

# Assessment of Environmental Risks of Heavy Metals and their Role in Promoting Phytoplankton Growth in Tap Water

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**Abstract:** Background: Drinking water is crucial that it is a second most needed substance for human life. About half of the world's population suffers from the problem of contaminated drinking water. Objectives: The current investigation presented a thorough assessment of heavy metal levels: lead, copper, cadmium, chromium along with phytoplankton frequencies at three stations. The results of statistical analysis revealed a significant ( $P=0.0011$ ) decreased in Lead levels ( $15 \pm 3$ ) in 3rd Station as compared with ( $20 \pm 5$ ) in 1ST Station and ( $27 \pm 2.645$ ) in 2nd Station. Notably in all stations these levels seems to have a seasonal variation, where they reduced in summer season. Also, significant ( $P=0.0220$ ) difference were recorded in Chrome levels, where their levels showed significant decrease in 1ST Station ( $51.666 \pm 2.887$ ) versus ( $64 \pm 3.605$ ) in 2nd Station and ( $60 \pm 5$ ) in 3rd Station; as well the Chrome levels were diminished in in summer season. On the other hand, Cadmium and Copper showed non-significant ( $P=0.3001$ ,  $0.6561$  respectively) differences in the distribution

of their levels across the studied stations and seasons. Chlorophyta showed the highest percent of appearance at 50.3%, while the least appeared phyla was Dinophyta at 5.36%, Cyanophyta and Bacillariophyta showed moderate percentage at (24.2% and 20.1% respectively). In addition, Cyanophyta and Chlorophyta were significantly ( $P=0.0006$ ,  $0.0284$ , respectively) more abundant at 3rd Station, with percentages of 50% and 46.7%, respectively. Dinophyta was significantly ( $P=0.0001$ ) abundant in 2nd Station, accounting for 62.5%, while it did not appear at all in 1ST Station. Bacillariophyta was also significantly ( $P=0.0483$ ) more abundant in 2nd Station, at 43.3%. Conclusion: Our study demonstrated spatial as well as seasonal differences in both chemical and biological indicators, emphasized the impacts of geographic position, anthropogenic activities, along with hydrological condition on quality of water.

**Keywords:** Phytoplankton, heavy metal, drinking water, Lead, Cadmium, Copper, Chrome

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## Introduction

Drinking water is crucial that it is a second most needed substance for human life. About half of the world's population suffers from the problem of contaminated drinking water (Amjad et al., 2020). Drinking water quality is one of important factors that influence human health and environmental sustainability (Li & Wu, 2019). Phytoplankton are microscopic organisms making their food from sunlight via photosynthesis and floating freely in aqueous environment, their plenty are widely utilized as measures for water quality and ecosystem validity (Jahan and Singh, 2023). Phytoplankton's investigations and surveillance are valuable to grasp the complexity of interaction between abiotic and biotic factors, as well as being important means to monitor ecological quality and health of watery environment (Matta et al., 2015). Among these, Cyanophyta (blue-green algae), Chlorophyta (green algae), Dinophyta (dinoflagellate), and Bacillariophyta (diatom) have ecologically importance, they responding clearly to environmental stressors, inclusive of the existence of heavy metals. The abundance, diversity, locative and seasonal distribution provide important insights into ecological status of aquatic system, especially in area where water sources

being exposed to anthropogenic constraint (Sharma and Kumari, 2023; Tekebayeva et al., 2024). Cyanobacteria (also called as Cyanophyta, Cyanoprokaryota, Chloroxybacteria, and blue-green algae) are prokaryotic organisms capable of nitrogen fixation and are often associated with eutrophic conditions. Their proliferation in drinking water sources can lead to harmful algal blooms and the release of cyanotoxins, posing serious risks to human health (Sukenik & Kaplan, 2021). Chlorophytes are a major diversified taxonomical assortment of algae, lived in all kinds of water bodies in marine, freshwater, along with terrestrial ecosystems (Graham et al., 1991). They usually predominate in freshwaters, and as a consequence these types of algae had a fundamental role in shaping of many aquatic environments (Celewicz et al., 2022). Dinophyta (also called dinoflagellates) are well-known for motility and bioluminescence, certain species implicated with toxic red tides (Wyatt & Zingone, 2014). Bacillariophyta (or diatoms) are distinctive by containing silica in their cell walls; they had a pivotal role in primary production and nutrients cycling (Guiry, 2012). Cooperatively, these phyla pose freshwater phytoplankton populations backbone and are intrinsic part in ecological valuations of water quality. Along with the biological indexes, existence of heavy metals like copper, lead, cadmium, and chromium in drinking water represent a major apprehension owing to their toxicity, stability, and possibility of bioaccumulation (Amjad et al., 2020; Sharma & Kumari, 2023). Heavy metals can arise from industrial dispense, agricultural drainage, alongside the wastes of urban areas, and their aggregation in water bodies could affect aquatic life and give rise health problems for humans and animals; or instance, long-term exposure to lead and cadmium was associated with neurological damages and renal dysfunction, while chromium and copper known to associate with gastrointestinal as well as liver disorders (Zhang et al., 2023). Levels of heavy metals such as lead and cadmium in drinking water in AL-Diwaniyah city exhibited high proportions violate permissible limits in some sites as previously revealed by Ghawi (2017), who attributed that to large-scale industrial activities and agriculture pollutions. The current research aims to evaluate the environmental distribution of phytoplankton in drinking water, along with estimate the levels of Lead, Cadmium, Copper, and Chrome in these water samples. By consolidating the biological and chemical analysis, the present study offers an inclusive assessment of water quality in this studied area.

## Methodology

The present study included sixty samples that have been collected from three stations in AL-Diwaniya province (1<sup>st</sup> Station: Al-Jazaayr, 2<sup>nd</sup> Station: AL-Askan, 3<sup>rd</sup> Station: Om AL-Khail) for the time from Feb. to Aug. 2025. The phytoplankton had been detected based on standard monographs and manuals (Prescott, 1984), samples were stored in pre-cleaned two-liter plastic bottles and Then the samples were fixed with 10 mL of Logle solution. The samples were then diagnosed using a light microscope with magnification powers of 40x and 100x (Al-Hassany and Hassan, 2014). All tests were conducted according to standard methods for water testing. Heavy metals in tested drinking water regions had been evaluated according to method referenced by El Zokm et al. (2021b).

## Results and discussion

### The concentrations of some heavy metals in drinking water across studied stations

Table (1) displays the concentrations of some heavy metals in drinking water that collected from three stations including (1<sup>ST</sup> Station, 2<sup>nd</sup> Station, and 3<sup>rd</sup> Station) in Diwaniyah province, these stations had been tested across three seasons: winter (February), spring (March-May), and summer (Jun-August). The results of statistical analysis revealed a significant ( $P=0.0011$ ) decreased in Lead levels ( $15 \pm 3$ ) in 3<sup>rd</sup> Station as compared with ( $20 \pm 5$ ) in 1<sup>ST</sup> Station and ( $27 \pm 2.645$ ) in 2<sup>nd</sup> Station. Notably in all stations these levels seems to have a seasonal variation, where they reduced in summer season. Also, significant ( $P=0.0220$ ) difference were recorded in Chrome levels, where their levels showed significant decrease in 1<sup>ST</sup> Station ( $51.666 \pm 2.887$ ) versus ( $64 \pm 3.605$ ) in 2<sup>nd</sup> Station and ( $60 \pm 5$ ) in 3<sup>rd</sup> Station; as well the Chrome levels were diminished in in summer season. On the other hand, Cadmium and Copper showed non-significant ( $P=0.3001, 0.6561$  respectively) differences in

the distribution of their levels across the studied stations and seasons.

**Table (1): Mean values of some heavy metals in studied stations**

Stations Parameter	1 <sup>ST</sup> Station			2 <sup>nd</sup> Station			3 <sup>rd</sup> Station			P-value
	Winter Feb.	Spring March -May	Summer Jun- August	Winter Feb.	Spring March -May	Summer Jun- August	Winter Feb.	Spring March -May	Summer Jun- August	
<b>Lead</b>	20	25	15	30	26	25	15	18	12	0.0011*
<b>Mean ± SD</b>	20 ± 5 <sup>b</sup>			27 ± 2.645 <sup>a</sup>			15 ± 3 <sup>c</sup>			
<b>Cadmium</b>	3.7	3.7	3	4	4.4	5	3	5	3.2	0.3001 <sup>N</sup> <sub>s</sub>
<b>Mean ± SD</b>	3.466 ± 0.404			4.466 ± 0.5033			3.7333 ± 1.1015			
<b>Copper</b>	2400	2500	2100	2600	2000	2200	2500	2400	2400	0.6561 <sup>N</sup> <sub>s</sub>
<b>Mean ± SD</b>	2333.333 ± 208.166			2266.667 ± 305.505			2433.333 ± 57.735			
<b>Chrome</b>	50	55	50	65	67	60	60	65	55	0.0220*
<b>Mean ± SD</b>	51.666 ± 2.887 <sup>b</sup>			64 ± 3.605 <sup>a</sup>			60 ± 5 <sup>a</sup>			

\*mean significant differences at the level of p value ≤0.05; NS: Non significant differences by ANOVA one way test, different letters referred to presence of significant differences

The evaluation of heavy metals levels in Potable Water Sources in three stations: 1<sup>ST</sup> Station, 2<sup>nd</sup> Station, and 3<sup>rd</sup> Station in AL-Diwaniyah city demonstrated locative differences, which reflect anthropogenic impacts together with geographic position. The notable reduce in lead levels at 3<sup>rd</sup> Station points out reduced exposure to urban and industrial runoff, this finding may be justified on the basis of its rural nature and remoteness from major pollution exporters. Lead contamination in surface waters is usually linked with vehicular emission, industrial dispenses, along with urban wastewater, all these pollutions are more abundant near dense populated regions. 2<sup>nd</sup> Station that closes to urban areas may be given higher pollutant burdens, while 3<sup>rd</sup> Station profits from dilution impacts and natural attenuation process. Our outcomes agree with the previous study of Al-Asadi & Al-Kafari (2022), which revealed increased lead concentrations in Al-Diwaniyah River segments near to industrial areas, emphasized the impacts of land usage and closeness to pollution exporters in shaping metals distribution. The ever-increasing threat of metal toxicity to the aquatic environment has recently increased, and lead is deemed a considerable environmental problem owing to their high carcinogenic and anti-carcinogenic toxicity (Niu et al., 2020). As for Chromium, their levels exhibited a significant reduce at 1<sup>ST</sup> Station, which may be attributed to sediment adsorption, vegetative filtration, along with decrease upstream industrial dispense. It had a potent affinity for particulates and prone to be settled in sediments, particularly in regions with slow flow rates and had natural vegetations (Byrne et al., 2016). The geographic context of 1<sup>ST</sup> Station, which distinguished by agricultural land along with riparian vegetation might lead to facilitate Chromium's retention and immobilization. This observation is supported by a recent study, which underscored roles of sediment-water interaction in modulating heavy metals levels, especially in areas with natural buffer zones (Feng et al., 2024).

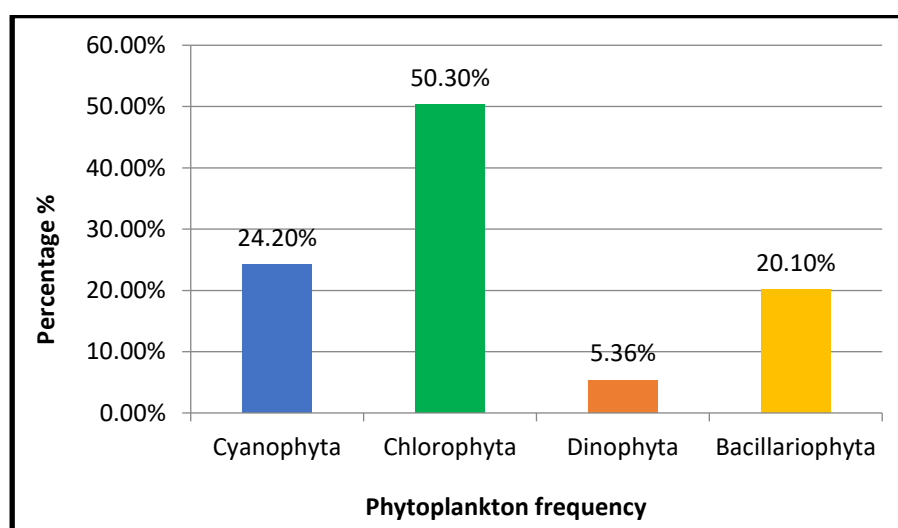
Regarding to cadmium and copper levels, they showed no-significant differences among the studied stations, this finding may be due to presence of diffuse, non-point exporters like agricultural runoff, household wastewater, along with natural geological leach, they commonly displayed low spatial differences unless affected by local industrial activity. Cadmium is a naturally occurring element that is uniformly distributed in the Earth's crust. Its presence is generally estimated at an average concentration of 3 µg/L, according to WHO and 5 µg/L, according to United States Environmental Protection Agency (USEPA). Industrial waste and leaching from landfills are the two main sources of cadmium contamination of water. Drinking water is commonly contaminated by galvanized iron pipes and coated plumbing fixtures in water distribution pipes. Cadmium is second only to mercury in toxicity (Sharma and Kumari, 2023). The uniformity recorded in the present investigation is in line with Kazem Al-Abadi and Walli (2025), they also reported stable cadmium and copper levels in various locations in Al-Diwaniyah city, and they justified this pattern to increase agricultural

practices and sediment interaction that mitigate metal fluctuation. The spatial dynamics underscored the significance of local environmental estimations and the requirement to behold land usage, hydrology, along with anthropogenic activities as interpreted water quality data.

Besides, our findings showed seasonal changes in the levels of heavy metals included in present study (lead, cadmium, copper, and chromium) in drinking water at the three stations in Al-Diwaniyah city, where a general lessen in their levels was found throughout summer season. In fact, the present seasonal pattern mirrors the impacts of environmental elements like high temperatures, escalated evaporation rates, and alterations in water flow, which collectively are leading to dilute the pollutant levels due to diminish industrial and agricultural activities during summer. Additionally, some heavy metals are linked with organic particles or sediments, and with increasing temperatures, the sedimentation rates or chemical reactions might escalate, thus lessening their levels in surface water. This current finding aligns with the previous study in Al-Fayoum Governorate in Egypt, which also supported the concept of seasonal variations in heavy metals levels, this study attributed these differences to temperature shift, rainfall pattern, as well as water flow dynamics (Mansour et al., 2024). Similarly, Redwan and Elhaddad, (2020) supported the seasonal variations in heavy metal levels despite this study did not examined the drinking water, but rather it deal with estimation the toxic trace metals pollution in Sediments of Damietta Branch of Nile River, they revealed that these metals were relatively higher in winter compared to summer, due to lower water discharge during the winter, which leads to higher concentrations. Another study in Ethiopia also supported seasonal variations in heavy metal concentrations in groundwater (Asfaw, 2022).

### Frequency of phytoplankton across studied stations

Figure (1) exhibited the general distribution on phytoplankton in present study, where the Chlorophyta showed the highest percent of appearance at 50.3%, while the least appeared phyla was Dinophyta at 5.36%, Cyanophyta and Bacillariophyta showed moderate percentage at (24.2% and 20.1% respectively). Table (2) displays the frequency of detected Phytoplankton in studied stations; Cyanophyta and Chlorophyta were significantly ( $P=0.0006$ ,  $0.0284$ , respectively) more abundant at 3rd Station, with percentages of 50% and 46.7%, respectively. Dinophyta was significantly ( $P=0.0001$ ) abundant in 2<sup>nd</sup> Station, accounting for 62.5%, while it did not appear at all in 1<sup>ST</sup> Station. Bacillariophyta was also significantly ( $P=0.0483$ ) more abundant in 2<sup>nd</sup> Station, at 43.3%.



**Figure (1): General frequency of phytoplankton across studied stations**

The high prevalence of Chlorophyta in present study may indicate that studied aquatic environment is relatively nutrient-rich and well-light, where species of Chlorophyta thrive in eutrophic conditions with abundant sunlight and adequate nutrient availability. Chlorophyta are distinguished by rapidly growing and adaptability, usually thriving in freshwater had a stable pH and squat toxicity levels

(Reynolds, 2006). The present finding agree with a previous report that demonstrated that from the Phytoplankton detected in freshwater, there are 32 species of Chlorophyta, which constituted 48.1% of phytoplankton population in Xuanwu Lake/China (Qu and Zhou, 2024).

With regard to moderate prevalence of Cyanophyta and Bacillariophyta, their existence rate at 24.2% and 20.1% respectively, may reflect a transitional environmental state and may be associated to seasonal variations or sediment dynamic in studied stations. Cyanophyta are often proliferating in niche recognized with high nitrogen and phosphorus levels, particularly in warmer temperatures (Paerl & Otten, 2013). As for species belong to Bacillariophyta, they are preferring cooler, fully-oxygenated waters and being sensitive to turbidity alongside flow rate (Smol, 2008). Our finding agree with a previous study conducted on Hongmen Reservoir/ China, where seasonal collection of water samples demonstrated that Cyanophyta and Bacillariophyta found at moderate prevalence rate else in dry, wet, and normal seasons (Liu et al., 2021). Also results of current study are in line with (Newcombe and Neto, 2021), who documented that Cyanophyta species are naturally existent in surface waters second-handed for drinking, at rates ranging between low-moderate. In addition, the study of Wu et al. (2022) had identified Cyanophyta and Bacillariophyta as dominant phyla, where each of then contributed approximately 20–25% of phytoplankton population in Jinjiang River Estuary. Where these findings underline their ecological significance and bolsters up our observation that both phyla species are consistently available in freshwater environment at moderate rates.

With respect to low frequency of Dinophyta (5%), this rate is align with their ecological predilection. Dinophyta are frequently presented in marine or brackish settings, and their restricted presence in freshwater is often assigned to lower salinity, decreased mobility, and their competitiveness with other phytoplankton species; these patterns of distribution line up with Guiry (2023), who confirmed the ecological impacts and distribution preferences of major phytoplankton phyla. The present study provides important insights about a sample of drinking water and their quality in Iraq, which aligns with Pham et al. (2023), who investigated the phytoplankton diversity and linked them with water quality in drinking water reservoir.

**Table (2): Phytoplankton frequency in studied stations**

Phyla	1 <sup>st</sup> Station	2 <sup>nd</sup> Station	3 <sup>rd</sup> Station	Total	P-value
<b>Cyanophyta</b>	7 (19.44 %)	11 (30.56 %)	18 (50%)	36 (24.2%)	0.0006*
<b>Chlorophyta</b>	25 (33.33%)	18 (24%)	35 (46.7%)	75 (50.3%)	0.0284*
<b>Dinophyta</b>	0 (0%)	5 (62.5%)	3 (37.5%)	8 (5.36%)	0.0001*
<b>Bacillariophyta</b>	10 (33.33%)	13 (43.3%)	7 (23.33%)	30 (20.1%)	0.0483*
<b>Total count No. (%)</b>	42 (28.2%)	47 (31.54%)	60 (40.26%)	149	0.3067 <sup>NS</sup>
*Significant difference at the 0.05 level by chi-square test. NS: Non-significant difference					

The present spatial variations in phytoplankton frequencies in the studied stations can reflect the interaction between ecological conditions and heavy metals levels, thus provides an insight into the ecological status of aquatic system in studied area. In 3<sup>rd</sup> Station, the significantly higher frequencies of Chlorophyta and Cyanophyta can attributed to lower levels of the toxic heavy metal (lead), which was demonstrated to be significantly decreased at this station, thus 3<sup>rd</sup> Station offers a propitious condition for photosynthetic growth. The species of Chlorophyta are preferring to grow in environments that characterized with nutrients-rich, low-toxicity freshwater, stable pH along with containing abundant light (Reynolds, 2006). In spite of the fact that Cyanophyta species tolerant to some pollutants, but they being sensitive to increased levels of heavy metals like lead and Chromium (Paerl and Otten, 2013). Consequently, reduced metals stress at 3<sup>rd</sup> Station, along with its rural setting and prospective for natural filtration, can reinforce the proliferation of these algae.

The current finding of higher frequencies of Dinophyta and Bacillariophyta in 2<sup>nd</sup> Station that is closeness to urban and industrial regions, where higher levels of Chromium and lead were recorded

as shown in Table (1). Despite Dinophyta common in brackish or marine ecosystems, its can grow in freshwater under some condition of organic enrichment and modest disturbance (Gómez, 2005). Bacillariophyta are able to tolerate modest levels of heavy metals, especially if bound to sediments (Smol, 2008). The presence of species belong to these phyla at 2<sup>nd</sup> Station can indicated the adaptive responses to metal stress, sediment interactions, and urban runoff dynamics; where it was previously reported two antioxidant systems (enzymatic and non-enzymatic) utilized by Algae species to shield themselves from impacts of heavy metals (Ismail and Ismail, 2017; Xiao et al., 2023). There are various stressors can affect the growth of phytoplankton and lead to physical and morphological alterations in phytoplankton across aquatic ecosystem, where heavy metals are considered as one of important these stressors (Permana and Akbarsyah, 2019). Other environmental stressors like high light, reactive oxygen species in microalgae (Coulombier et al., 2021). Thus phytoplankton frequency can utilize as a bio-indicator for heavy metals and other stressors affect the different ecosystem (Permana and Akbarsyah 2019). Moreover, the present findings are proportionate with broader environmental models that linked metals stress, nutrients dynamic, and phytoplankton population's composition (Pham et al., 2023). Generally, the ecological evaluation of phytoplankton and estimation of heavy metals in drinking water is deem a relevant area of research, exceptionally in light of growing concerns in the context water quality and ecological health.

Interestingly, our research outcomes contribute valuably to achieve of a number of Sustainable Development Goals (SDGs) in Iraq, especially, those linked with ecological health as well as water quality. By evaluating heavy metals levels and diversity of phytoplankton at Al-Diwaniyah province, our study lines up the sixth goal of SDGs: Clean Water and Sanitation, via focusing on surveillance of drinking water sources. The recognition of pollution patterns and seasonal differences as well aligning with third goal of SDGs: Good Health and Well-being, via underscoring the possible risk to public health. Additionally, environmental insights obtained from phytoplankton inspection contribute to fourteen goal of SDGs: Life Below Water, by boosting grasping of freshwater's biodiversity and ecosystems dynamics. In countries countering mounting ecological pressures, like Iraq, research like this can offer necessary data for sustainable resource administration and support the significance of consolidating the scientific research into general development delineation.

## Conclusion

The current investigation presented a thorough assessment of heavy metal levels: lead, copper, cadmium, chromium along with phytoplankton frequencies at three stations: 1<sup>st</sup> Station, 2<sup>nd</sup> Station, and 3<sup>rd</sup> Station in Al-Diwaniyah city. Our study demonstrated spatial as well as seasonal differences in both chemical and biological indicators, emphasized the impacts of geographic position, anthropogenic activities, along with hydrological condition on quality of water. Altogether, this investigation highlights the significance of integrated chemical and biological surveillance in appraising freshwater ecosystem health. Our outcomes can enrich the localized water management strategies and upholding prospective research on pollution alleviation and environmental resilience in Iraqi river systems. In countries countering mounting ecological pressures, like Iraq, research like this can offer necessary data for sustainable resource administration and support the significance of consolidating the scientific research into general development delineation.

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