The effect of some environmental factors on the production of hepatotoxins (Microcystin) in the Shatt al-Arab waters in Basrah Governorate southern Iraq

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ABSTRACT

The current study included diagnosing microcystins their concentrations in the waters of the Shatt al-Arab River, as well as in the algal biomass of three sites along the stream of the river, namely Al-Siba, Al-Ashar and Al-Haritha. Water samples were collected monthly for each site for a full year, starting in October 2020 until September 2021. The current study included measuring some physical and chemical environmental factors on a monthly basis in the three study sites, The average air temperature ranged from 31.5 °C in the Al-Ashar site to 28 °C in the Siba site, As for the water temperature, there were no significant differences between the study sites, the pH values tended to be neutral between the sites, as the pH rates ranged from 7.1 in the Al-Siba site during the month of June to 8.7 in the Al-Haritha site during the month of September, The average salinity concentrations ranged from 0.53 g/L at Al-Haritha site during the month of September to 22.06 g/L at Al-Siba site during the month of July. During this study, the concentrations of some important nutrients such as active nitrate and active phosphate were measured. The nitrate levels ranged from 14.1 µg/L in Siba site during the month of October to 0.01 µg/L in the same site, while for the effective phosphate values it ranged between 2.24 µg/L at Al-Haritha site during the month of September to 0.01 µg/liter in Siba site during the months of October. The results of the study showed that the highest concentration of hepatotoxins in the biomass of phytoplankton throughout the study period was in Al-Haritha site during the month of June, reaching 5.5 µg/L, while the lowest concentration of these toxins was in Al-Ashar site, reaching 0.1 µg/L during the month of March, in When the highest concentration of hepatotoxins in the Shatt al-Arab waters was 4.8 µg/Lin AL-Siba site during the month of February, and the lowest concentration was in the months of March, September and June in AL-Siba, Al-Ashar and Al-Haritha, respectively, as it amounted to less than 0.15 µg/L. In this study, it was found that some of those environmental factors measured during the study period had an effect on the concentrations of hepatotoxins (MCs) in the phytoplankton biomass in the Shatt Al-Arab River through a significant positive correlation with salinity concentrations at Al-Haritha site, and a significant negative correlation with the air and water temperature in the AL-Siba site also at the probability level $P \leq 0.01$, while the concentrations of those toxins at the level of significance $P \leq 0.05$ in the Shatt Al-Arab water were not related to any of those factors. This study also showed that the concentrations of nutrients of nitrates and phosphates did not have a clear effect on the concentrations of hepatotoxic MCs in the phytoplankton biomass and water in the Shatt Al-Arab River.

Keywords:

1-Introduction

The blue-green algae, which is known as cyanobacteria, is a variety of prokaryotes (Yamada, 2020), which belongs to the Kingdom of primitives Monera, The real bacteria section Eubacteria, Cyanobacteria row (Percival and Williams, 2014) .It is one of the oldest living organisms capable of Photosynthesis and provide the atmosphere for the ground with oxygen, It has had an effective role in that since the first ages and most likely for more than 3.5 billion years (Chittora *et al* .,2020) . Cyanobacteria is generally distributed in various water environments, including ponds, rivers, lakes, and fresh water (Schmidt *et al.*, 2014). In aquatic environments blue-green algae release a wide range of toxic secondary metabolites compounds known as cyanobacterial toxins or cyanotoxins, which was classified according to its toxicity to Hepatotoxins, Nurotoxins, Cytotoxins, Dermatotoxins and Irritating toxins (Blaha *et al.*, 2009) . Chemically algae toxins are classified

Into three groups: alkaloids, alkaloids that include (Anatoxin, saxitoxin and cyclopeptid that include microcystins, and Lipopolysaccharides (Bettina *et al.*, 2000), as these toxins are released into the environment after the death and decomposition of algae cells or when the Bloom occure (Massango, 2007) , as it poses a threat to human health, animal, plant and environment worldwide (Alsultan and Hatem, 2019). The presence of these toxins in the water may reduce their quality and lead to their accumulation and transmission along the food chain, causing the poisoning of other organisms (Zhang et *al.*, 2019) Microcystin is a powerful, carcinogenic hepatic toxin, the most widespread in aquatic environments (Massey *et al.*, 2020). , as this poison is produced by several races belonging to the blue green algae *Anabaena*. Spa, *Anabaenopsis* sp, *M. aeroginosa*, *Nostoc*. Sp , Oscillatory. Sp phormidium and Westiellopsis prolifica (Piyathilaka et al., 2015; Khadairi Nowruzi and Porzan, 2021) et al., 2021.

The Microcystins are Monocyclic Heptapeptides is made up of various amino acids that are essential to express toxicity (Dawson, 1998),

Toxins enter the body through the mouth or via skin contact (Greer et *al.*, 2018). In view of the lack of environmental studies related to the diagnosis and measurement of the concentrations of algal toxins , especially the hepatic toxins (microsystins) in Iraqi water bodies and environmental factors that help in producing them, the current study decided to measure some environmental factors and estimate the concentration of important nutrients such as nitrate and phosphate and its relationship with concentrations of toxins in the waters of the Shatt Al-Arab River in selected sites as well as the quantitative and qualitative diagnosis of microcystins in the waters of Shatt al -Arab as well as in the algal biomass and for a full year in the selected sites

2 . Material and methods

1- Study sites

Three sites were chosen along the Shatt Al Arab River in Basra Governorate in southern Iraq, and they were represented by Siba, Al - Ashar and Al -Hartha. The study focused on the measurement some environmental factors as well as quantitative and qualitative estimate of hepatic toxins in the waters of the Shatt al - Arab River and the live mass of wandering algae in it

2-Sampling collection:

The water samples were collected on a monthly way and for a full year, starting from October 2020 until September 2021 using a small boat, and the direct collection of the water samples included each of the three sites Siba ,Al -Ashar and Al -Hartha , used clean ,airtight plastic bottles made of polyethylene 500 -1000 milliliter , it was collected from under the surface of the water to a depth ranging from 15-20 centimeter, then the water samples were brought to the laboratory for the purpose of determining the concentrations of hepatotoxins MCs in them and nutrients . Some physics and chemical factors were measured directly in the field by three repeat of each of them and included the following factors:

1-Temperature of air and water

Air and water temperatures were recorded in study sites using the Multi-Meter device Model 340i and expressed the output of the category °C.

2- PH

The acidity was measured for the water of the three sites using the Multi-Meter Model 340i after the calibration of the device is done every month before starting the measurement in the field.

3 – **Salinity**

The salinity was measured by using the Multi-Meter Model 340i and expressed the results of a gram / Liter

3- Estimate the concentration of nutrients

The concentration of nitrate and phosphate was estimated by following the roads contained in Persons *et al.*, (1984), APHA, (2012) as the nutrient concentration is estimated at microgram / Liter

4- Estimating the concentrations of hepatotoxins in the waters of the Shatt al-Arab and the living mass of the phytoplanktons

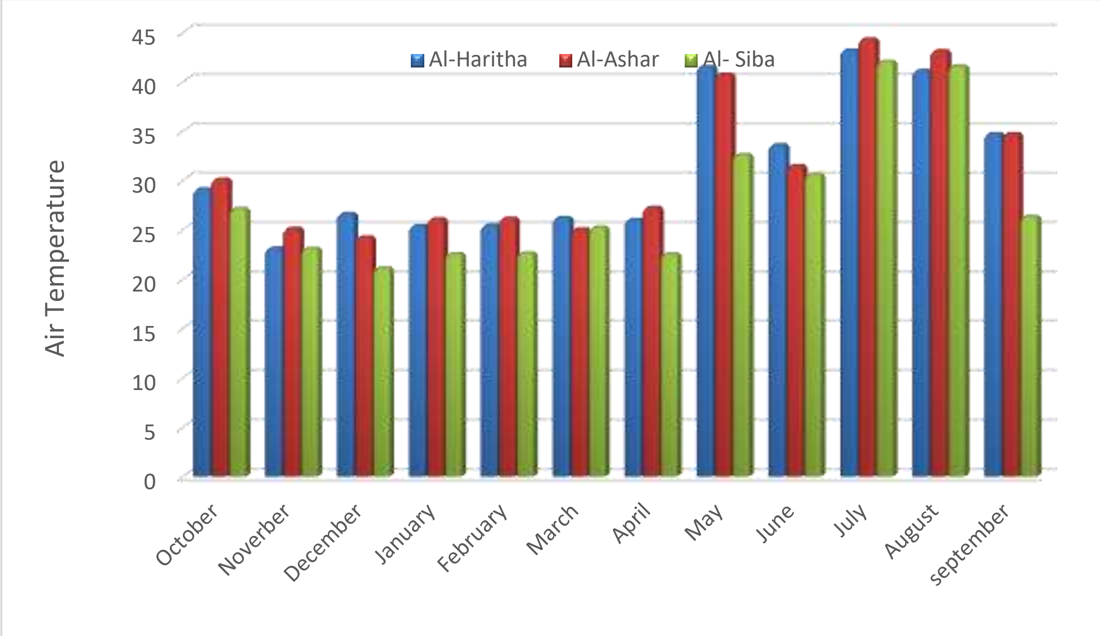
The concentrations of the hepatotoxins were estimated to follow its method Luukkainen *et al.*, (1993), which includes extracting hepatic toxins. After filtering one liter of the water sample for each of the study sites per month using the GF/C filter leaves, following by the technology of gel filtration chromatography, which was explained from Namikoshi,(1993) , then water samples were estimated for all the months of the study and for the three sites by following the associated immunotherapy technology In Enzyme linked Immuno-Sorbent Assay by adopting ready-made solutions kit ELISA-kit and Reader Elisa Biotic, type It includes the addition of 100 Micro liter from both standard solutions to each hole of the Micro titer Plate, following the steps and times included in the private working paper and attached to With ready - made solutions kit and depending on the method (Fisher *et al*., 2001)

3 - Results and discussion

1–Physical and chemical factors

1-1: Air temperature

The lowest average air temperature was recorded at the site of Al -Siba, as it reached 21.1 °C during the month of December, while the highest average was 44.3 °C in July at the Al -Ashar site, and it was noted that the Al -Hartha site recorded the lowest average of air temperature in November, as it reached 23.1 °C and the highest average it reached 43.1 °C in July, as the results of the statistical analysis showed the presence of moral differences in the average of air temperatures between the months of each location at the moral level P≤.0.05 (figure1). As high values were recorded from May and extended to September to all sites and values decreased in the rest of the study months, and this change is normal, as the difference in temperatures returns to the climate in Iraq, which is characterized by heat and dehydration during the summer, cold and rain during the winter as the water temperature is affected by the climatic conditions of the location where the water surface is located (Lou *et al* .,2011)

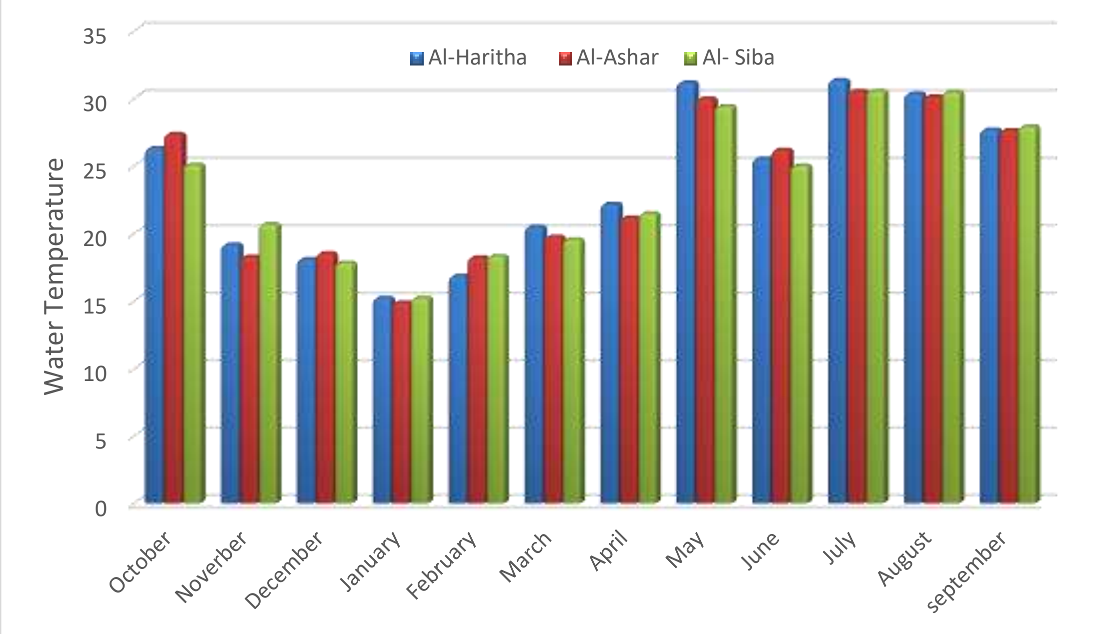


RLSD (Al-Haritha site = 1.09, Al-Ashar site = 0.072, Al- Siba site = 0.331)

Figure (1) Average air temperature (°C) in the Shatt al-Arab waters in the three locations for all months of the study

1-2: water temperature

The results indicated that there are moral differences in the average of water temperatures between the months of each site at the moral level P≤.0.05, as the lowest average of water temperatures was in January in all sites as it reached 14.8 °C in Al -Ashar site and 15.2 °C in the two sites Al- Siba and Al -Haritha, while it was the highest average during the month of July at the site of Al -Harath, as it reached 31.3 °C (figure 2) . Al-Hajuje (2014) indicated that the monthly changes in the air temperature are reflected in the changes in the water temperature in general, as they were high throughout the summer due to the length of the day, and therefore noticeable differences emerged between the months as a result of the manifestation of the context of those conditions on the temperatures of the waters of the Shatt al –Arab river, as it witnessed a rapid rise in water temperatures during the month of May , it reached its peak during the months of July and the Augest, as the waters of the Shatt al -Arab River are affected by the transformations and differences that occur between the seasons of the year(Sarker *et al* ., 1980) and therefore this result is logical , and compatible with most of the previous studies that have been completed on Shatt al -Arab, including the study of(Abdul Razak , 2016 ; Moyel and Hussain , 2015)

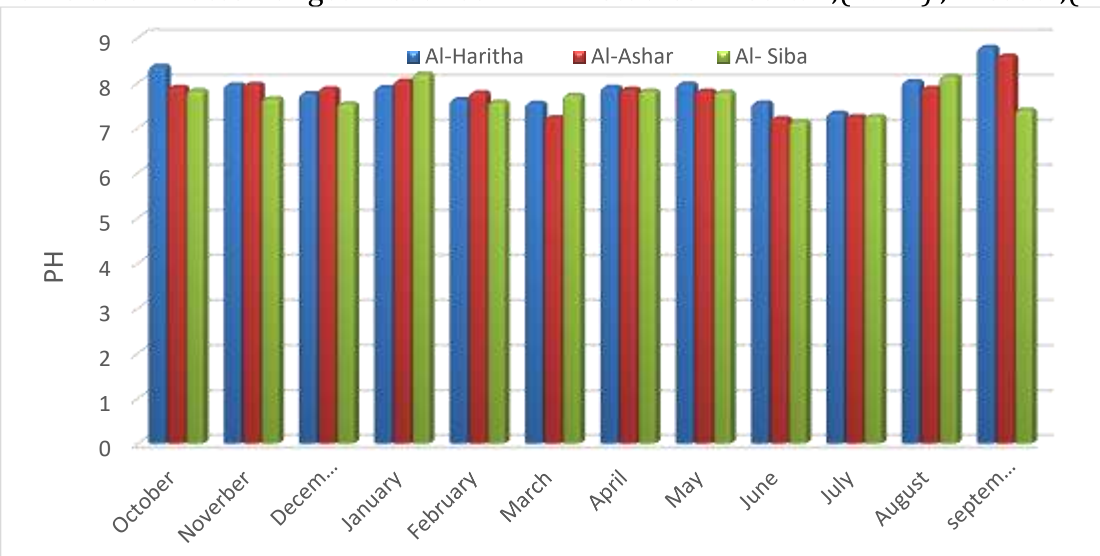


RLSD (Al-Haritha site = 1.21, Al-Ashar site = 0.303, Siba site = 1.057)

Figure (2) Average water temperature (c^0) in the Shatt al-Arab waters in the three sites for all months of the study

1- 3 pH:

The values of the pH did not show a significant disparity between the sites, no significant moral differences appeared under the level of significance P≤0.05 for all months (figure 3), as it reached the highest rate of 8.7 at the Al -Hartha site during the month of September and recorded the lowest rate at the site of Al -Siba during the month of June, as it reached 7.1 ,At the Al -Ashar site all rates ranged between both values during the study period. The current study showed that the values of pH in the waters of the Shatt al -Arab River were within the normal range of aquatic neighborhoods, as it ranged between 8.7 - 7.14, as it tends to be alkaline to neutral throughout the months of the study, which is a dominant feature of Iraqi water surfaces, and this is consistent with what is mentioned in previous studies Al-Sultan,(1999) ,Al-Saadi,(2002).

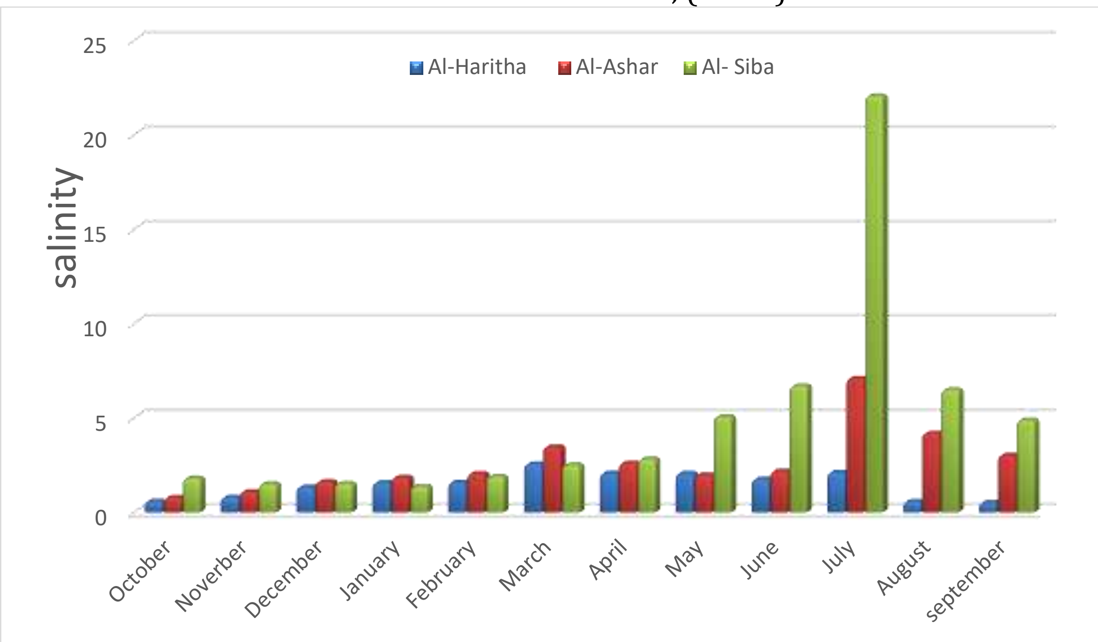


RLSD (Al-Haritha site = 0.35, Al-Ashar site = 0.092, Siba site = no significant differences)

Figure (3) the average pH in the Shatt Al-Arab water in the three sites during the Study

1-4 Salinity:

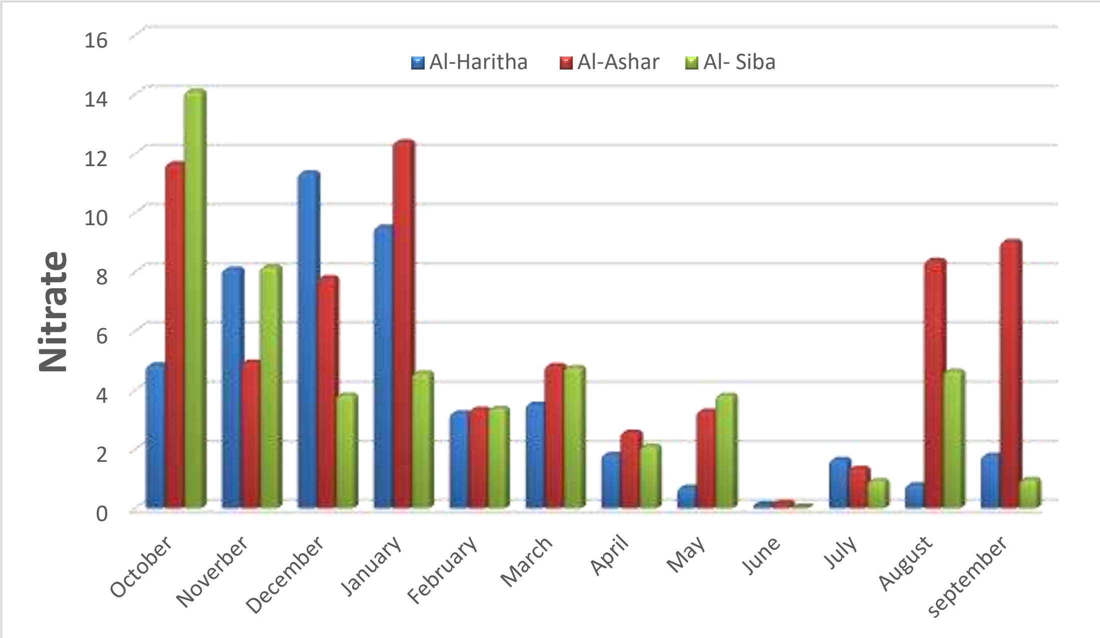
The results indicate that the lowest rate of salinity concentration during the months of the study was recorded on the site of Al -Hartha during the month of September reached 0.53 gram /L, the highest concentration rate reached 2.57 g/L during the month of March in the same site. The values of salinity rates at Al-Ashar site ranged between 7.1 - 0.8 g / L ,
but it increased very clearly at the site of Al - Siba during the months of May, Jun, July, August and September, and reached its peak in July, reaching 22.06 g /L with a moral difference p≤0.05 (figure 4). The results of the current study showed the high rates of salinity concentrations whenever we head to the south, so the highest rate is a record at the site of Al - Siba, while the lowest rate for it at the Al - Hartha site, and this is consistent with what was mentioned in the previous studies conducted by Adam *et al*.,(2007) ; Comine *et al*., (1983) .On the one hand the summer months witnessed an overall increase in salinity concentrations, which reached its peak during July. this may be due to the decrease in water levels and the high temperature rates in the summer, which cause evaporation (Adamus *et al* ., 2001) . On the other hand, the salinity decreased clearly during the winter and autumn months, and this may be due to rain and high level water Adam *et al*., (2007) , this corresponds with the study of AL – Hajaj *et al* ., (2019).



RLSD (Al-Haritha site = 0.339, Al-Ashar site = 0.79, Siba site = 0.281)
(Figure4) Average salinity concentrations (g/l) in Shatt Al-Arab waters in the three sites during the study months

2- Nutrients

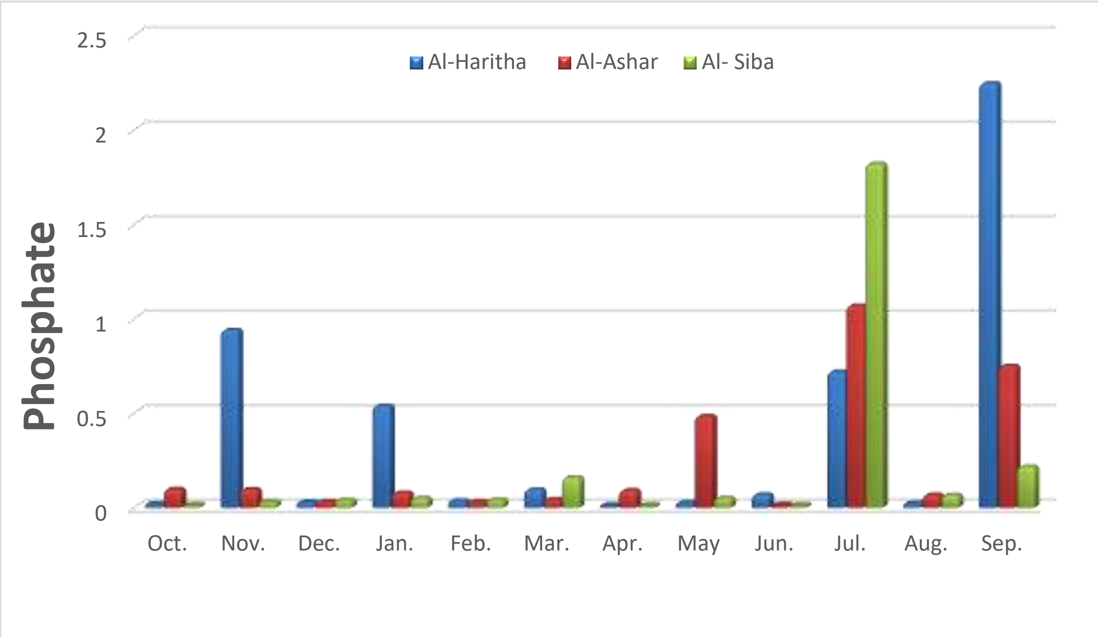
The study recorded high concentrations of nitrate in the three study sites during the months of the study, as they reached 14.1, 12.39 and 11.34 microgram/L during the months of October, January and December in the Al -Siba, Al -Ashar and Al –Hartha sites, respectively, as well as very low concentrations were recorded during the month of June in the three sites. It amounted to 0.17, 0.12 and 0.01 microgram/L in Al -Siba, Al -Ashar and Al -Hartha, respectively, the differences were significant at the level of significance P≤0.05 between the rates of nitrate concentration between the months in each of the study sites (figure 5). It was noticed through the results of the study that most of the high concentrations of nitrate were recorded from October to January in all study sites, after which it decrease from February to September, with the exception of the Al -Ashar site in which it returned to rise during August and September.The rise in the three sites may be attributed to the flow of nitrogen -rich pollutants used in the form of fertilizers and fertilized materials during the surface flow of agricultural fields accompanying the rain during that period (Pradeep *et al* .,2012) or it is possible that it will be due to the shrinking volume of the coming water from the Tigris River to the Shatt al -Arab River during the secondary channels related to it and it decreases the water level and the nitrate concentrations are increasing due to the high content of nitrogenous pollutants in that water , which oxidize and release nitrates into the aqueous ocean due to microorganisms (Turanove *et al*., 2009).



RLSD (Al-Haritha site = 0.049, Al-Ashar site = 0.559, Al-Siba site = 0.911)
Figure (5) Average nitrate concentration (micrograms/liter) in Shatt Al-Arab water in the three sites during the study months

2 -2 Active phosphate PO_4
The results showed significant differences at a level of significance $P \leq 0.05$, the highest concentration of phosphate was recorded in the Al –Hartha site, which amounted 2.24 microgram / Liter in September, followed by the Siba and Al- Ashar sites, which amounted 1.82 and 1.07 microgram / liter , respectively during the month of July, and that the lowest concentration was 0.01 microgram / Liter during the month of April at the Al -Hartha & Siba site(figure 6) .The current study indicated a clear and severe increase in the rate of phosphate concentrations during the months of July and September and for all the study sites and a noticeable decrease in the rest of the months and for all sites as well, and this may be attributed to the rise in temperature rates during the summer, which is accompanied by an increase in the occurrence of evaporation, low water levels and the decline of drainage from The Tigris River exacerbates the concentrations of pollutants coming to the Shatt al -Arab with different types, including the container containing phosphate in their composition such as detergents and agricultural fertilizers as well as the water of the unparalleled sewage, and that the dissolution of dead aquatic neighborhoods contributes to removing phosphorus into the

environment (Valdes and Real ,2004)while the decline may be due to the escalation of the activity and prosperity of phytoplankton and the growth of aquatic plants due to its consumption of abundant amounts of phosphate in water (Lind , 1979) the results of the current study were an approach to the results of the study of Al-Waeli (2021) .



RLSD (Al-Haritha site = 0.049, Al-Ashar site = 0.274, Al-Siba site = 0.019)

Figure (6) average concentration of phosphate (micrograms / liter) in Shatt Al-Arab waters in the three sites during the months of the study

3- Correlation coefficient between ecological factors and concentration of hepatotoxins (MCs

the results of the study showed that there is a positive or negative correlation between the concentration of hepatotoxins in the water of the Shatt al-Arab River for the three sites and environmental factors, but it did not reach the level of significance P≤ 0.05, as it was found that there is a negative inverse relationship between the concentration of hepatotoxins and the pH concentrations in Al-Hartha site, as Spearman's correlation coefficient r = -0.5 , While it was observed that there was a significant correlation between some of these factors and the concentration of hepatotoxins in the biomass at the moral level of P≤ 0.05 and P≤0.01, as the concentration of hepatotoxins was significantly positively correlated with each of the air and water temperature, as well as salinity in the Al-Haritha site. Spearman's correlation coefficient was r = 0.58, r = 0.608, r = 0.636, respectively. , while its correlation was inversely and negatively with each of the air and water temperature at the Siba site, as Spearman's correlation coefficient r = -0.755 and r = -0.79, respectively. It was also found that there is a positive correlation between the concentrations of toxins within the algal cells and the pH at the Al-Ashar site, as Spearman's correlation coefficient reached r = 0.521, and it was a weak correlation that did not reach the level of significance P≤ 0.05 (Table 1).

Table (1) the correlation between environmental factors and hepatotoxins concentrations in water and the biomass of Shatt Al-Arab water expressed by the correlation coefficient (r)

Hepatotoxins concentration at study sites (µg/L)		Environmental factors
Biomass	Water	

Siba	Ashar	Hartha	Siba	Ashar	Hartha	
-0.755**	0.21	0.58*	0.259	-0.217	0..224	Air temperature
-0.79**	0.133	0.608*	0.329	-0.133	0.175	Water temperature
-0.472	0.521	0.211	0.007	-0.345	-0.500	pH
-0.434	-0.196	0.636*	0.294	-0.035	0.315	Salinity

* = Significant at P≤ 0.05 ** = Significant at P≤0.01

4- Correlation coefficient between nutrients and concentration of hepatotoxins (MCs)

The results of the study showed that there is a significant negative correlation at the probability level of P≤0.05 between the concentration of phosphate and the concentration of hepatotoxins in the Shatt Al-Arab water in the Al-Ashar site. The value of the correlation coefficient was r= -0.664 *, and the correlation was positive in the sites of Al-Haritha and Al-Siba, but it did not reach the level of significance P≤0.05 Table (2). it was negative in Al-Ashar and Al-Siba sites, but it was very weak and did not reach the level of significance P≤0.05. The results also showed that the correlation between nitrate concentrations and hepatotoxins concentrations in the Shatt al-Arab waters is a weak negative correlation in the three study sites. Also, nitrate concentrations did not show a significant effect on the hepatotoxins concentrations in the algal biomass.

Table (2)

Correlation coefficient (r) between nutrients and hepatotoxins concentration in the study sites

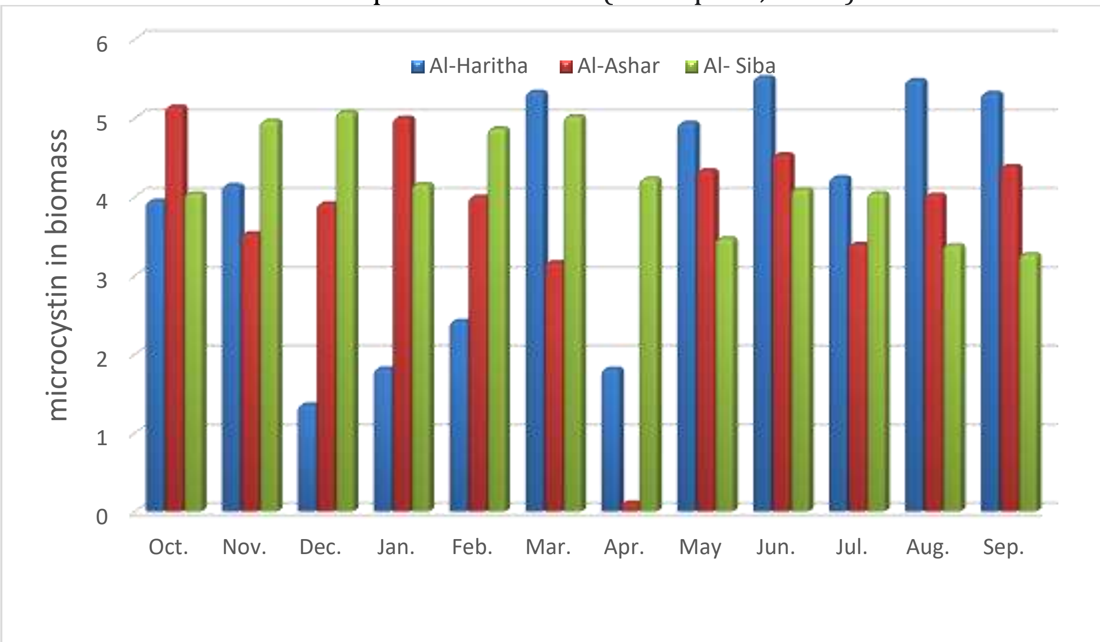
Hepatotoxins concentration at study sites (µg/L)						Nutrients (µg/L)
Biomass			Water			
Siba	Ashar	Hartha	Siba	Ashar	Hartha	
-0.357	-0.77	0.084	0.210	-0.664*	0.308	Active phosphate
0.168	0.343	-0.301	-0.084	-0.091	-0.371	Active nitrate

* = Significant at P≤ 0.05 ** = Significant at P≤0.01

5- Concentration of liver toxins of the biomass of algae in the waters of the Shatt al -Arab between the months of the three sites:

The hepatotoxins differed for the biomass of phytoplankton in the study sites and a significant difference at a moral level p≤0.05 between the highest value of it, which reached 5.50 microgram/liter during the month of June at the Al -Harath site, followed by Al-Ashar site, as the concentration of toxins reached 5.13 microgram/liter during the month of October (figure 7) , then the site of Al -Siba, where the highest value of toxins reached 5.07 microgram/liter during the month of December, then these concentrations decreased to 0.1 microgram/liter in the Al -Ashar site during the month of April, followed by Al-Hartha site where the concentration reached , 1.35 microgram/l during the month of January and finally Al -Siba site 3.26 microgram/L during the month of September .

The high concentrations of toxins in June may be attributed to the conditions available for the best growth of blue green algae, and thus increase their ability to produce microcystins , as the temperature reached 25 and this is a logical result consistent with the study of (Rapala *et al* ., 1997) so those studies show that the temperature has a major impact on the process of producing hepatotoxins ,and that the optimal rate of temperature suitable for producing the highest concentration of hepatotoxins is 25,especially for the genera *Anabaena. sp* and *Microcystis. sp* which contains high levels of microcystins with higher concentrations of slow –growing cells (Long *et al* ., 2011) . In the Al-Ashar site, the concentration of microcystin increased during the month of October only, and it is likely that this is due to the high concentrations of nitrate, as their concentration reached 11.65 micrograms / liter, as nitrate is the inorganic form of nitrogen and it can turn into the organic form by the process of mineralization as a result of the indirect effect of temperatures and as a result the concentrations of organic nutrients in the aquatic environment increases and thus increase the rate of production of hepatotoxins within algal biomass (Kosten *et al* ., 2010) . Salinity also effectively and accurately affects the environment of phytoplankton, as it contributes to their growth and prosperity in the water and the increase in the rate of production of toxins in it (Thompson, 2001).



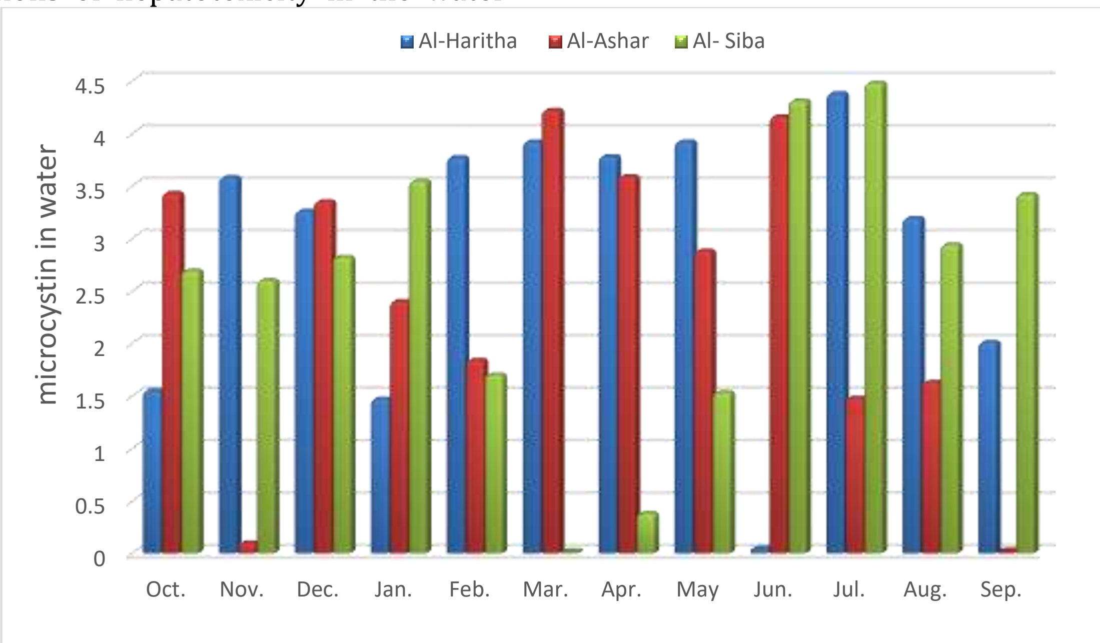
RLSD (Al-Haritha site = 0.045, Al-Ashar site = 0.045, Siba site = 0.759)
Figure (7) Concentration of hepatotoxins of the biomass of the algae in the Shatt al-Arab waters among the months in the study sites

6- Concentrations of Toxins hepatotoxins in the waters of the Shatt al - Arab between the months of the three study sites:

The hepatotoxins in the study sites varied between their highest value, which amounted to 4.48 micrograms / L at the site of Al -Siba during the month of July, followed by the value 4.38 microgram / L in the Al -Harra site during the same month 4.38 and then 4.22 microgram / L during the month of March at Al-Ashar site (figure 8) , differed After that, the high concentrations values to up to very low concentrations of less than 0.15 microgram/l at the Al -Ashar site during the months of November and September, and it reached 0.01 and 0.019 microgram/l, respectively, and in the Al –Hartha site amounted to 0.0423 microgram/l during the month of June, as for the site Al –Siba has reached 0.01 microgram/L during the month of March, as it found significant differences in the concentrations of toxins in the water between the months of the study sites at the moral level P≤0.05 . The reason for this rise may be due to the emergence of the phenomenon of eutrophication, which is accompanied by an increase in phosphate concentrations (Sharpley, 2001). This corresponds to the environmental conditions in the month of July, which was distinguished from the rest of the months by the availability of high concentrations of phosphate and high temperatures at the Siba site, which are the favorable conditions for the occurrence of this phenomenon , and this is compatible with the environmental conditions in the month of July, which was unique than the rest ,this may lead to the recovery and bloom of blue-green algae and increased its bio-volume, and consequently, its higher production of hepatotoxins (Paerl *et al* ; 2011).

High salinity results in a higher percentage of toxins per cell and a faster release into the water as well as proteins and amino acids by *Microcystis auroginosa*, the genus and species most famous for producing these toxins.

. (Osburn *et al* .,2022). The high rate of concentrations of these toxins in the water may be attributed to the decomposition of algal cells after their death and the arrival of their cells to the stage of senescence, so the high concentrations of hepatotoxicity in the water reach the water in which there are (Lam *et al* ., 1995) . As for the decrease in hepatotoxic concentrations in some months in the three sites, this may be due to some aquatic microorganisms that live in riverine and wastewater environments that destroy and degrade hepatotoxins through the biodegradation process (Jones *et al*., 1994; Lahti *et al*., 1997). Arthrobacter sp, Sphingomona sp and Rhodococcus are genera of hepatotoxins aquatic bacteria (de la Cruz *et al*., 2011). The presence of those aquatic bacteria in the water is likely one of the reasons for the low concentrations recorded during the current study, as the concentrations were very low. It was less than 0.15 µg/L during the months of March, June and September in Al-Siba , Al-Harth and Al-Ashar sites, respectively.



RLSD (Al-Haritha site = 0.08, Al-Ashar site = 0.204, Siba site = 0.140)
Figure (8) Concentration of hepatotoxins (µg/L) in Shatt Al-Arab water among the months in the study sites

7- Hepatotoxins of phytoplankton biomass and water for the three sites

The results of the statistical analysis showed that there were significant differences in the concentrations of hepatotoxins between the water and the algal biomass in the Shatt al-Arab river water below the level of significance P≤0.05, as it was found that the concentrations of hepatotoxins in the algal biomass were higher than in the water, reaching 3.95 µg/L. While it decreased in water to 2.62 µg / liter (Figure 9)

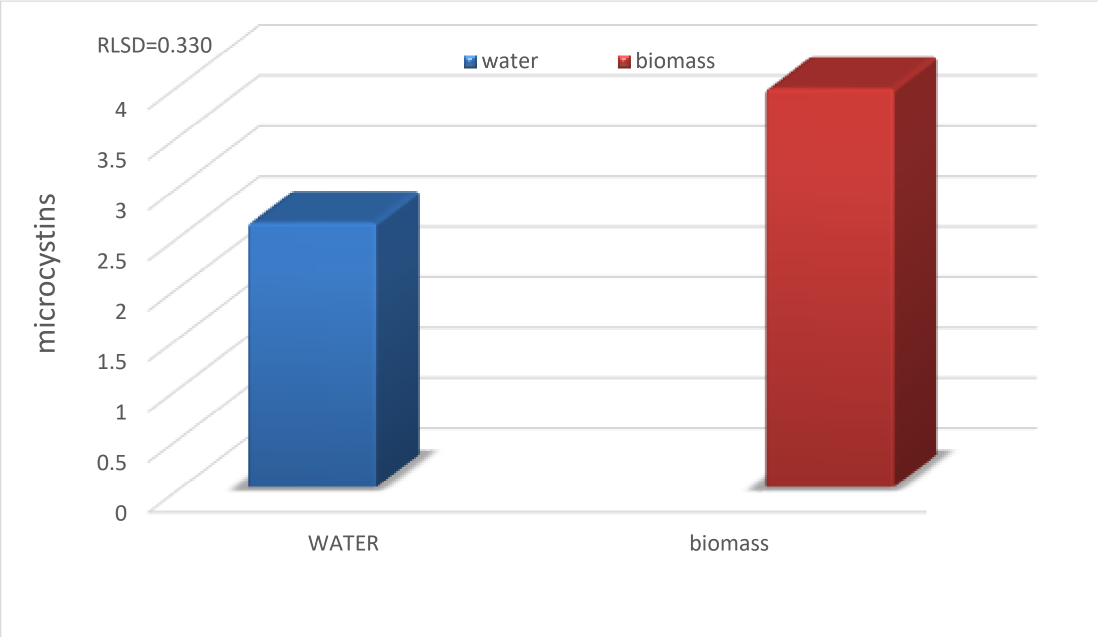


Figure (9) Concentrations of hepatotoxins of algal biomass and water in the Shatt al-Arab River for the three sites and for all months of the study

4 -Conclusion :

The average water temperature did not show any difference as it did not reach the level of morale and was high from May to October and decreased during the rest of the study months and salinity concentrations were high in Siba site during the month of July . The study showed that the highest rate of nitrate concentration was in Al-Ashar site during the study period, and that the highest concentration was recorded during the month of October in Al-Siba site, while the rates of phosphate concentrations did not reach the level of significance in the three study sites, and the highest concentration rate was during the month of September in Hartha site. The concentration of hepatotoxins in algal biomass is higher than that in river water, as it ranged between 5.5-1.81 μg/L and 1.47-4.8 μg/L, respectively. Respectively. This indicates that the water of the Shatt al-Arab has exceeded the limits allowed by the World Health Organization 1 μg / liter. The temperature of air, water, salinity, have a clear effect on the production of hepatotoxicities in the living mass of phytoplankton in the Shatt al-Arab waters. Phosphate and nitrate concentrations did not show a significant effect on the production of these toxins in water and biomass.

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