Journal of Advanced Laboratory Research in Biology
E-ISSN: 0976-7614
Volume 7, Issue 1, 2016
PP 8-13
https://e-journal.sospublication.co.in

Research Article

A study on a sulfur spring (Ain Al Kibrit) ecosystem along Tigris River Mosul, Iraq

Yousif J. Al-Shahri[1], Bahram K. Maulood[2], Janan J. Toma[3*]

[1]*College of Education, University of Mosul, Mosul, Iraq.*
[2]*Hawler Botanical Garden, Hawler, Kurdistan Region of Iraq.*
[3]*College of Science, University of Salahaddin, Hawler, Kurdistan Region of Iraq.*

Abstract: Ain Al Kibrit sulfur spring along Tigris River in contrast with two other stations, before and after the input to the Tigris River were studied. Some chemical, physical parameters (water temperature, pH, EC, alkalinity, total hardness, and sulfate) and total number of phytoplankton were studied during 2003-2004. Samples were taken from the spring, inlet, and outlet along the Tigris River. The results show 5-20 fold differences between stations in almost all parameters, whereas, thermostatic conditions were confirmed in Ain Al Kibrit (24±1). In contrast, the total number of phytoplankton when observed to be fifty folds less in Ain Al Kibrit. This study may be regarded as a first attempt to deal with such factors in this area.

Keywords: Temperature, pH, Electrical conductivity, Alkalinity, Total hardness, Sulfate, Phytoplankton.

1. Introduction

Water is the world's most precious resource because the life of animals and plants depends on it. Most industries also require water for various applications, so one can state that the global economy depends on water. Springs are the places where groundwater is discharged at specific locations on the earth; they vary dramatically as to the type of water they discharge. Many of the springs are the result of long cracks or joints in sedimentary rock, and discharge water which has a temperature above that of the normal local groundwater are called thermal springs (Helwag, 2000 and Todd, 1980). Thermal springs are sites where warm or hot groundwater issues from the earth on a regular basis for at least a predictable period and is significantly above the ambient ground temperature. The distinguishing features of these specialized habitats are their elevated temperature, depressed dissolved oxygen level and high radioactivity (Andrews, 1991). Thermal spring waters are increasingly being used for industrial processing, agriculture, aquaculture, bottled water and the extraction of rare elements (Lund, 2000; Baradacs *et al.*, 2001). Like all natural resources, thermal springs should be managed in a sustainable manner. The availability of current scientific information on thermal springs and their properties is a prerequisite for sound decision-making regarding resource use and development. The physical, chemical and biological composition of water influences to a great extent by different factors including climate, geomorphology, and geology. Thermal springs are characterized by high temperature almost stenothermal, total dissolved solids concentration is high and their value outweighs that in surface water (Darley, 1982). The organisms in these sorts of environment have been dealt with by many authors. Their ecology and taxonomy have been studied in many parts of the world (Odum, 1973; Wetzel, 1979 and Goldman, 1983). In Iraq and Kurdistan, such environment gets less attention and left behind. Apart from, Ibrahim (1981), Al-Nimma and Maulood (1992), Bilbas (2004) there are no studies on such areas. For further increasing our knowledge, this may be regarded as the first attempt for ecology and total number of phytoplankton in thermal springs in Mosul province.

1.1 Description of the area

Iraq is located between latitudes 29° 27' North and longitudes 23° 37' East. It covers an area of 450 thousand square kilometers. Iraq has a hot, dry climate characterized by semi-dry hot summers and cold winters (Al-Shalash, 1966 and Rzoska, 1980) approach of Irano-Turanian type that characterized by the occurrence of three seasons in a year (Al-Shalash, 1966). The source Tigris River, which is the longest river in the Iraqi border, from the water springs in southeastern Turkey. Penetrates about 188 kilometers

*Corresponding author:
E-mail: janan_toma73@yahoo.com.

from the Iraqi border to reach the city of Mosul and canceled along with the river from upstream to downstream about 1718 kilometers. While the total length of the river within the city of Mosul, about 22 kilometers and width of about 650 meters in and receives the river since the entry into the city of Mosul and different variety of pollutants that run on a direct impact on water quality and suitability for different purposes sources (Al-Sanjari, 2001).

Three stations were selected along the Tigris River in the city of Mosul, the first station (Dandan station) is located on the left side of the Tigris River under the fourth bridge directly into the city and one kilometer away almost all Khosr River estuary of the river and the river is characterized in this region down the water flow and the near agricultural lands. The second station (appointed sulfur) on the right bank of the River Tigris near PashTabia citadel, one of the eyes that people come to seek treatment for a long time because the water temperature is warm sulfur eye on throughout the year. Sulfur eye, about 30 miles from the Tigris riverbank. Third station (forest station) this station was chosen on the Tigris River as a natural area is not influenced by faeces of the city, as is the water in this region is not contaminated because it does not pass the residential neighborhoods of the city of Mosul, this is the area before the meeting place of the Tigris River in Khosr River about 3.5 kilometers.

2. Materials and methods

Three stations from Ain al Kibrit sulfur spring were chosen to collect the water samples for the present investigation. Samples are taken from the spring, inlet, and outlet along the Tigris River, and taken in pre-cleaned polyethylene bottle. All water quality parameters are estimated by the standard methods given by (APHA, 1998). Water temperature recorded immediately on the site by mercury thermometer. pH value of the water sample measured by using Digital pH meter. EC values of the water sample under investigation were measured using Digital Conductivity meter. Phenolphthalein and Total alkalinity of the water samples were determined by titrating with H_2SO_4 using phenolphthalein and methyl orange as indicators. The total hardness of the water sample were determined by complexometric titration with EDTA using Eriochrome Black T as an indicator. The sulfate was estimated using UV-Visible spectrophotometer. The modified McNabb method was used to count the total cell number of phytoplankton (Hinton and Maulood, 1980).

3. Results

The Water temperature at the inlet and outlet station were shown in Fig. (1) as the value varied from 5ºC-32ºC in the inlet whereas the outlet value between 5ºC and 22ºC, so the variation was 17-27ºC respectively, in contrast, the spring water temperature sustained around 24ºC with an annual variation with 1ºC, the effect of sulfur spring on the river sample was not evident. pH (Fig. 2) in the spring varied for maximum of 7.6 during the winter (December) to a minimum of 6.7 during the summer (August). In another word the annual variation of 0.9 during the two years of the study. In contrast, the variation of pH value in both outlet and inlet stations were 0.6 and 1.08 respectively. The maximum value was around 8.1 in both stations during the winter, whereas the minimum value never depleted below 7.44 in inlet station and 7.03 in outlet station, this means both maximum and minimum value in the spring were lower than other two stations. Electrical conductivity (Fig. 3) varied from 3900µs/cm to 5615µs/cm with annual variation of 1715µs/cm. In contrast, the annual variation did not exceed to 450µs/cm in both other stations. The maximum value never exceeds to 800µs/cm at any station, whereas the inlet station, the maximum was only 565µs/cm. The annual variation of alkalinity (Fig. 4) in the spring exceeds to 100mg $CaCO_3$/L but the minimum value never fell below to 520mg $CaCO_3$/L, whereas the maximum value exceeded to 630mg $CaCO_3$/L, the other two stations the alkalinity showed almost four-fivefold less than in the spring as maximum value was around of 210mg $CaCO_3$/L and the minimum value was around of 170mg $CaCO_3$/L. Total hardness (Fig. 5) values were always more than 5 folds higher in the spring compared to other station. The maximum value exceeded to 1800mg $CaCO_3$/L which is almost double of that of alkalinity and the minimum never fell below to 1480mg $CaCO_3$/L, the other two station values varied from 200-300mg $CaCO_3$/L. The minimum value of sulfate (Fig. 6) in the spring were recorded 960mg/L in November, whereas the maximum 1150mg/L were recorded during July were a minimum value in the Tigris river in the outlet was only 70mg/L with an annual variation in the river water between 40-70mg/L, whereas the variation in spring water was around of 200mg/L. Total number of phytoplankton (Fig. 7) in the Tigris river before and after in Ain Al Kibrit spring was between 6.7×10^3 to 1.5×10^6 and 0.9×10^3 to 1.7×10^6, in contrast, the spring water total number of phytoplankton never exceeds 0.3×10^3 and fell to as low as 0.07×10^3.

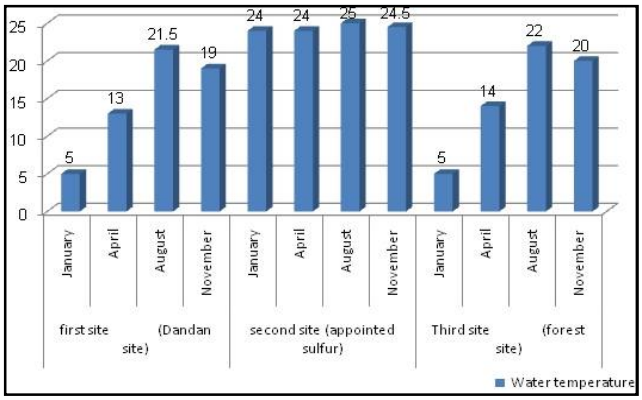

Fig. 1. Water temperature values (Cº) recorded in different sites during the studied period.

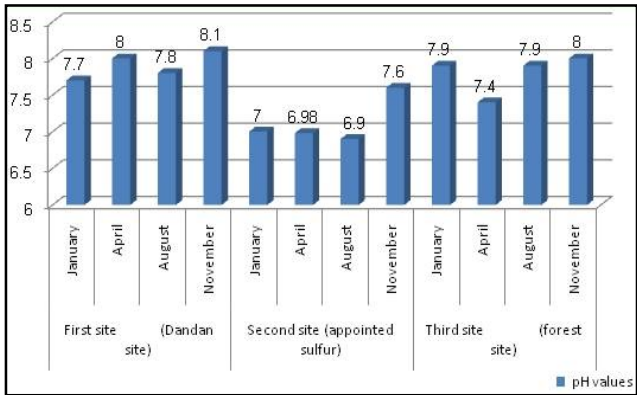

Fig. 2. pH values recorded in different sites during the studied period.

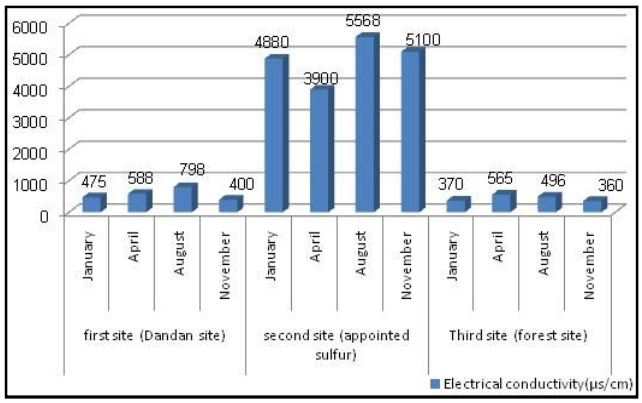

Fig. 3. Electrical conductivity (µs/cm) values recorded in different sites during the studied period.

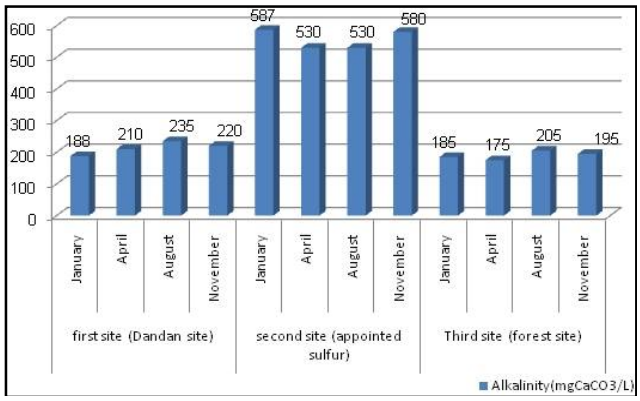

Fig. 4. Alkalinity (mg $CaCO_3$/L) values recorded at different sites during the studied period.

4. Discussions

Temperature is one of the main factors that affect the biological activity both in aquatic environments or land. The great variability in temperature between summer and winter is a natural phenomenon in the study area (site 1 and 3), which lies within the climate Irano-Turanian climate (Talling, 1980). Results showed that the highest water temperature 22ºC were recorded in the August at the site of (3) in the Tigris River while the less water temperature was 5ºC recorded in the month of January in the Tigris River sites (1 and 3).

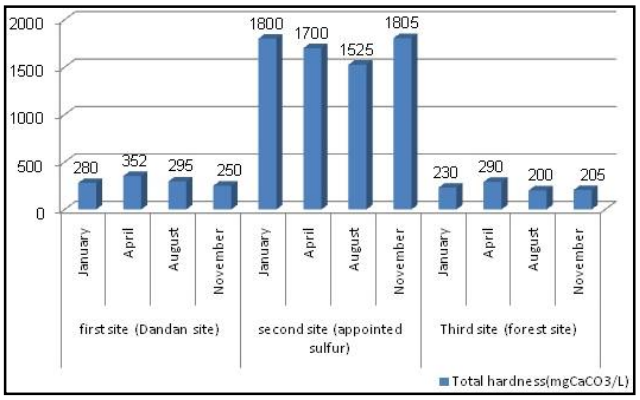

Fig. 5. Total hardness (mg $CaCO_3$/L) values recorded in different sites during the studied period.

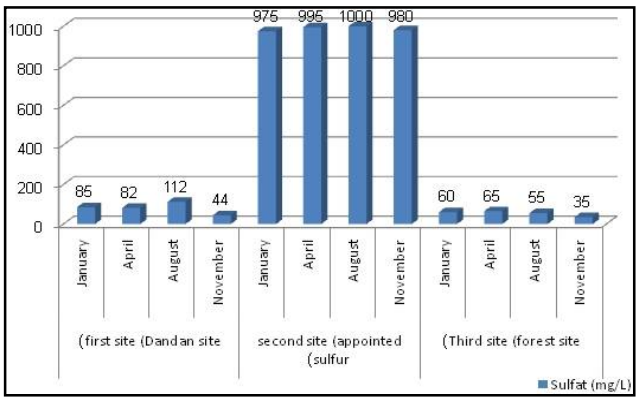

Fig. 6. Sulfate (mg/L) values recorded in different sites during the studied period.

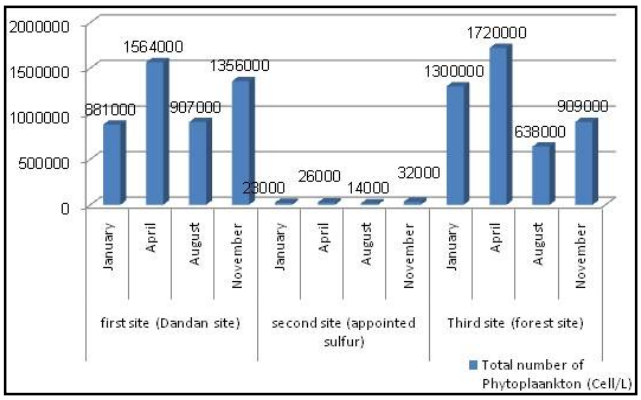

Fig. 7. Total number of phytoplankton (cell/L) values recorded in different sites during the studied.

The rise and fall in the surface water temperature are affected by air temperature in the region despite the slow affected by water to changes in the atmosphere due to the characteristics of the water in terms of its ability to retain temperature despite fluctuating ambient temperature (Al-Mandel, 2005). The rise and fall in water temperatures recorded in the Tigris River sites followed the rise and fall in the air temperature and the

intensity of the sun and the clouds showed their effect on the water temperature this was evident in the beginning of spring and autumn and comes in accordance to (Al-Nimma, 1982).

A little change of water temperature (24-25°C) was recorded in Hammam Ali sulfur spring throughout the year. A phenomenon known in the waters of springs and wells referred to Tallee *et al.*, 2002. Tallee *et al.*, 1994, observed the water temperature in appointing Nuran was (20-22ºC). Similar conclusion observed by Hinton and Maulood (1980) in Serchinar water and appointed Khormal, and Raoof (2002) appointed sulfur north Dohuk Lake.

When studying the qualitative characteristics of natural water, pH plays a significant role in the chemical and biological balance in these waters (Khamese and Ayoub, 1989).

Results indicate that the pH value in the study area ranges between 6.9 to 8.1. These findings are consistent with the findings of Al-Sanjari (2001) and Tallee *et al.*, (1994) with their study of the waters of the Tigris River in the city of Mosul. Talling (1980) observed that the pH value of the inland waters of Iraq is near to 8.0 which is close to a base. The tendency of these values toward the basal relatively may be due to the presence of ions; carbonate and bicarbonate (APHA, 1998). Which indicates that the natural water tends toward a base because of the presence of bicarbonate and carbonate basal ions, as the study area characterized by soil and groundwater bodies its proximity high proportion of carbonate (Al-Safawi, 2006).

The higher pH values in the study area of the Tigris River was during the rainy season and was the lowest values during the summer season and is due to the erosion of the soil with the floods and wash the streets of the city Mosul and transfer to the Rivers, when it rains, carrying with them the carbonate lead to the lifting of values pH. As well as increasing the pH value coincides with the activity of algae and increases the number of phytoplankton (Goldman and Horn, 1983).

Similar conclusion observed by Tallee and Al-Qazaz, 1997 and Tallee *et al*., 1994, in Tigris and Khosr River in the city of Mosul. As for the relative variation of the values of pH in the appointed sulfur, which ranged between 6.9 to 7.6, was due to the influence of rainwater, and the nature of the geological formations through which water was appointed sulfur (Al-Safawi, 2006).

Electrical conductivity of the water is a measure of the ability of water to carry electric current depends on the concentration of ions dissolved in water and water temperature (Hasssan, 2001).

In this study, it has been observed that the electrical conductivity of the water during the winter and spring is decreased, and attributed the cause of the dilution of the water due to the rains and increased river discharge. Water, either in times of electrical conductivity in all station values have increased and that was a result of increased evaporation and concentration of element ions in the water during the summer and autumn. The phenomenon of low electrical conductivity values during the winter and increase during the summer have been observed by both Talling (1980) and Sanjari (2001) in Iraqi Rivers.

The sulfur appointed station has the highest electrical conductivity values recorded in this study compared to other stations, reaching the electrical conductivity values in the month of August is 5568µs/cm. The high electrical conductivity values observed in the sulfur appointed due to the geological nature of the study area back to Lower fars Knight and rich. The fossil-rich salts, gypsum and lime, which is working to increase the concentration of sulfate ions, calcium, and chloride magnesium and others when it dissolves in water, where it works to raise the electrical conductivity values (Al-Sawaf, 1977), this approach as a result of the findings of the Al-Nimma and Maulood (1992).

The base is a function of water content of carbonate, bicarbonates, and hydroxides are used to determine the validity of water for various purposes (APHA, 1998). Because the pH values during the study period reached 6.9 to 8.1, this indicates that the basal cause in the water and this is bicarbonate a series of studies in the region (Al-Sanjari, 2001; Al-Refai, 2005 and Muhammad, 2004). The result of this study is approached to results obtained in different studied in different part of Iraq (Abdul-Jabbar, 1981; Maulood and Hinton, 1980 and Al-Shahwani, 1980).

The sulfur appointed station has recorded the highest values of total base during the study period, compared to the stations studied and mainly this is due to the geological composition of the area, a result of what he referred to approach Jamel *et al.*, (1990), when their study of groundwater in the province of Kirkuk.

The hardness of water varies depending on water resource, as surface water is less than ten compared to groundwater. This follows the geological character of the land is by the water or passes through (Sawyer and McCarty, 1978). Results showed the total hardness values of 200-1805mg $CaCO_3$/L during the study period. This variation in hardness values of the collage may be due to the concentration of calcium and magnesium ions in the water and sewage discharged into the river. Moreover, the geological nature of the sites selected for this study (Sawyer and McCarty, 1978).

The results obtained were approach of the results those were obtained by the Al-Sanjari (2001) and Al-Refai (2005) in River Tigris within Mosul city. In other parts of Iraq, the values recorded for hardness close to what was obtained in this study (Al-Nimma, 1982; Al-Barzingy, 1995; Ganjo, 1997 and Bapper, 2004).

In this study, the highest values of total hardness are recorded at the sulfur appointed station. It has the highest total hardness percentage 1805mg $CaCO_3$/L and this is much higher total hardness observed in other stations, and this is due to the properties of mineral

water, for example the nature of the geological rock gypsum and limestone located in an area that runs from which even up to the surface a significant impact on the overall increase in hardness that station due to the content of these rocks of elemental calcium and magnesium that increases the hardness in water (Jamel *et al*., 1990).

The sulfate ions of the most prevalent forms of compounds sulfur in natural water as exists with different concentrations ranging from a few milligrams to thousands of milligrams per liter, according to the geological nature (APHA, 1998).

The variation of sulfate ion concentrations during the study period is due to several reasons, including variation in the discharge of sewage in the Tigris River, as well as the presence of sulfur appointed at the some of the study sites and to the geological nature of the study area (Tallee *et al*., 1997).

As for the station has appointed a high sulfur concentration recorded amounted to 1,000mg/liter, which is much higher than surface water studied, the reason that goes back to the geological nature of the city of Mosul, leading to melting gypsum rocks (Al-Asho, 1987). Results of this study approach to the results obtained by Al-Mashhadani *et al*., (1989).

Maulood and Al-Saadi (1996) explain that the kinds of algae wandering and outstanding constitute the main base in ecological pyramid water bodies and in the production estimate. The obvious difference in the total number of algae in the Tigris River regions and sulfur appointed station came expecting as studies published in the rivers Tigris and Euphrates in Iraq by different authors (Maulood and Al-Saadi, 1990; Al-Saadi *et al*., 1976 and Al-Lami, 1986).

The results show that the height of the growth of algae during the spring in the Tigris River began in March and lasted in the month of June, reaching the total number of algae to around a million and seven hundred thousand cells per liter and this can be compared and confirm with Abdul-Jabbar (1981) said that the total number reached one million and six hundred thousand cells per liter in the Lesser Zab river. While the Al-Nimma (1982) observed that the total number of algae reached to three and a half million cells per liter in the study of the Euphrates River. The second peak of the growth of algae during the study period on the Tigris River was observed during the autumn, where the number increase to one million and three hundred thousand cells per liter, and for this we note that the peak of the fall was lower about the peak of a spring, and this is consistent with what has been observed by Hassan (2001) in River Tigris in Mosul.

The appointed sulfur station showed low numbers of algae compared to other stations during this study, in terms of numbers of algae 32,000 cells per liter reached in the month of November and 26,000 cells per liter in April. The low growth of algae at this station goes back to the characteristics that distinguished the mineral water as a result of the nature of the geology of the area (Al-Sawaf, 1977). These results are consistent with the Kana, (2001) when his observation for a few types of algae when appointed sulfur station in the city of Mosul.

However, the more detail study is required to understand the role of the factors in aquatic ecosystem especially thermal springs or sulfur springs. Such springs still used for medical treatment and skin disease.

References

[1]. Abdul-Jabbar, R.A. (1981). An ecological study on lesser Zab. M.Sc. Thesis, Univ. of Sulaymaniyah, Iraq.

[2]. Al-Asho, M.O. (1987). Engineering Geology. Ministry of Higher Education. University of Mosul. Iraq.

[3]. Al-Barzingy, Y.O.M. (1995). Phycological study within Erbil Province. M.Sc. Thesis, Univ. of Salahaddin –Erbil.

[4]. Al-Lami, A.A. (1986). An ecological study on the phytoplankton in some marshes in southern Iraq. M.Sc. Thesis, University of Basrah, Iraq.

[5]. Al-Mandel, F.A.M. (2005). Ecological and Limnological study on phytoplankton Regulatory Mosul Dam Lake. M.Sc. Thesis, Mosul University. Iraq.

[6]. Al-Mashhadani, Y.D., Tallee, A.Y. and Al-Hafouzi, S.M. (1989). Groundwater that extended between Mosul city and Bashiqa district. *Journal of Education and Sciences*, 9:11-21.

[7]. Al-Nimma, B.A. and Maulood, B.K. (1992). A study on the distribution of algae in some thermal springs in Nineveh province, Iraq. *J. Ibn. Al-Haitham*, 3(2): 1-9.

[8]. Al-Nimma, B.A.B. (1982). Studies on the limnology of Tigris and Euphrates River. M.Sc. Thesis, Salahaddin University, Erbil, Iraq.

[9]. Al-Refai, M.H.M. (2005). Assess the quality of the water basin and bitter Valley and its impact on the quality of the Tigris River water. M.Sc. Thesis, Mosul University, Iraq.

[10]. Al-Saadi, H.A., Hadi, R.A. and Huq, M.F. (1976). Preliminary studies on the phytoplankton of north-west Arab Gulf. 1. Related environmental characters, chlorophyll-a content and phytoplankton species. *Bangladesh J. Bot.*, 5(1):9-21.

[11]. Al-Saadi, H.A., Al-Lami, A.A. and Kassim, T.I. (1996). Algal ecology and composition in the Garmat-Ali River, Iraq. *River, Research and Applications*, 12:27-38.

[12]. Al-Safawi, A.Y. (2006). Environmental pollution of the city of Mosul and methods of treatment. Ph.D. Thesis, Mosul University. Iraq.

[13]. Al-Sanjari, M.F.M. (2001). Environmental study of the Tigris River in the city of Mosul. M.Sc. Thesis, Mosul University. Iraq.

[14]. Al-Sawaf, F.D.S. (1977). Sulfate reduction and sulfur deposition in the Lower Fars Formation, northern Iraq. *Economic Geology*, 72:608-618.
[15]. Al-Shahwani, S.M.H. (1980). A study on the primary productivity of Serchinar. M.Sc. Thesis, Univ. of Sulaimaniya, Iraq.
[16]. Andrews, J.N. (1991). Radioactivity and dissolved gases in the thermal water of Bath. In: Kellaway, G.A. (Ed), The hot springs of Bath: Investigations of the thermal waters of the Avon valley. Bath: Bath City Council, pp 157–170
[17]. APHA (1998). "Standard Methods for the Examination of Water and Wastewater", *American Public Health Association*, 20th edition, Washington. D.C.
[18]. Bapeer, U.H.K. (2004). Ecological study on the distribution of algae in different aquatic habitats within Erbil province. Ph.D. Thesis. University of Salahaddin, College of Sciences, Erbil, Iraq.
[19]. Baradacs, E., Hunyadi, I., Dezso, Z., Csige, I., Szerbin, P. (2001). Rain geothermal and bottled mineral waters of Hungary. *Radiation Measurements*, 34(1-6): 385-390.
[20]. Bilbas, A.H.A. (2004). Phycolimnological study on some springs within Erbil province. M.Sc. Thesis University of Salahaddin, Iraq.
[21]. Darley, W.M. (1982). Algal Biology: a physiological approach. 1st edition. Blackwell Scientific Publication, Oxford, London 168pp.
[22]. Ganjo, D.G.A. (1997). An Ecological study on Ruwandiz river path within Erbil province, Iraq. Ph.D. Thesis. Univ. of Salahaddin, Iraq.
[23]. Goldman, C.R. & Horne, A.J. (1983). Limnology. McGraw-Hill Book Company, New York, 464 pp.
[24]. Goldman, C.R. and Horne, A.J. (1983). Limnology. International Student Edition. McGraw-Hill International Book Company, London, pp. 197– 220.
[25]. Hasssan, F.I.M. (2001). Limited to the impact of the increase of algae in the Tigris River and its impact on the filter stations in the city of Mosul. M.Sc. Thesis, Mosul University. Iraq.
[26]. Helwag, O.J. (2000). Water for a growing population: Water supply and groundwater issue in developing countries. *Water International*, 25(1): 33-39.
[27]. Hinton, G.C. and B.K. Maulood (1980). Some diatoms from brackish water habitat in southern Iraq. *Nova Hedwigia*, 33: 475-486.
[28]. Ibrahim, A.M.K.A. (1981). Study on algal ecology of springs in Sulaymaniyah province. M.Sc. Thesis, Sulaymaniyah University.
[29]. Jamel, A.A., Fazel, L. and Talee, A.Y. (1990). The study of qualitative characteristics of some water sources in Tamim province and its suitability for civil and industrial uses, irrigation. Second scientific conference of the Center for Saddam, University of Mosul, Dam Research. Iraq.
[30]. Kana, A.M.A. (2001). Typical study of sulfur Groundwater in Mosul province. M.Sc. Thesis, University of Mosul, Iraq.
[31]. Khamese, H.S. and Ayoub, M.H. (1989). Biological fresh water. Higher Education Press in Mosul.
[32]. Lund, J.W. (2000). Balneological use of thermal water in the USA. *GHC Bulletin*, September, 31-34.
[33]. Maulood, B.K. and Hinton, G.C.F. (1980). A study on the pollution ecology of Kliassan river particular reference to Sulaimania Sugar factory. *Zanco (Sci. J. Univ. Sulaimania, Iraq), Series A*, 6(1): 97-124.
[34]. Maulood, B.K. and Al-Saadi, H.A. (1990). Aquatic Ecology in Southern Iraq. Eleventh Scientific Conference of Iraq. Biology. Soc. Basrah. 27 Feb-2 March 1990.
[35]. Muhammad, S.A. (2004). An ecological study on the aquatic life of Serchinar spring and Kliassan streams. M.Sc. Thesis, Sulaimania University, Iraq.
[36]. Odum, E.P. (1971). Fundamentals of ecology. 3rd edn. W.B. Saunders Co., Philadelphia and Toppan Co. Ltd., Tokoyo, Japan. 574p.
[37]. Raoof, I.Y. (2002). A phycolimnological study on Duhok impoundment and its main Watershed. Ph.D. Thesis, University of Dohuk.
[38]. Sawyer, C.N. and McCarty, P.L. (1978). Chemistry for Environmental Engineering. 3rd edition. McGraw-Hill Book Company. 365pp.
[39]. Tallee, A.Y.I. and Al-Qazaz, Kh.N. (1997). A study of some chemical properties to assess Khosr River water for irrigation. Fourth Scientific Conference. Saddam Center for Research.
[40]. Tallee, A.Y., Al-Qazaz, Kh.N., Khalil, M.A. and Salim, M.S. (1994). Khosr River water pollution and its impact on the Tigris River water quality at the center of the city of Mosul. *Journal of River Engineering*, 3:45-56.
[41]. Tallee, A.Y., Ibrahim, A. and Safawi, N.T. (2002). The study of groundwater quality Alkonsah village and suitability for domestic use. *Journal of Education, Science*. 4:19-29.
[42]. Talling, J.F. (1980). Phytoplankton. In: Rzoska, J. (ed), Euphrates and Tigris, Mesopotamia Ecology and Destiny. Vol. 38. Monographiae Biologica. W. Junk. The Hague-Boston. London. 122pp.
[43]. Todd, D.K. (1980). Groundwater Hydrology. 2nd edn., Wiley, New York.
[44]. Wetzel, R.G. (1983). Limnology. (2nd Edition; Complete Revision) Saunders College Publishing, Philadelphia. 858 pp.