Mesopotamia Journal of Agriculture

https://magrj.uomosul.edu.iq/

EVALUATION OF MOSUL INFLOW'S WASTEWATER QUALITY FOR IRRIGATION

Mohammed A. Altaee [1,2], **Abd Al-kader A. Alhadede** [1], **Waheeda A. Ahmad Al-badrani** [1]
Department of Soil Science and Water Resources, College of Agriculture and Forestry, University of Mosul, Iraq 1
College of Agriculture, University of Telafer, Iraq 2

Article information
Article history:
Received: 10/6/2024
Accepted: 16/2/2025
Published: 31/3/2025

Keywords:
Inflow, lead, limits, nickel, wastewater.

DOI:
10.33899/mja.2025.150808.1470

Correspondence Email:
mohammed.a.abdullah@uotelafer.edu.iq

ABSTRACT

Wastewater is industrial, and agricultural liquid wastes that contain biodegradable materials, as well as non-biodegradable materials and compounds., such as pesticides, and plastic. 80% of non-treatment wastewater globally is used to irrigate crops which leads to the accumulation of salts, compounds, and heavy metals in the soil and crops, which causes soil deterioration and problems in plant growth and may be transmitted to humans through the food chain. Nine sites were chosen for wastewater from Mosul inflow. Samples were collected monthly for each sites between March 2022 to February 2023. The results indicated that the concertation of lead, zinc, copper, nickel, and cobalt ranged (0.179 -1.533), (1.55 -2.69), (Nill-0.442), (0.201 -0.695) and (0.021-0.081) respectively, most sites exceeded the Iraqi standard for irrigation. The value of total solids (TDS), nitrates, phosphates, and sulfates ranged between (493 -845), (3.6-10.3), (2.3-6.2) and (162-350) respectively, all sites were within global and Iraqi standard limits for irrigation. Al-Danville inflow was the most polluted sites with lead and nickel because they collect industrial wastewater. Wastewater in all sites is considered very hard and can lead to deposits, blockage of pipes, and damage to irrigation systems. We recommend not using wastewater for irrigation in all sites Because it contains high concentrations of heavy elements and most of the characteristics exceeded the international and Iraqi standards of irrigation and this causes soil deterioration and pollution and poses health and environmental risks.

INTRODUCTION

Water is an essential natural resource for living organisms and humans. The global use of fresh water has increased sixfold compared to the past hundred years, and with this increase, there are significant challenges affecting water quality due to industrialization processes, agricultural production, and urban life (Xu *et al*., 2022). Many farmers suffer from a lack of irrigation water to meet the needs of crops, and the provision of water to them is insufficient unless its quality is high, as poor-quality water hurts the physical and chemical composition of the soil and the quantity and quality of crops (Mahmoud *et al*., 2021). Wastewater is the term used for domestic, industrial, and agricultural liquid wastes that contain organic and mineral materials, acids, and biodegradable salts, in addition to non-biodegradable materials and compounds such as heavy metals, pesticides, and plastic (Ahmed *et al*., 2021).

An estimated 80% of wastewater globally, especially in poor countries, is used to irrigate crops without prior treatment, especially with the scarcity of water resources (Lin *et al*., 2022). Therefore, without appropriate treatment and management strategies, the use of poor-quality wastewater in irrigating agricultural lands leads to the accumulation of salts, compounds, and heavy metals in the soil and crops, which causes soil deterioration and problems in plant growth and productivity or may be transmitted to humans through the food chain through plant and animal products, thus causing multiple health risks International organizations and countries set standard specifications or critical concentrations for metals in irrigation water to evaluate their risks to soil, plants, and ecosystems, which is the maximum concentration of the metal in water with no long-term harmful effects on living organisms and the ecosystem **(**Koptsik and Koptsik, 2022; Al-Taee *et al*., 2024). In 2012, Iraq issued Law No. 3, which refers to the standard specifications or national determinants for using treated wastewater in agricultural irrigation. It aims to prevent the use of wastewater in a way that leads to harm to public health, surface and groundwater resources, or damage or pollution to the soil that affects its production capacity or the food chain by setting standards to achieve safe levels of using wastewater for agricultural irrigation. Studies conducted by (Al-Shanona *et al*., 2020; and Ansam *et al*., 2022) indicated high concentrations of heavy elements and some pollutants in the wastewater water of the city of Mosul. This research aims to evaluate the quality of wastewater for irrigation in the city of Mosul and compare it with Iraqi and international standard specifications, especially since most of it is used for the irrigation of crops at several sites in the city of Mosul.

MATERIALS AND METHODS

Study site

Nine sites were chosen for wastewater collection from Mosul inflow. These are inflow in which urban, agricultural, and industrial waste from several neighborhoods and villages of the city of Mosul is collected. They are distributed on both sides of the Tigris River and flow into it, as shown in Figure (1).

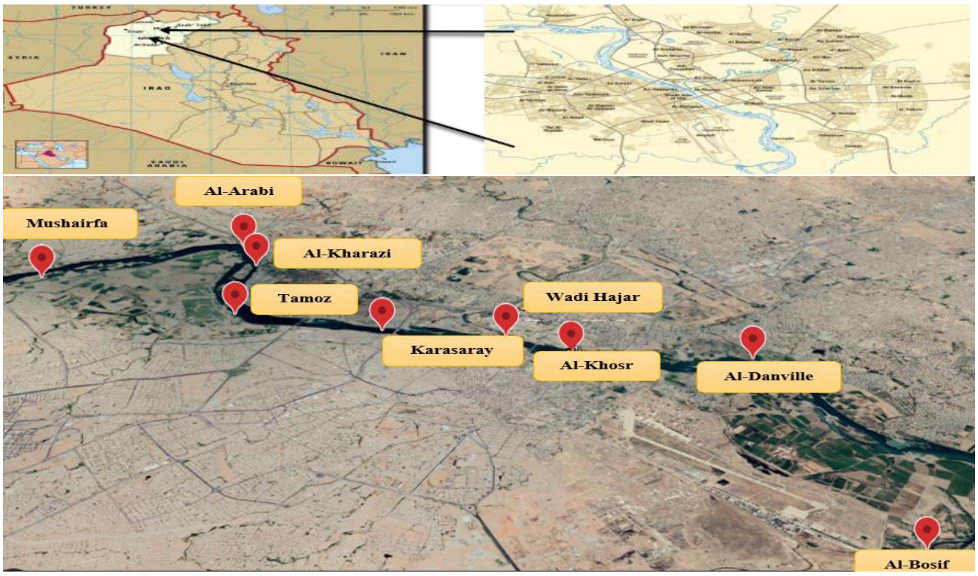

Figure (1): Samples sites on the map

Water Sample Collection and Preparation

Samples were collected monthly with five replicates for each of the study sites for a full year, for the period between March 2022 to February 2023. They were collected using tightly sealed plastic bottles that were washed with sample water and then filled with it. Inflow water was taken from the end of its inflow before it reached the Tigris River. All samples were filtered using filter paper, and drops of nitric acid were added to the samples in which heavy elements were estimated to prevent their precipitation. The samples were kept in the refrigerator at a temperature of 4 C° until the required analysis was performed according to (APHA, 2017).

Field and Laboratory Analyzes of Water

The total dissolved solids (TDS) were measured using portable field devices. Laboratory analyses of water were conducted in the laboratories of the Department of Soil Sciences and Water Resources and the Central Laboratory of the College of Agriculture and Forestry at the University of Mosul, according to (APHA, 2017).

Chlorides were determined by stripping with silver nitrate $AgNO_3$ (0.005) molar and using the potassium chromate $K_2Cr_2O_7$. Sulfate was determined by precipitation with barium chloride ($BaCl_2$) in an acidic medium to form turbidity resulting from barium sulfate. The intensity of the turbidity was measured with a spectrophotometer at a wavelength of 492 nanometers. Nitrates were determined using a spectrophotometer at a wavelength of 206 nanometers. This was done by taking (10) ml of the sample, adding (2) ml of HCl (1)N acid, and reading the absorbance using a spectrophotometer at a wavelength of (206) nanometers. Phosphate ions were estimated by taking 50 ml of the sample and adding 2 ml of ammonium molybdate $(NH_4)_2MoO_4$ and drops of tin rose chloride ($SnCl_4$) until a blue-colored compound was formed, and then measuring the colour absorbance intensity using a spectrophotometer at a wavelength of 690 nm. The total hardness of the water samples was estimated by adding the buffer solution, ammonium chloride NH_4Cl to sample, until the degree of reaction reached (pH = 10), then lubricating with EDTA-containing drops from the E.B.T. guide until the colour of the solution changed from violet to blue and estimations of heavy metals (copper, Cu, zinc, Zn, lead, Pb, cobalt, nickel, Ni) were determined using the atomic absorption device of the laboratory of the College of Agriculture and Forestry at the University of Mosul.

Statistical analysis

The statistical analysis was carried out using the SAS program and a randomized complete block design (RCBD) at a significance level of 0.05 utilizing Duncan test by (Elliott and Woodward, 2023).

Table (1): Global and Iraqi standards for irrigation water quality

Parameter (mg/L)	TDS	NO_3^-	PO_4^{-3}	$SO_4^=$	Cl^-	Cu	Zn	Pb	Co	Ni
*Global standards	2000	45	-	920	100	0.2	2.0	0.1	0.05	0.2
◊Iraqi standards	2500	50	25	-	0.5	0.2	2.0	0.1	0.05	0.2

* FAO limits (Ayers and Westcot,1985) ,◊ Iraqi limit (Law No3 ,2012)

RESULTS AND DISCUSSION

(TDS) Total Dissolved Solids

The values of total dissolved solids for wastewater in the inflow indicated in Table (2) showed significant differences between the inflow sites. The lowest value was in Wadi Hajar Inflow (515 mg/L), and the highest value was in Al-Bosif Inflow (773 mg/L). The discrepancy between values is due to the quantity and nature of the pollutants loaded into inflow and the living nature of the population on both sides of the river. The inflow water contains different quantities of dissolved and suspended mineral materials, microorganisms, and organic materials. Inorganic, soluble, and insoluble substances, such as carbohydrates, sugars, proteins, fats, salts, detergents, and soluble acids, affect their chemical and physical properties (Abbass, 2010; Asthana, 2017). The effect of seasons was significant. The lowest average was in winter with a value of 561 mg/L, while the highest average was in autumn with a value of 618 mg/L. As for the effect of interaction between sites and seasons, the results indicates that there were also significant differences, and the lowest value was in Al-Arabi Inflow in winter. It reached 493 mg/L, and the highest value in the Al-Bosif Inflow in summer was 845 mg/L.Total dissolved solids (TDS) values of the inflow water are suitable for irrigation according to Iraqi and international standards.

Table (2): Seasonal average of total dissolved solids (TDS) in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	576 j	691 e	627 g	563 l	614 c
2	Al-Arabi	493 s	499 r	582 i	544 m	530 f
3	Al-Kharazi	515 q	507 q	530 o	546 m	525 f
4	Tamoz	550 m	582 i	563 l	594 i	573 e
5	Karasaray	570 k	544 m	646 f	621 g	595 d
6	Al-Khosar	576 j	589 i	614 h	672 e	613 c
7	Wadi Hajar	499 r	509 q	520 p	533 n	515 g
8	Al-Danville	595 i	653 f	621 g	710 d	645 b
9	Al-Bosif	672 e	794 b	845 a	781 c	773 a
means		561 c	596 b	616 a	618 a	

Nitrates (NO_3^-)

Nitrate is a form of nitrogen and is found in terrestrial and aquatic ecosystems. It is one of the primary plant nutrients, but when present in high concentrations, it can cause significant problems with water quality. Nitrate and phosphorus encourage increased growth of aquatic plants and changes in the types of marine plants and animals. This, in turn, reduces dissolved oxygen and the degree of temperature. (Coronel *et al*., 2008). The results in Table (3) indicate a significant effect of sites on the concentration of nitrates in the inflow water. The lowest value was in Al-Arabi Inflow, and the highest was in Al-Khosar Inflow, with concentrations of (4.5) mg/L and (8.2) mg/L, respectively. This is because Al-Khosar Inflow is one of the large inflows and passes through many villages and agricultural areas before entering the city of Mosul. Agricultural and animal waste, fertilizer waste, and organic materials are drained into it. In addition, the organic materials resulting from the waste in residential neighborhood's release nitrate ions, when decomposed by microorganisms, lead to an increase in nitrate concentrations Zhai *et al*. (2021) indicated that water contaminated with nitrate results from throwing agricultural and animal waste into it because nitrate is included in the composition of chemical and organic fertilizers and is widely used in soils, so it reaches water through surface runoff, soil erosion, and agricultural lands.

Table (3): Seasonal average of nitrates (NO_3^-) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	4.5 s	4.5 s	4.9 q	4.7s	4.7 g
2	Al-Arabi	5.1q	4.9q	4.2t	3.9u	4.5 h
3	Al-Kharazi	6.8 g	6.5 h	5.4 n	6.3 i	6.3 c
4	Tamoz	5.6m	5.2o	4.0t	3.6v	4.6 g
5	Karasaray	6.7 h	5.8 l	4.9 q	3.9 u	5.3 f
6	Al-Khosar	10.3 a	8.9b	7.4c	6.2 j	8.2 a
7	Wadi Hajar	6.0k	6.9f	5.2o	5.6m	5.9 e
8	Al-Danville	7.3 e	6.5 h	5.2 o	5.4 n	6.1 d
9	Al-Bosif	7.6 c	7.5 c	7.1 e	6.3 i	7.1 b
means		6.7 a	6.3 b	5.4 c	5.1 d	

More than 50% of water pollution with nitrates in streams, rivers, and groundwater is due to agricultural operations through the use of pesticides and fertilizers that seep into water bodies. The seasons significantly affect the average concentration of nitrates in the water. The lowest value was in the autumn season, while the highest value was in the winter season, with an average concentration of (5.1) mg/L and (6.7) mg/L, respectively. Also, the interaction between sites and seasons had a significant impact on the nitrate concentration, and it was the lowest concentration in Tamoz Inflow during the autumn season and the highest concentration in Al-Khosar inflow during the winter season, with a concentration value of (3.6) mg/L and (10.3) mg/L, respectively.

The results were higher than the average nitrate concentrations that I found (Ramadhan, 2018) for Al-Khosar Inflow, which amounted to 6.03 mg/According to the international specifications mentioned in Table (1), the inflow water is considered suitable for crop irrigation, and despite this, the Environmental Protection Agency (EPA) (2012) stated that the normal level of nitrate in surface water should be less than 1 mg/L.

Phosphate (PO_4^{-3})

Phosphorus is one of the basic nutrients for plants and aquatic organisms. It is involved in the synthesis of DNA and cell membranes and participates in energy transfer processes. It is also an essential metal in the occurrence of the phenomenon of eutrophication in water, which is one of the complex pollution problems (Stackpoole *et al*., 2019).

The statistical analysis results in Table (4) indicated that the seasonal average concentration of phosphate in the inflow water showed significant differences between the sites. The lowest value was in the Al-Bosif Inflow, with a concentration of (2.8) mg/L; the highest was in the Al-Bosif Inflow, with a concentration of (5.8) mg/L. As for the effect of the seasons, significant differences were also recorded between the averages. The lowest value was in the winter and autumn seasons, with a concentration of (4.1) mg/L, and the highest value was in summer, with a concentration of (4.4) mg/L. The reason for this disparity may be due to several factors, including the quantity and quality of liquid wastes thrown into the inflow water, whether domestic, industrial, or agricultural; the influence of microorganisms that decompose organic compounds; the size of the plants spread on both sides of the inflow, which absorb phosphorus as it is an essential metal for plant life; and the size of ion exchange reactions such as adsorption and precipitation of phosphorus. Quantity of sediments, such as clay, organic materials, and calcium carbonate, reach the inflow through soil erosion by rainwater in winter and spring. Rain also washes away agricultural soil waste fertilized with mineral and organic phosphates, which works to raise the concentration of phosphate dissolved in water during spring and winter seasons. Ruzhitskaya and Gogina (2017) indicated that 30–50% of the phosphorus in wastewater comes from residential neighborhood waste as a result of the widespread use of detergents and washing materials, in which phosphorus constitutes 50–70% of their composition, in addition to containing soluble organic compounds. As for agricultural waste, it leads to phosphorus contamination of wastewater as a result of the extensive use of mineral and organic phosphate fertilizers, as well as the dumping of animal waste rich in phosphorus. As for the effect of the interaction between sites and seasons, the results indicated the presence of significant differences, and the lowest was in Al-Kharazi Inflow during spring season, with a concentration of (2.3) mg/L, and the highest value was in Al-Bosif Inflow during spring season, at a concentration of (6.2) mg/L.

Table (4): Seasonal average of Phosphate (PO_4^{-3}) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	3.3 p	3.4 o	3.6 n	3.9 l	3.6 f
2	Al-Arabi	2.8 r	2.4 t	3.5 o	2.6 s	2.8 g
3	Al-Kharazi	3.1 q	2.3 u	3.3 p	2.9 r	2.9 g
4	Tamoz	4.0 k	4.5 j	3.8 m	4.8 h	4.3 d
5	Karasaray	3.7 n	4.0 k	3.5 o	3.7 n	3.7 e
6	Al-Khosar	4.9 h	5.3 f	5.7 d	5.2 f	5.3 c
7	Wadi Hajar	3.8 l	4.7 i	5.0 f	3.5 o	4.3 d
8	Al-Danville	5.9 c	5.4 e	5.8 c	4.9 h	5.5 b
9	Al-Bosif	5.3 f	6.2 a	5.8 c	6.0 b	5.8 a
Means		4.1 c	4.2 b	4.4 a	4.1 c	

Total Hardness

Table (5) shows the seasonal average of total hardness in the inflow' water, which indicates a significant effect of the inflow' sites. The lowest value was in the Al-Arabi and Tamoz inflow, at 530 mg/L, and the highest value was in the Al-Khosar Inflow, at 788 mg/L. This disparity in total hardness values between inflow may be attributed to the nature and quantity of pollutants loaded in the inflow, the role of microorganisms in decomposing organic materials and releasing CO2 gas, which forms carbonic acid, and the role of some mineral and organic acids that work to dissolve calcium salts, especially lime, which work to raise The concentration of calcium in the water, as well as the geological nature of the soil near the inflow (Shelor and Dasgupta, 2017), The average values of total hardness in the seasons had a significant effect between the averages, and autumn season had the lowest value, while the highest value was in spring season with a value of (545 mg/L) and (647 mg/L), respectively. Regarding the interaction between sites and seasons, the results indicated a significant effect. The lowest value was for Tamoz Inflow in autumn, and the highest value was in Al-Khosar Inflow during winter, at 410 mg/L and 960 mg/L, respectively.

Table (5): Seasonal average of total hardness in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	520 r	590 k	517 s	500 u	532 f
2	Al-Arabi	550o	534p	520r	516s	530 f
3	Al-Kharazi	576m	558n	531p	526qr	548 e
4	Tamoz	601j	598j	510t	410w	530 f
5	Karasaray	579l	601j	522r	480v	546 e
6	Al-Khosar	960a	811b	700 e	673f	788 a
7	Wadi Hajar	633h	628h	550o	601j	603 d
8	Al-Danville	718d	700e	649g	612i	670 c
9	Al-Bosif	793c	806b	613i	589k	700 b
means		659 b	647 a	569 c	545 d	

The inflow water in all sites is considered very hard according to the classification of Todd (1980), and this is the result of the dissolution of carbonate and sulfide minerals that form part of the prevailing soil components in the region This is consistent with (Alzubaidy and Al Azzo ,2022) Those who explained the cause of hardness to the dissolution of evaporated minerals such as gypsum and anhydrite and carbonaceous minerals such as calcite, aragonite and dolomite. Wastewater in all sites is not suitable for irrigating crops, and Schiavon and Moore (2021) indicated that the total hardness of irrigation water exceeding 300 mg/L can lead to deposits, blockage of pipes, and damage to irrigation systems. The results are consistent with what Ibrahim, (2024) obtained, who found that all inflow were very hard except for Mushairfa inflow.

Sulfates ($SO_4^{=}$)

The seasonal average of sulfate concentration in the inflow water shown in Table (6) shows that there were significant differences between the sites. The lowest value was in Wadi Hajar Inflow, with a concentration of 176 mg/L; the highest was in Karasaray Inflow, with a concentration of 242 mg/L. This difference between the inflow sites is because the domestic, industrial, and agricultural wastes that are thrown into the inflow water that contains high and varying percentages of sulfates, such as cleaning and cosmetic powders, textile and tanning factories, vehicle batteries, fertilizers, and medicines, as well as the soil minerals that make up the region, which contain high concentrations of sulfur, and sulfates may be present in the atmosphere. As a result of the combustion of fuel and the decomposition of some organic materials to form diluted sulfuric acid, which reaches surface water through rain, organic materials present in inflow water also release sulfate ions when decomposed by microorganisms. In this field, (Talaiekhozani *et al*., 2016) indicated that bacteria and fungi working on analyzing organic materials in wastewater could release sulfate ions, which are responsible for the unpleasant odor in wastewater. As for the effect of the seasons, significant differences were also recorded between the averages. The lowest value was in winter with a concentration of 196 mg/L, and the highest value was in summer with a concentration of 239 mg/L. As for the effect of interaction between sites and seasons, the results indicated significant differences and the lowest value was in the Wadi Hajar inflow. In winter season, with a concentration of 162 mg/L, the highest value was in Karasaray Inflow in summer, with a concentration of 350 mg/Sulfate concentrations in the wastewater of all sites did not exceed international standards for irrigation of crops, which are equivalent to 920 mg/L.

Table (6): Seasonal average of sulfate ($SO_4^{=}$) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	172u	197 p	234 g	265 b	217 c
2	Al-Arabi	190 q	177 t	233 g	247 d	212 d
3	Al-Kharazi	197 p	185 r	203 o	210 n	199 e
4	Tamoz	234 g	194 p	246 e	252 c	232 b
5	Karasaray	163 v	193 p	350 a	263 b	242 a
6	Al-Khosar	171 u	174 t	228 h	218 l	198 e
7	Wadi Hajar	162v	170 u	183 s	189 q	176 f
8	Al-Danville	254 c	226 i	230 g	224 j	234 b
9	Al-Bosif	221 k	257 c	240 f	215 m	233 b
means		196 c	197 c	239 a	231 b	

Zinc (Zn)

The results of the statistical analysis shown in Table (7) indicated that the seasonal average concentration of zinc for wastewater in the inflow showed significant differences between the sites; the lowest value was in Al-Arabi Inflow, and the highest value was in Mushairfa Inflow, with concentrations of 1.66 mg/L and 2.53 mg/L, respectively. This difference between the inflow may be due to the quantity and type of waste thrown into the inflow, which may be rich in zinc or may be contaminated with waste from dyes, rubber, and batteries in which zinc is included, as well as the number of plants and reeds growing in them that work to withdraw the metal which linked to it in multiple physiological mechanisms and accumulate it in their bodies (Priya *et al*., 2023). As for the effect of the seasons, significant differences were also recorded between the averages, and this indicates the effect of the climatic seasons on the concentration of zinc in the inflow water. The lowest value was in the winter and spring seasons, with an average concentration of (1.92) mg/L, and the highest value was in summer (2.21) mg/L. As for the effect of the interaction between sites and seasons, the results indicated that there were differences. Significantly, the lowest value was in Al-Arabi Inflow during spring and the highest value in Mushairfa Inflow during summer, with a concentration of 1.55 mg/L and 2.69 mg/L, respectively. Some inflow water exceeded the permissible limits for zinc concentration for irrigation of crops, according to Iraqi and international standards.

Table (7): Seasonal average of zinc (Zn) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	2.35 d	2.42 c	2.69 a	2.66 a	2.53 a
2	Al-Arabi	1.60 n	1.55 o	1.73 l	1.76 l	1.66 e
3	Al-Kharazi	1.75l	1.68m	1.81k	1.85j	1.77 d
4	Tamoz	1.57 o	1.61 n	1.77 l	1.81 k	1.69 e
5	Karasaray	1.97 i	2.12 g	2.55 b	2.34 d	2.25 b
6	Al-Khosar	2.19 f	2.17 f	2.27 e	2.45 c	2.27 b
7	Wadi Hajar	2.05h	2.16f	2.65a	2.36d	2.31 b
8	Al-Danville	1.95 i	1.84 j	2.05 h	2.14 f	2.00 c
9	Al-Bosif	1.81 k	1.77 l	2.41 c	1.93 i	1.98 c
means		1.92 c	1.92 c	2.21 a	2.14 b	

Copper (Cu)

The results in Table (8) indicated significant differences between the sites in the seasonal average concentration of copper in the water. This shows the effect of the site on the copper concentration. The lowest value was in the Karasaray Inflow with a concentration of 0.008 mg/L, and the highest value was in the Al-Danville Inflow. At a concentration of 0.395 mg/L, this increase is because the Al-Danville Inflow loads the water of the industrial zone (Al-Karama) on the left side of the city of Mosul. Bains, (2000) indicated that copper is widely used in welding operations and is used in In the manufacture of automobile parts, such as wires, brake tubes, radiators, dynamos, and ignition switches, Zubair *et al*. (2008) indicated that industrial liquid waste contains high concentrations of heavy metals and copper. As for other inflow containing copper, it may come from organic materials from liquid civil waste that contain concentrations of copper, as well as animal and agricultural wastes such as fertilizers and pesticides, which lead to variations in copper concentrations between sites. The seasons had a significant impact on copper concentration; the lowest value was in winter with a concentration of (0.078) mg/L, and the highest value was in autumn with a concentration of (0.152) mg/L. As for the effect of the interaction between sites and seasons, the results indicated that there were significant differences, and no reading (Nill) was recorded for the inflow (Mushairfa, Al-Arabi, Al-Kharazi, and Karasaray) during winter and spring. The reason for this is due to rain and low temperatures that increase the factor of diffusion and dilution since most of the inflow that flow into the Tigris River are not fed by natural surface water, whether from streams or springs. The source of their water is civil and industrial liquid waste from the neighborhoods of the city of Mosul and rainwater. The highest value of copper concentration was in the Al-Danville Inflow during summer, with a concentration of 0.442 mg/L.Al-Danville Inflow is considered unsuitable for irrigation in all seasons, and the Al-Khosar Inflow in summer and autumn seasons is considered unsuitable for irrigation due to copper concentrations in it, which exceeded the global limits. This is consistent with what was indicated by Ibrahim and Al-Youzbakey (2023): that the water of the Al-Danville and Al-Khosar Inflow was unsuitable. For irrigation, depending on the copper concentrations in it.

Table (8): Seasonal average of copper (Cu) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	Nill s	Nill s	0.018 r	0.033 q	0.013 h
2	Al-Arabi	Nill s	Nill s	0.07 m	0.09 k	0.040 f
3	Al-Kharazi	Nill s	Nill s	0.08lm	0.06o	0.035 g
4	Tamoz	0.106 i	0.095 k	0.177 g	0.183 g	0.140 c
5	Karasaray	Nill s	Nill s	0.013 r	0.018 r	0.008 i
6	Al-Khosar	0.103 j	0.124 h	0.225 f	0.310 e	0.191 b
7	Wadi Hajar	0.07m	0.05p	0.09k	0.116i	0.082 e
8	Al-Danville	0.318 d	0.390 c	0.442 a	0.431 b	0.395 a
9	Al-Bosif	0.105 j	0.095 k	0.129 h	0.124 h	0.113 d
means		0.078 d	0.084 c	0.138 b	0.152 a	

Lead (Pb)

The results shown in Table (9) indicated that the seasonal average lead concentration of inflow water showed significant differences between the sites, and the lowest value was in the Al-Arabi Inflow with a concentration of (0.227) mg/L. This decrease may be due to many factors affecting the concentration and solubility of lead, such as the quantity and type of waste, the speed of water flow in the inflow, the extent of its renewal, and the percentage of it containing sediments that work to absorb and precipitate lead. The highest concentration of Pb was in the Al-Danville Inflow (1.182 mg/L). This increase may be attributed to the Al-Danville Inflow being considered one of The large, important inflow in the city of Mosul, with a length of 12 km and a drainage rate of 68 m3/s, collects the waste of many residential neighborhoods as well as the waste of the industrial area, as industrial areas are the main source of lead contamination of water, the waste of which is thrown into The rivers are untreated due to their lack of treatment facilities (Mokarram *et al*., 2020). The waste of fuel, diesel, welding wires, radiator and battery repair shops, and other car parts in the industrial area is one of the sources of lead pollution. For this reason, we notice high lead concentrations in the Tamoz Inflow, which also collects liquid waste. For the Wadi Akkab industry. The results of the statistical analysis indicated that there was a significant difference between the average concentration of lead in water.

Table (9): Seasonal average of lead (Pb) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	0.212 w	0.225 w	0.272 u	0.254 v	0.241 g
2	Al-Arabi	0.201 x	0.179 y	0.245 v	0.281 u	0.227 h
3	Al-Kharazi	0.312t	0.329t	0.410q	0.419p	0.368 f
4	Tamoz	0.751 h	0.667 j	0.988 d	0.954 e	0.840 b
5	Karasaray	0.375 r	0.274 u	0.477 o	0.350 s	0.369 f
6	Al-Khosar	0.533 m	0.431 p	0.700 i	0.890 g	0.639 d
7	Wadi Hajar	0.492o	0.510n	0.563l	0.572l	0.534 e
8	Al-Danville	1.058 c	0.931 e	1.206 b	1.532 a	1.182 a
9	Al-Bosif	0.606 k	0.714 i	0.873 g	0.915 f	0.777 c
means		0.504 c	0.473 d	0.637 b	0.685 a	

The lowest value was in spring and the highest value in autumn, with concentrations of (0.473) mg/L and (0.685) mg/L, respectively. Significant differences were also obtained regarding the interaction between sites and seasons. Al-Arabi Inflow obtained the lowest concentration during spring season, while Al-Danville Inflow obtained the highest concentration in autumn season with a value of 0.179 mg/L and 1.5332 mg/L, respectively.

The results agree with what was obtained by Ibrahim and Al-Youzbakey (2023), who found that the lead concentration in the Al-Danville Inflow ranged between 1.22 and 0.38 mg/L, as well as with Ahmed (2024), who indicated that the lead concentration in wastewater in Irbel city ranged between 0.215 and 0.471 mg/L.

All inflow sites are considered unsuitable for irrigation and contaminated with lead, and this is consistent with what was obtained by Agha *et al*. (2022), who indicated that the water of the Al-Khosar Inflow in various sites exceeded the Iraqi limits for lead concentration and is considered unsuitable for irrigation.

Cobalt (Co)

The results in Table (10) show that there is a significant effect of the site on the seasonal average of cobalt concentration in the water. Mushairfa Inflow obtained the lowest concentration (0.029) mg/L, while Al-Danville Inflow obtained the highest concentration (0.071) mg/L. This discrepancy in cobalt concentrations between inflow may be due to the type and size of waste dumped in them because cobalt is present in most sites at levels that differ in concentration, as urban, agricultural, and industrial liquid wastes and soil-forming minerals are among the main sources of cobalt (Nagpal, 2004), and in this field (Kulkarni, 2016) indicated that the sources of cobalt in wastewater may be automobile exhausts, organic materials, animal and plant waste, medical waste, and industrial workshop waste, as it is used in the installation of electronic devices, semiconductors, heavy cutting tools, the manufacture of alloys, batteries, glass, ceramics, and dyes. Significant differences were also recorded between the season averages. The lowest value was in spring with a concentration of

(0.041) mg/L, and the highest value was in autumn with a concentration of (0.052) mg/L.

Table (10): Seasonal average of cobalt (Co) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	0.026 x	0.021 y	0.035 r	0.033t	0.029 i
2	Al-Arabi	0.030 u	0.028 w	0.034 s	0.039 o	0.033 g
3	Al-Kharazi	0.029v	0.026x	0.031u	0.036q	0.031 h
4	Tamoz	0.039 o	0.037 p	0.039 o	0.046 l	0.040 f
5	Karasaray	0.038 o	0.041 n	0.044 m	0.059 h	0.046 d
6	Al-Khosar	0.056 i	0.064 f	0.077 b	0.081 a	0.070 b
7	Wadi Hajar	0.041n	0.038o	0.045l	0.048k	0.043 e
8	Al-Danville	0.068 d	0.066 e	0.078 b	0.071 c	0.071 a
9	Al-Bosif	0.061 g	0.049 k	0.065 e	0.052 j	0.057 c
means		0.043 c	0.041 d	0.050 b	0.052 a	

The interaction between sites and the seasons had a significant effect on the concentration of cobalt in the water. The lowest value was in Mushairfa Inflow during spring with a concentration of (0.021) mg/L, while the highest value was in Al-Khosar Inflow during autumn with a concentration of (0.081) mg/L. The results are consistent with what was obtained by Ibrahim and Al-Youzbakey (2023) for the concentration of cobalt in the Al-Khosar Inflow of 0.07 mg/L.Some inflow water exceeded the permissible limits of cobalt concentration for irrigation of crops, according to Iraqi and international standards.

Nickel (Ni)

The results of the statistical analysis in Table (11) indicate that there are significant differences in the concentration of nickel in the water for the inflow sites. It was the lowest in Mushairfa Inflow and the highest concentration in Tamoz Inflow, with a value of (0.298) mg/L and (0.598) mg/L. Respectively, the seasons also affected significantly; the lowest concentration was in winter and the highest concentration was in summer (0.398) mg/L and (0.520) mg/L, respectively. The interaction between sites and seasons also had a significant effect on the average. The Karasaray Inflow obtained the lowest concentration during winter, while the Al-Danville Inflow obtained the highest concentration during summer, with values of 0.201 mg/L and 0.695 mg/L, respectively. The increase may be due to the amount of organic matter and domestic, industrial, and agricultural waste loaded in Al-Danville Inflow, as well as the decomposition products of animal fertilizers that contain different concentrations of nickel. Ibrahim (2024) indicated that the Al-Danville Inflow is about 5.9 km long and starts from the green apartments located east of the city in the industrial zone and flows into the Tigris River, which is one of the most polluted inflows in the city, as industrial and household waste is spread near it. The results are consistent with Al-Hayani (2018), who obtained a concentration of 0.64 and 0.34 mg/L for nickel in the Al-Danville Inflow near the Tigris River.

All inflow water is considered contaminated with nickel and is not suitable for irrigation of crops as a result of the random discharge of contaminated industrial, domestic, and agricultural liquid waste into the inflow without treatment, such as organic fertilizers, animal waste, soil waste, agricultural waste, and waste from the industrial district (Wadi Akkab and Al-Karama Industry), which includes car maintenance and painting workshops and other manufacturing plants as laboratories. Aluminium, blacksmithing, gas and chemical manufacturing factories, printing and dye factories, diesel waste, machine oils and grease, and materials for welding alloys and metals.

Table (11): Seasonal average of nickel (Ni) concentration in wastewater (mg/L) in different sites between March 2022 to February 2023

Sites		Average seasons				means
		Winter	spring	summer	autumn	
1	Mushairfa	0.220 p	0.250 o	0.310 m	0.410 k	0.298 f
2	Al-Arabi	0.300 m	0.330 l	0.355 l	0.340 l	0.331 e
3	Al-Kharazi	0.420k	0.450k	0.562f	0.578e	0.503 d
4	Tamoz	0.530 h	0.610 d	0.653 b	0.600 e	0.598 a
5	Karasaray	0.201 p	0.230 o	0.255 o	0.296 n	0.246 g
6	Al-Khosar	0.420 k	0.510 i	0.581 e	0.620 c	0.533 c
7	Wadi Hajar	0.509i	0.517i	0.598e	0.543g	0.542 c
8	Al-Danville	0.490 j	0.543 g	0.695 a	0.581 e	0.577 b
9	Al-Bosif	0.493 j	0.530 h	0.668 a	0.650 b	0.585 a
means		0.398 c	0.441 b	0.520 a	0.513 a	

(Ceasar *et al*., 2019) indicated that irrigating crops with this water will cause soil pollution and toxicity to plants, as high concentrations of nickel reduce seed germination, impair the growth of roots, shoots, and vegetative growth, hinder various physiological processes (photosynthesis and transpiration), and cause oxidative stress in plants , In addition, the use of this water leads to accumulation of nickel in plants, which may reach humans through the food chain and cause serious health problems. This is consistent with (Abdul *et al*., 2023) who found high concentrations of nickel in bread produced from wheat irrigated with polluted water.

CONCLUSIONS

Significant differences were obtained between the landfill sites and seasons, due to the difference in the quantity and type of waste discharged into the water and the effect of temperature and rainfall, which affected most of the studied characteristics. Al-Danville and Tamoz estuaries were the most polluted estuaries with copper, nickel and lead. The reason is that these estuaries collect industrial liquid waste from the Wadi Aqab and Al-Karamah industries. TDS, nitrates, phosphates, and sulfates for all sites was within global and Iraqi standard limits for irrigation. Wastewater in all sites is considered very hard and can lead to deposits, blockage of pipes, and damage to irrigation systems. The water was hard in all the outfall sites and caused technical problems when used for irrigation, as it damaged and clogged the irrigation systems. Most of the wastewater contains high concentrations of heavy elements that may be transferred to the soil and accumulate in plants and may reach humans through the food chain and cause serious health problems, so they are not suitable for irrigation.

ACKNOWLEDGMENT

The authors want to express their deep thanks to the staff of the Central Laboratory at the College of Agriculture and Forestry at the University of Mosul and the Department of Soil Sciences and Water Resources for providing the tools and materials for the research.

CONFLICT OF INTEREST

The work's authors declare that there are no conflicts of interest associated with its publication.

تقييم نوعية مياه مصبات الصرف الصحي في مدينة الموصل لأغراض الري

محمد احمد عبد الله الطائي [1,2]، عبد القادر عبش سباك الحديدي [1]، وحيدة علي احمد البدراني [1]
قسم علوم التربة والموارد المائية / كلية الزراعة والغابات / جامعة الموصل / الموصل / العراق [1]
كلية الزراعة / جامعة تلعفر / العراق [2]

الخلاصة

المياه العادمة او مياه الصرف هي النفايات السائلة المنزلية والصناعية والزراعية التي تحتوي على مواد قابلة للتحلل، بالإضافة إلى مواد ومركبات غير قابلة للتحلل كالمبيدات والمواد البلاستيكية. ان نحو ما يقدر 80% من مياه الصرف غير المعالجة على الصعيد العالمي تستخدم لري المحاصيل مما يؤدي إلى تراكم الأملاح والمركبات والعناصر الثقيلة في التربة والمحاصيل مما يسبب تدهور التربة ومشاكل في نمو النبات وقد تنتقل إلى الإنسان عبر السلسلة الغذائية. تم جمع العينات شهرياً لكل موقع للفترة ما بين اذار 2022 ولغاية شباط 2023. وأشارت النتائج إلى أن تراكيز الرصاص والزنك والنحاس والنيكل والكوبالت تراوحت بين (1.5332−0.179) و(2.69−1.55) و(Nill−0.442) و(0.695−0.201) و(0.081−0.021) ملغم. لتر$^{-1}$ على التوالي وتجاوزت أغلب المواقع المواصفات القياسية العراقية لمياه الري. تراوحت قيم المواد الصلبة الكلية TDS والنترات والفوسفات والكبريتات بين (845−493) و(10.3−3.6) و(6.2−2.3) و(350−162) ملغم. لتر$^{-1}$ على التوالي وكانت جميع المواقع ضمن الحدود القياسية العالمية والعراقية للري. مصب الدانفيلي كان أكثر المواقع تلوثاً بالرصاص والنيكل وذلك لتجمع مياه الصرف الصناعي فيه. تعد مياه الصرف الصحي في جميع المواقع شديدة العسرة وقد تؤدي إلى حدوث ترسبات وانسداد الأنابيب وتلف أنظمة الري عند استخدامها للري. نوصي بعدم استخدام مياه الصرف الصحي للري في جميع المواقع لأنها تحتوي على تراكيز عالية من العناصر الثقيلة ومعظم خصائصها تجاوزت المواصفات القياسية العالمية والعراقية للري وهذا يسبب تدهور التربة وتلوثها ويشكل مخاطر صحية وبيئية.

الكلمات المفتاحية: المصبات، المحددات، الصرف الصحي، الرصاص، النيكل.

REFERENCES

Abbass, J. (2010). Analytical study of the most important sources of contaminants wastewater in aleppo. *Mesopotamia Journal of Agriculture*, *38*(2), 165-173. https://magrj.uomosul.edu.iq/article_27843.html

Abdul, N. A., Abdulrahman, A. M., Talb, S., & Mhamad, H. J. (2023). Mineral processing impact on wheat and barley (Tiry bread and samoon as an example). *Mesopotamia Journal of Agriculture*, *51*(2), 36-0. https://doi.org/10.33899/magrj.2023.138377.1219

Agha, B. Z. K., Al-Hamdany, A. A. S., & Al-Tayyar, T. A. T. (2022). Assessment of Pollution by Heavy Metals in the Water and Sediment of Al-Khosur River Bed. *Pakistan Journal of Medical and Health Sciences*, *16*(08), 908-908. https://doi.org/10.53350/pjmhs22168908

Ahmed, J., Thakur, A., & Goyal, A. (2021). Industrial wastewater and its toxic effects. https://doi.org/10.1039/9781839165399-00001

Ahmed, T. A. (2024). Lead, Nickel And Copper Concentration In Wastewater Used For Irrigation In Erbil City Kurdistan Region, Iraq. https://www.researchgate.net/publication/381733605

Al-Hayani, A. G., (2018). State of some heavy metals in Danfeeli stream vally (Mosul city) and its effect on soil, plant and water pollution (Doctoral dissertation, University of Mosul). http://dx.doi.org/10.13140/RG.2.2.17594.24004

Al-Shanona, R. A., Al-Asaaf, A. Y., & Al-Maathide, A. T. (2020). The environmental status of Tigris River water in Mosul city, northern of Iraq. https://plantarchives.org/20-1/3051-3056%20(6095).pdf

Al-Taee, N., Mohammad, M., & Abdul-Majeed, A. (2024). The effect of partial replacement of animal protein with duckweed grown in the treatment unit of the nineveh pharmaceutical factory water on the growth performance of common carp *Cyprinus carpio L.* FISH. *Mesopotamia Journal of Agriculture*, *52*(3), 22-0. https://doi.org/10.33899/mja.2024.145298.1316

Alzubaidy, Z., & Al Azzo, O. (2022). Monitoring seasonal variation in ground water quality and evaluation of its suitability for irrigation in the nimrud area south–east of mosul–iraq. *Mesopotamia journal of agriculture*, *50*(4), 90-0. https://www.iasj.net/iasj/download/be1cbe8adf34c9c1

Ansam, B. Z. K. A., Al-Hamdany, A. S., & AL-Tayyar, T. A. T. (2022). Studying Some Physical and Chemical Properties of Al-Khosur River in Mosul city. *NeuroQuantology*, *20*(10), 5360. Studying Some Physical.pdf

APHA. (2017). " *Standard methods for the examination of Water and waste water*". American Public Health Association, 23D ed., Washington DC, USA. https://yabesh.ir/wp-content/uploads/2018/02/Standard-Methods-23rd-Perv.pdf

Asthana, M., Kumar, A., & Sharma, B. S. (2017). Wastewater treatment. Principles and applications of environmental biotechnology for a sustainable future, 173-232. https://link.springer.com/chapter/10.1007/978-981-10-1866-4_6

Ayers, R. S. & D. W. Westcot. (1985). Water for agriculture. Irrigation and Drinage paper (29 Rev.I). FAO, Rome, Italy https://www.fao.org/4/t0234e/t0234e00.htm

Bains, B. (2000). The recovery of copper from automotive wiring harnesses. https://scholar.uwindsor.ca/etd/4190

Ceasar, S. A., Lekeux, G., Motte, P., Xiao, Z., Galleni, M., & Hanikenne, M. (2020). di-Cysteine residues of the Arabidopsis thaliana HMA4 C-terminus are only partially required for cadmium transport. *Frontiers in Plant Science*, *11*, 560 https://doi.org/10.3389/fpls.2020.00560

Coronel, G., Chang, M., & Rodríguez-Delfín, A. (2008, August). Nitrate reductase activity and chlorophyll content in lettuce plants grown hydroponically and organically. In International Symposium on Soilless Culture and Hydroponics 843 (pp. 137-144). https://doi.org/10.17660/ActaHortic.2009.843.16

Elliott, A. C., & Woodward, W. A. (2023). *SAS essentials: mastering SAS for data analytics*. John Wiley and Sons. https://shorturl.at/YanYl

EPA. (2012). Environmental Protection Agency. Guidelines for Water Reuse 600/R-12/618; Washington, DC, USA, 2012. Environmental Protection Agency.pdf

Ibrahim, E. (2024). Water Quality Evaluation of the main Valleys for Agricultural Uses on the left side of Mosul City. Iraqi National Journal of Earth Science, 24(1), 62-0. https://doi.org/10.33899/earth.2023.141188.1098

Ibrahim, I. F., & Al-Youzbakey, K. T. (2023). A geochemical study of the main inflow' waters on the left part of Mosul (Iraq*). Italian journal of engineering geology and environment*, *(1)*, 45-60. https://doi.org/10.4408/IJEGE.2023-01.O-04

Koptsik, S. V., & Koptsik, G. N. (2022). Assessment of current risks of excessive heavy metal accumulation in soils based on the concept of critical loads: A review. *Eurasian Soil Science*, *55*(5), 627-640 https://doi.org/10.1134/S1064229322050039

Kulkarni, S. J. (2016). Research and studies on cobalt removal from wastewater. *International Journal of Research and Review*, 2237, 41-44.https://www.ijrrjournal.com/IJRR_Vol.3_Issue.7_July2016/IJRR008.pdf

Lin, L., Yang, H., & Xu, X. (2022). Effects of water pollution on human health and disease heterogeneity: a review. *Frontiers in environmentalscience*, *10*,880246. https://doi.org/10.3389/fenvs.2022.880246

Mahmoud, E. M., Nour ElDin, M. M., El Saadi, A.M & Riad, P. (2021). The effect of irrigation and drainage management on crop yield in the Egyptian Delta: *Case of El-Baradi area Ain Shams Engineering Journal* 12 119–134 https://doi.org/10.1016/j.asej.2020.08.009

Mokarram, M., Saber, A., & Sheykhi, V. (2020). Effects of heavy metal contamination on river water quality due to release of industrial effluents. *Journal of Cleaner Production*, *277*, 123380. https://doi.org/10.1016/j.jclepro.2020.123380

Nagpal, N. K. (2004). *Technical report, water quality guidelines for cobalt* (p. 59). Victoria, BC, Canada: Water Protection Section, Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection. Technical report, water quality guidelines.pdf

National determinants of the use of treated wastewater in irrigation: Law No. (3) of (2012). https://faolex.fao.org/docs/pdf/irq149859.pdf

Priya, A. K., Muruganandam, M., Ali, S. S., & Kornaros, M. (2023). Clean-Up of Heavy Metals from Contaminated Soil by Phytoremediation: A Multidisciplinary and Eco-Friendly Approach. *Toxics*, *11*(5), 422. https://doi.org/10.3390/toxics11050422

Ramadhan, O. M., Al-Saffawi, A. A. Y., & Al-Mashhdany, M. H. (2018). Application of water quality index [CCME WQI] to assess surface water quality: A case study of Khosar and Tigris rivers in Mosul, Iraq. Int. J. of Enhanced Res. in Sci., Techn. & Engin, 7(12), 1-8. https://www.researchgate.net/publication/330509251

Ruzhitskaya, O., & Gogina, E. (2017). Methods for removing of phosphates from wastewater. In MATEC Web of Conferences (Vol. 106, p. 07006). EDP Sciences. https://doi.org/10.1051/matecconf/201710607006

Schiavon, M., & Moore, K. K. (2021). How to properly read your irrigation water analysis for turf and landscape: *ENH1352/ep616*, *12*/2021. Edis, 2021(6). https://doi.org/10.32473/edis-EP616-2021

Shelor, C. P., & Dasgupta, P. K. (2017). Automated programmable pressurized carbonic acid eluent ion exclusion chromatography of organic acids. *Journal of Chromatography A*, *1523*, 300-308. https://doi.org/10.1016/j.chroma.2017.05.036

Stackpoole SM, Stets EG, Sprague LA (2019). Variable impacts of contemporary versus legacy agricultural phosphorus on US river water quality. *PNAS 116*:41. https://doi.org/10.1073/pnas.1903226116

Talaiekhozani, A., Bagheri, M., Goli, A., & Khoozani, M. R. T. (2016). An overview of principles of odor production, emission, and control methods in wastewater collection and treatment systems. *Journal of environmental management*, *170*, 186-206. https://doi.org/10.1016/j.jenvman.2016.01.021

Todd, D. K. (1980) *Ground Water hydrology*, *Second Edition*. John Wiley and Sons, Inc., New York https://linksshortcut.com/qxJjB

Xu, X., Wang, Q., & Li, C. (2022). The impact of dependency burden on urban household health expenditure and its regional heterogeneity in China: Based on quantile regression method. *Frontiers in public health*, *10*, 876088. https://doi.org/10.3389/fpubh.2022.876088

Zhai, S., Jacob, D. J., Wang, X., Liu, Z., Wen, T., Shah, V., ... & Liao, H. (2021). Control of particulate nitrate air pollution in China. *Nature Geoscience*, *14*(6), 389-395. https://doi.org/10.1038/s41561-021-00726-z

Zubair, A., Farooq, M. A., & Abbasi, H. N. (2008). Toxic Trace Element Pollution in Storm Water of Karachi: A Graphical Approach. *The Pacific Journal of Science and Technology*, *9*(1), 238-253. Toxic Trace Element Pollution.pdf