniques.

The primary objective of interpretation is to condense the enormous volume of data gathered from extended life cycle assessment research into a manageable number of crucial concerns that support decision-making. One of the key benefits of the Eco-Indicator 99 approach is that it makes comparisons between various items rather obvious. The 99 Environmental Index is most commonly weighted using panel approach, equal weighting, and monetization strategies.

SimaPro is one of the greatest tools for getting life cycle inventory data at various levels of modeling and analysis. SimaPro's efficient creation and examination of LCA models provides experts and decision makers with a multitude of analytical choices. One advantage of Eco-Indicator 99 is that, as Figure 2 illustrates, it is integrated into the LCA SimaPro program.

System boundaries and functional unit analysis

The current LCA research allows for a comprehensive analysis of the drinking water system, providing a detailed profile of environmental consequences that can be assessed across many impact categories. The activity structure that was employed in this investigation is shown below.

As the name implies, a functional unit is a quantitative measurement of an item that is evaluated as part of its life cycle. It is defined with reference to the object's function. The majority of research on water systems have historically defined their functional unit as the volume of water (processed, distributed, collected, etc.) in connection with the study's objectives and the system's usage limitations since this technique accurately specifies the product (water). It enables the comparison of various processes or life cycle phases.

It also facilitates the comparison of a water treatment plant's output and environmental performance. One cubic meter of treated water served as the functional unit of the research's reference case. Another potential functional unit is the „capita size" of the people serviced; but, in this instance, it cannot be applied because of contradictory evidence on the intricacy of Iraq's water infrastructure.

We employed a novel method to define the functional unit by emphasizing the Iraqi water treatment plant's environmental performance in addition to providing one cubic meter of water. Any plant's primary objective is to remove contaminants from raw water, thus it's helpful to pinpoint a functional unit that helps it do so, like a contaminant removal unit.

Our method considers both raw and processed water quality in the WQI and LCA definition, with a focus on plant operating performance. Two additional indicators were tested versus conventional treatment (1 m^3 of treated water) in order to examine this viewpoint: kg of suspended particles removed/year and kg of organic matter represented as TOC removal/year. The building and operating stages of the Al-Hashimiyah water treatment plant's life cycle are covered in this research; the decommissioning phase was left out owing to a lack of data.

LCA methedology

This life cycle research aims to assess the six units of the Al-Hashimiyah water treatment plant, which have an hourly treatment capacity of 6,000 cubic meters, and offer recommendations for mitigating the plant's adverse effects. To be more specific, the goals are as follows:

- Determining the primary cause of Al-Hashimiyah water treatment plant's environmental issues,

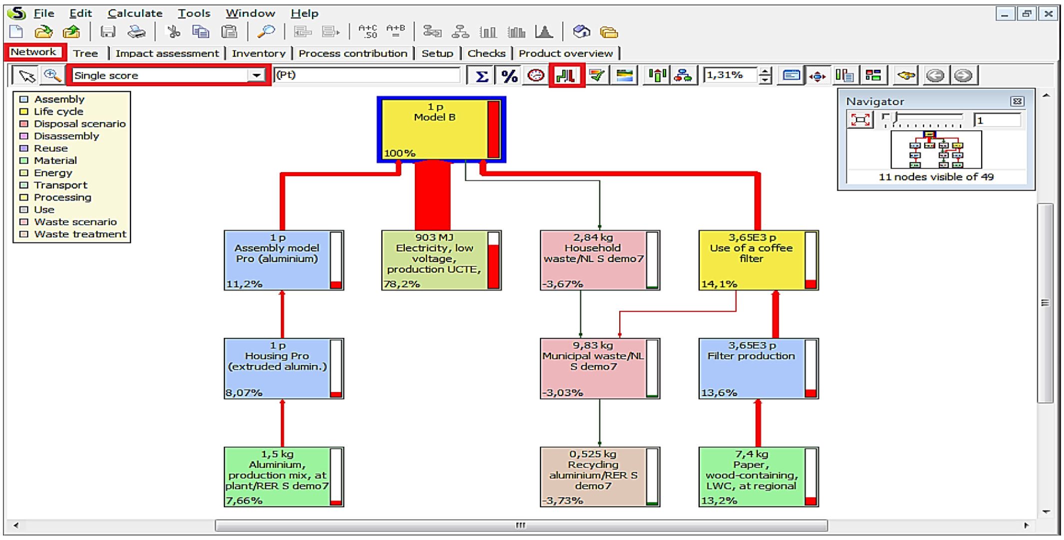

Figure 2. SimaPro with Eco-Indicator 99 decision-makers for LCA model analyzer

- Evaluating the effects on the environment of supplying the energy required for the Al-Hashimiyah processing facility using natural gas vs diesel,
- Compare the advantages of using treated water for agriculture irrigation against the possible environmental costs of releasing treated water into the drinking water system.

The operating stage of a water treatment plant has more influence than the building and end-of-life stages, according to an analysis of the various stages of the facility's life cycle. Thus, the primary focus of this study is on the effects associated with the water treatment plant's operating phase. One of the constraints of the system is the use of treated water for farming.

Inventory analysis

At this point, information about the different processes taking place inside the system limits is gathered and shown. Pumping is one of the many operations in the water treatment plant that are powered by thermal and electrical energy sources. The water treatment facility uses 6.25 MW of power in total to treat water. Burning the gas generated by anaerobic digestion produces 80% of the required energy; the remaining 80% is produced by gas power plants. The main chemical utilized in a water treatment facility is chlorine. In order to eradicate microorganisms, the latter is required. Every day, 4500 kg of chlorine are consumed. It thus has no negative effects on surface water resources. The impacts of releasing treated water into rivers and utilizing it for irrigation were contrasted in order to achieve the study's goals.

Impact assessment

The three main endpoint effect categories identified by the Environmental Index 99 are resource depletion, ecosystem quality, and human health. Figure 3 displays the effect categories and routes that the EI99 strategy addresses. It is important to note that this study's three main effect categories entirely align with those found in the EDI99.

Operational phase

Only a small number of sources mention the building of water treatment facilities, and the majority of life cycle assessment studies of various water systems often concentrate on the operating period. The Al-Hashimiyah factory's two stages are considered in the life cycle inventory: (1) the construction phase, which includes building materials related to the functional unit and land occupation, accounts for the treatment plant's 40-year service life; (2) the operation phase – waste outputs, energy, and material inputs are considered. Transportation of chemicals and materials

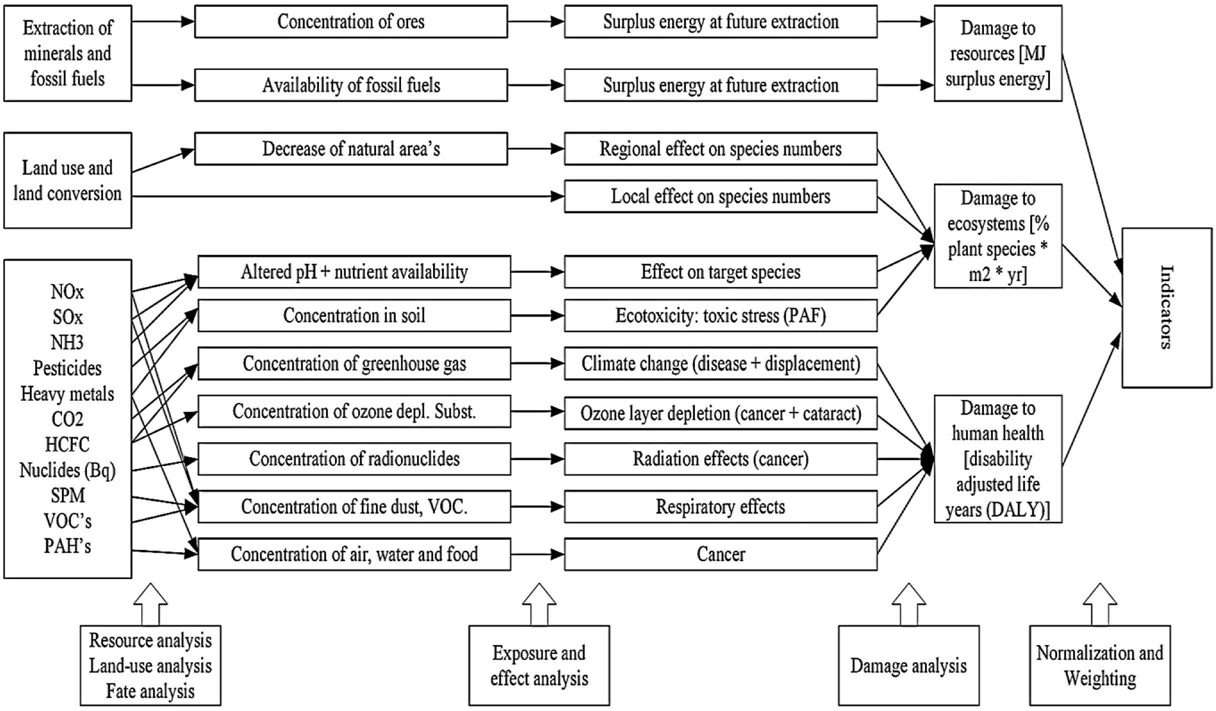

Figure 3. Impact categories and pathways covered by the Eco-Indicator 99 methodology

utilized during the operating time is included in inventory. It is computed with consideration for each material supplier's location. SimaPro software is utilized to create inventory entry models that incorporate pre-defined unit activities from the Eco-Indicator 99 database.

RESULTS AND DISCUSSION

Prior to determining the WQI value for every sample of raw and treated water, statistical analysis was carried out on the relevant parameters. The WHO drinking water standards are shown in Tables 2 and 3, together with the statistical characteristics of the samples that were utilized. The findings show that the average values of BOD, TDS, TSS, T.H., pH, E.C., temperature, turbidity, K, NaCl, Mg, Ca, SO_4, and Alk are higher than the IQS drinking water standard. This is because of the solubility of carbonate sediments and the geological structures, which cause an increase in the concentration of these ions in treated water.

Raw water quality index (RWQI)

Table 2 displays the case study station's raw water quality index values. According to the findings, the Al-Hashimiyah station's raw water quality was (57.07) in March 2021 and (290.28) in October 2021. River quality was (134.83) on average. Based on the values, the river water at the station examined between March 2021 and March 2023 was categorized as either „severely polluted" or „undrinkable" for the research period. of the index of water quality. The Hilla River's low water quality is caused by an untreated home pollution disposal site that is instantly discharged through sewage (Singh 2010). The monthly raw water values (WQI) are shown in Figure 4. For the length of the inquiry, the WQI for the chosen station is displayed in this figure.

Table 2. Calculations of WQI of raw water for Al-Hashimiyah water station

Month	Indicators															Σq_i	WQI
	BOD	TDS	TSS	T.H	pH	EC	Temp.	Turbidity	K	Na	Cl	Mg	Ca	SO_4	Alk		
March 2021	3	912	75	408	7.2	1100	20.5	18	4.5	110	155	45	130	415	128	2063.9	57.07
April 2021	5	908	62	406	7.4	1122	24.2	12.1	4.5	128	127	52	132	438	122	2402.2	110.09
May 2021	4	607	18	350	7.3	1008	25.9	12.2	3.8	85	90	36	84	261	114	1885.6	97.31
June 2021	5	914	159	527	7.8	1403	28.9	3.8	4.2	110	147	45	136	435	112	2514.3	91.76
July 2021	4	950	155	485	7.6	1442	26.5	7.1	4.2	129	155	35	159	459	110	2324.1	142.85
August 2021	6	672	108	411	7.5	1103	25.1	20	3.7	79	107	33	110	324	86	2664.3	149
September 2021	3	682	126	411	7.1	1114	22.7	16.2	3.5	57	101	35	112	339	106	1942.1	232.65
October 2021	5	917	162	485	7.7	1332	20.8	12.5	4.5	160	176	48	122	368	146	2677.3	290.82
November 2021	3	909	185	488	7.4	1352	18.1	12.3	4.9	189	235	45	128	447	162	2311.0	187.55
December 2021	6	905	112	517	7.7	1477	17.5	12.5	4.1	145	255	57	145	431	190	2913.2	135.12
January 2022	2	916	70	476	7.9	1431	16.6	3.5	4.3	106	147	39	126	425	122	1708.3	145.44
February 2022	6	954	64	537	7.9	1481	18.5	7.5	4.8	121	147	39	149	439	120	2635.6	187.33
March 2022	5	932	82	510	7.2	1446	20.9	6.2	4.5	115	145	36	145	428	110	2267.6	227.69
April 2022	7	974	64	528	7.7	1472	23.6	16.2	4.7	130	142	42	156	420	124	3000.0	71.25
May 2022	5	946	60	481	7.8	1486	25.2	20	4.5	123	160	44	118	396	108	2650.2	138.14
June 2022	3	924	149	507	7.8	1403	27.9	31	4.4	149	156	51	119	416	108	2661.7	87.39
July 2022	3	910	172	495	7.7	1442	26.2	35	3.9	125	148	45	109	424	122	2718.9	122.38
August 2022	2	904	86	498	7.3	1422	24.9	15.7	5.1	106	149	53	113	424	120	1934.1	65.6
September 2022	1	901	101	507	7.8	1487	22.5	25	4.4	122	152	48	112	442	122	2035.8	103.46
October 2022	3	866	124	499	7.8	1434	20.1	3	4.8	116	150	49	120	402	120	2013.3	57.53
November 2022	5	834	52	481	7.9	1350	17.4	18.1	3.6	77	144	44	119	375	142	2547.8	216.5
December 2022	3	812	78	454	7.9	1284	16.9	12.2	4.2	135	142	38	120	319	148	2062.1	82.92
January 2023	5	934	80	512	7.8	1485	15.9	2.8	4.4	150	174	47	127	358	156	2370.1	128.8
February 2023	6	1066	88	576	7.6	1669	17.2	7.7	4.8	179	227	46	131	437	172	2759.6	83.92
March 2023	3	1082	88	580	7.8	1687	19.5	6.5	4.2	175	225	52	140	421	170	2199.3	158.26
K	0.14	35.14	3.13	19.15	0.30	54.19	0.84	0.34	0.17	4.64	5.98	1.73	4.97	15.79	5.02		
Wi	0.27	0.04	0.05	0.04	0.04	0.05	0.03	0.07	0.02	0.02	0.02	0.06	0.03	0.04	0.03		
Si	0.5	1000	60	500	7.5	1000	30	5	10	200	250	30	150	400	150		

Table 3. Calculations of WQI of treated water for Al-Hashimiyah water station

Month	Indicators															Σq_i	WQI
	BOD	TDS	TSS	T.H	pH	E.C	Temp.	Turbidity	K	Na	Cl	Mg	Ca	SO_4	Alk		
March 2021	0	914	50	404	7.5	1095	20.6	6.8	4.1	118	166	48	139	410	118	1269.9	38.81
April 2021	0	888	19	398	7.6	1101	23.8	4.9	4	132	138	50	145	418	119	1215.9	74.86
May 2021	0	588	25	348	7.5	992	26.1	2.2	3.1	88	93	35	98	247	110	929.6	66.17
June 2021	0	902	185	527	7.8	1407	28.8	2.9	4	125	154	33	144	433	118	1515.7	62.40
July 2021	0	906	162	481	7.7	1445	26.2	0.7	4.1	133	167	40	160	458	108	1443.4	97.14
August 2021	0	710	24	404	7.8	1102	24.9	4.4	3.7	88	115	34	133	347	86	1106.1	101.32
September 2021	0	714	62	404	7.4	1103	22.6	4.6	3.6	64	132	34	137	365	106	1100.6	158.20
October 2021	0	916	122	481	7.6	1225	20.6	4.2	4.8	180	199	49	130	379	139	1441.3	197.76
November 2021	0	876	83	488	7.4	1330	18.1	4.8	8.9	199	252	44	131	464	154	1434.8	127.53
December 2021	0	888	89	512	7.6	1452	17.2	4.5	4.1	182	265	51	152	462	188	1502.2	91.88
January 2022	0	912	52	472	7.7	1434	16.7	2.9	4.6	113	158	37	148	473	118	1254.0	98.90
February 2022	0	984	18	533	7.6	1477	18.2	0.8	4.8	129	158	40	150	448	118	1179.1	127.38
March 2022	0	892	44	508	7.2	1409	20.5	5	4.5	118	172	38	147	447	114	1198.6	154.83
April 2022	0	964	44	524	7.6	1462	23.5	2.6	4.7	139	164	41	161	469	120	1294.4	48.45
May 2022	0	954	34	474	7.6	1490	25.1	3.8	4.5	126	183	46	137	425	112	1282.3	93.94
June 2022	0	912	105	502	7.8	1407	27.9	17.1	4.4	157	167	52	138	423	106	1733.4	59.43
July 2022	0	916	112	491	7.6	1445	26.1	10	4	129	161	44	132	437	118	1519.5	83.22
August 2022	0	886	49	492	7.5	1420	24.7	4.3	5.1	118	156	52	134	442	120	1304.6	44.61
September 2022	0	886	85	502	7.6	1450	22.6	4.8	4.1	136	160	45	131	459	120	1372.1	70.35
October 2022	0	908	74	491	7.6	1437	20.4	1.2	4.5	129	153	49	131	448	112	1276.1	39.12
November 2022	0	844	10	477	7.6	1347	17.1	4.5	3.6	89	147	47	136	391	138	1174.6	147.22
December 2022	0	800	58	447	7.7	1281	16.8	3.7	4.2	141	161	40	133	388	144	1256.1	56.39
January 2023	0	1064	40	509	7.8	1455	15.7	1.2	4.5	162	193	49	135	389	150	1310.5	87.58
February 2023	0	1068	60	572	7.6	1663	17.6	1.6	8.8	187	239	42	142	484	164	1440.3	57.07
March 2023	0	1108	60	564	7.6	1717	19.3	3	4.2	182	234	49	145	462	168	1453.7	107.62
K	0	35.23	1.66	18.95	0.30	53.68	0.84	0.10	0.17	5.02	6.51	1.71	5.50	16.59	4.92		
Wi	0	0.04	0.03	0.04	0.04	0.05	0.03	0.02	0.02	0.03	0.03	0.06	0.04	0.04	0.03		
Si	0	1000	60	500	7.5	1000	30	5	10	200	250	30	150	400	150		

Treated water quality index (TWQI)

Table 3 displays the monthly WQI values of the treated water for that specific facility during the course of the study. This indicates that the TWQI, or treated water quality index, ranged from 38.81 to 197.76. The monthly measurements WQI of the plotted treated water are displayed in Figure 5.

Furthermore, Tables 2 and 3 demonstrate that all chemical and physical parameter values of the examined water treatment plant are within Iraqi norms, with the exception of total suspended particles and electrical conductivity of raw and processed water.

As seen in Figure 6, the findings indicated that Al-Hashimiyah efficiency is around 32%. Because of the poor raw water quality and low water efficiency (E%), it can be said that the station is comparatively inefficient.

Statistical analysis of raw WQI

Based on the attributes of each factor and the overall average values, standard deviations, and standard error rates for each of them, descriptive statistical raw water data were collected for the Al-Hashimiyah Water Treatment Plant. The outcomes for the months of March 2021 through March 2023 are displayed here. A thorough account of the reality is given in Table 4.

Statistical analysis of treated WQI

The descriptive statistical statistics below display the treated water data for the Al-Hashimiyah Water Treatment Plant for the period of March 2021 to March 2023. The features of each factor, as well as the general averages, standard deviations, and standard error rates for each of them, were used to record this data. A comprehensive

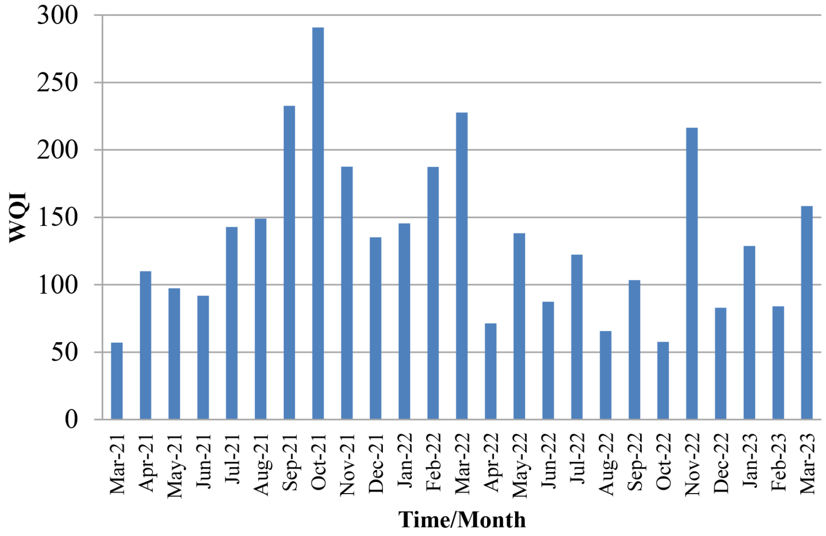

Figure 4. Temporal variation in WQI from March 2021 to March 2023 for raw water

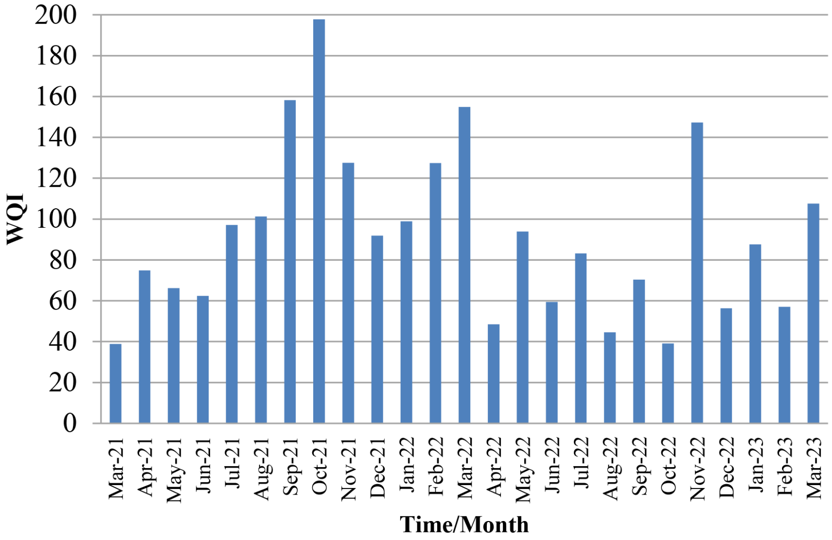

Figure 5. Temporal variation in WQI from March 2021 to March 2023 for treated water

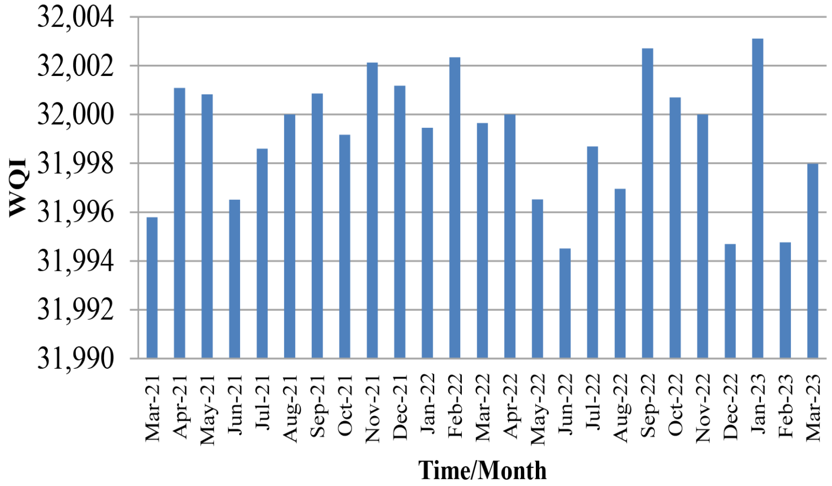

Figure 6. Efficiency comparison of water quality index for Al-Hashimiyah water treatment plant with the selected months

Table 4. Means, standard deviations, and average error of raw water characteristics

The characteristics	N statistic	Mean		Standard deviation
		Statistic	Standard error	
WQI	25	134.8	12.2	60.9
Biological oxygen demand (BOD)	25	4.1	0.3	1.5
Total dissolved solids (TDS)	25	893.2	21.4	107.1
Total suspended solids (TSS)	25	100.8	8.6	43.1
Hydrotimetric (T.H)	25	485.2	10.8	54.0
Potential hydrogen (pH)	25	7.6	0.1	0.3
Electrical conductivity (EC)	25	1377.3	34.2	171.2
Temperature	25	21.7	0.8	3.9
Turbidity	25	13.5	1.7	8.4
Potassium (K)	25	4.3	0.1	0.4
Sodium (Na)	25	124.8	6.4	32.0
Chlorine Cl	25	158.2	8.0	39.9
Magnesium (Mg)	25	44.2	1.3	6.5
Calcium (Ca)	25	126.5	3.3	16.7
Sulfate (So_4)	25	401.7	9.7	48.6
Alkaline (Alk)	25	129.6	4.9	24.8

Table 5. Means, standard deviations, and average error of treated water characteristics

The characteristics	N statistic	Mean		Standard deviation
		Statistic	Standard error	
WQI	25	91.6	8.2	41.4
Biological oxygen demand (BOD)	25	0.0	0.0	0.0
Total dissolved solids (TDS)	25	896.0	22.1	110.9
Total suspended solids (TSS)	25	66.6	8.7	43.7
Hydrotimetric (T.H)	25	480.2	10.7	53.7
Potential hydrogen (pH)	25	7.6	0.02	0.1
Electrical conductivity (EC)	25	1365.8	35.4	177.0
Temperature	25	21.6	0.7	3.9
Turbidity	25	4.2	0.6	3.3
Potassium (K)	25	4.5	0.2	1.3
Sodium (Na)	25	134.5	6.7	33.9
Chlorine Cl	25	171.4	8.1	40.5
Magnesium (Mg)	25	43.5	1.2	6.0
Calcium (Ca)	25	138.7	2.4	12.2
Sulfate (So_4)	25	422.7	10.3	51.5
Alkaline (Alk)	25	126.7	4.6	23.2

summary of the fact is given in Table 5. Lastly, the study's authors advise monitoring freshwater quality with sensor devices. Potential sensing technologies include electromagnetic sensors and microwaves (Omer et al. 2021; Ryecroft et al. 2021). Monitoring emissions from surrounding enterprises was also recommended due to their direct influence on the quality of surface water. Cement manufacturers, for instance, are the source of emissions that contribute to various pollution problems, such as carbon dioxide (Shubbar et al. 2020b) and fine particulate matter (Kazim et al. 2020a; Al 2021).

The abundance of evaporative deposits seen on the plain's surface and in the aquifers' varying depths in this region may be the cause of the rise in EC values and the higher mean value than the IQS specifications. The operations of the industrial units in this area may also account for the elevated concentration of the heavy metal chromium. The study's samples were drawn from both urban and rural locations, and they were also in close proximity to several industrial and agricultural facilities, thus variations in BOD and other water quality indices were possible. Given that the mean pH values fall within the acceptable range as established by the IQS and the mean values of the other parameters fall below the acceptable limit, it is possible to classify more than half of the samples as having appropriate water quality.

Life cycle assessment results

The impact of one cubic meter of treated water is depicted in the overall environmental profile (Figure 7), which was created during the life cycle impact assessment's characterisation stage.

According to this profile, chemical consumption and chemical transportation are the two main drivers of the facility's effect, with energy consumption and plant construction and operation accounting for the remaining small shares across all impact categories. Figure 7 indicate that the water treatment plant in Al-Hashimiyah has a notable environmental impact, mostly due to water productivity and energy consumption. In this sense, the energy mix's composition has a significant impact on the Al-Hashimiyah Water Treatment Plant's environmental state. The ecological performance of this plant is mostly comparable to other research in the literature (Ahmadi et al., 2016; Ortíz Rodriguez et al., 2016; Salahaldain et al., 2023) in terms of overall structure and morphological contributors, despite the fact that a thorough comparison is nearly impossible owing to important factors. distinctions in the definitions of systems. The building phase's overall influence on the total impact profile is minimal.

Construction only slightly affects the metal attrition category (about 30%, which is negligible in a traditional file), as Figure 7 illustrates. In contrast to earlier studies (Igos et al., 2014), the building phase had less of an impact in our situation. Nevertheless, this comparison is once more overly general because it depends on data from several systems.

It is crucial to remember that choosing and putting into practice treatment plans should be done in conjunction with professionals, keeping in mind the unique features of the research field, the resources at hand, and any applicable laws. Furthermore, community involvement and public knowledge are essential to the success of any restoration work because they may encourage wise water usage and support the long-term sustainability of water supplies.

CONCLUSIONS

The following conclusions are provided in light of the findings:

1. Al-Hashimiyah station's raw water quality ranged from 57.07 to 290.2) and treated water quality index ranged from 38.81 to 197.76. Based on these values, the river water at the station was categorized as either "severely polluted" or "undrinkable" for the research period. of the index of water quality.
2. The primary sources of the impact, which result in effects in water-related impact categories (eutrophication and ecotoxicity), are chemical and energy consumption.
3. Although it is limited to performing a life cycle analysis on average monthly data reported for

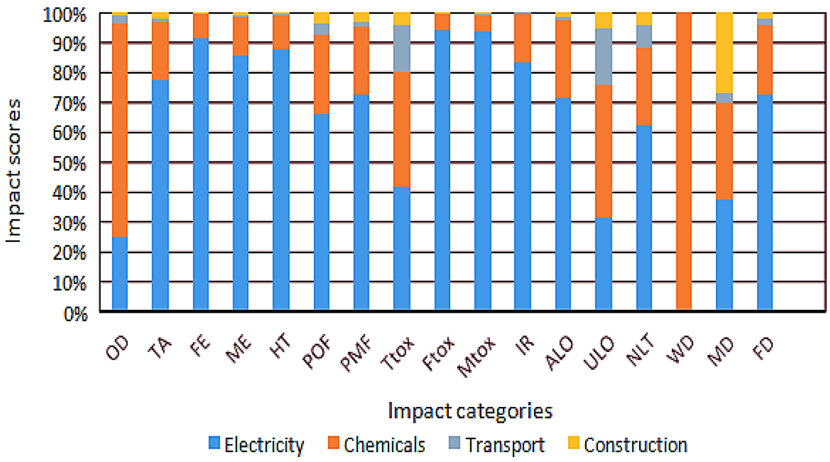

Figure 7. General environmental impact of Al-Hashimiyah WTP (characterization)

the initial and final concentration values of the pollutants under consideration (which involves high fluctuations in the derived impacts), this study allowed an accurate calculation of the environmental impacts resulting from the removal of specific pollutants from raw water.

4. Using natural gas instead of diesel has a substantial positive influence on the environment at the Al-Hashimiya water treatment plant (energy consumption is decreased to one-third of its former level, for example).
5. Releasing treated water into a water treatment facility poses a risk to public health. Cooking is one of the many domestic chores it may be used for, as the fire's strong heat eliminates any lingering bacteria, parasites, and other impurities. However, it shouldn't be ingested because of its high impurity level. in relation to human health.
6. In South Hilla, using treated water for agriculture irrigation is seen as a more ecologically benign method, particularly when taking eutrophication (4% of the "discharge to surface water" option) into account.
7. The Hashemite water treatment plant's water quality index varied from satisfactory to unsuitable for drinking water, according to the mathematical approach.
8. There exists a robust correlation between water quality and chemical and physical markers.

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