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Spatial and Temporal Variability Analyses of Water Quality in Jaghjagh River, Syria

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Abstract

Intensively used for irrigation, the Jaghjagh River in the northeastern region of Syria is polluted by municipal and industrial wastewaters. This study is aimed at assessing the spatial and temporal changes in the water quality of the Jaghjagh River in order to evaluate the existence of any potential impact of the water of the river used for irrigation and agriculture. Monthly water samples were collected regularly during the years 2012-2013 from three locations that are 2 km apart. The samples were analyzed for physicochemical characteristics. The results of the analysis showed that water quality parameters varied spatially and temporally. The spatial variation of the parameters was clearly shown at the location from 1 to 3, and the significant difference of SS, EC, TDS, CODcr, BOD5, PO43-, Cl- and NH4+ was obvious at location 3 compared to the values at locations 1 and 2, reaching the values of 56.6 mg/l, 744.0 µS/cm, 326.5 mg/l, 111.7 mg/l, 10.57mg/l, 99.4 mg/l and 22.17 mg/l respectively, while Nitrate demonstrated decreasing values at locations 1 to 3. Depending on the seasonal stream flow in winter (high rainfall) and summer (no rainfall), the temporal variation with significant difference was clearly recognized for the following parameters EC, TDS, PO43- . NH4+ and Cl- reached the values of 670.0 µS/cm, 329.4 mg/l, 9.30 mg/l, 4.22 mg/l and 15.0 mg/l respectively. So to improve the water quality of the Jaghjagh River, basin management and treatment of municipal and industrial wastewaters are recommended. Moreover, further detailed studies of spatial and temporal modelling and prediction are required.

Keywords: Jaghjagh River, irrigation, pollution, Syria, wastewater

1. Introduction

The importance of rivers and surface water resources for communities has been recognized and stressed by several authors (Priscoli, 1998; Khadse et al., 2008). For this reason, most cities, industrial centers, and agricultural activities were established very close to streams and other surface water resources (FAO, 2011). As a result of the rapid population growth and climate change (Al-Dabbas, et al., 2018), water quality has become an important issue in recent years. The provision of drinking and irrigation water faces major challenges, including the shortage of water and the poor quality of the waters (Al-Ansari, 2013). Water pollution, whether from sewage, industrial waste, or chemicals used in agriculture such as pesticides and fertilizers, has led to a lack of adequate water for domestic, industrial, and agricultural needs (ESCWA, 2000). Due to the intense development of industry and agriculture, the water ecosystem has been perceptibly altered in several respects in recent years. Today, water resources are exposed to a variety of local disturbances across the globe (Vencatesan, 2007). Often, wastewater is drained into rivers, valleys, and agricultural land without treatment, especially in third world countries due to the high costs of processing and treatment (FAO, 2003; Hussein et al., 2004). Wastewater brings with it significant quantities of organic and inorganic pollutants to the water bodies and agricultural soils (Feizi, 2001; Wang et al., 2003; Hussain et al., 2006).

In several arid and semi-arid countries, water deficits have forced planners and decision-makers to utilize any available source of water that can be used cheaply to encourage further development. This has led to a decline in freshwater sources in most Mediterranean regions and an urgent need to preserve and protect those resources (Bahri, 2002). Population growth, climate change, drought, and the increasing demand for water resources have added greater pressure on water resources while simultaneously impairing surface water quality as a result of pollution discharge from industrial and agricultural activities (IPCC, 2007; Razzaghmanesh et al., 2005). On the whole, spatial variation in river water quality is motivated by natural catchment characteristics (e.g., climate, geology, soil type, topography, and hydrology) and also by human undertakings within catchments (e.g., Land use and management, plants cover etc.) (Lintern et al., 2018). However, the capability to manage and decrease water quality effects is disadvantaged by the variability in water quality both spatially and temporally, and the incapacity to expect this variability. (Ai et al., 2015). So, in order to develop operative management strategies for rivers' water quality, it is critical to be able to predict these spatio-temporal variabilities (Danlu el at, 2019).

According to spatial and temporal changes in the water quality of the river, the situation requires the development of an integrated program to monitor the physicochemical variables at different locations along the river in order

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to draw a clear map of the water quality (Kenneth, 2003). Therefore, water quality monitoring is critical for ensuring that water resources are managed correctly and remain within the acceptable limits for sustainable use. The agricultural lands in some villages of Al-Qamishli region are haphazardly irrigated by water from the Jaghjagh River without awareness of the impact of irrigation with this water quality on soil management, crops, and the wider social and natural environments. The aim of this research is to estimate the spatial and temporal changes in water quality of the Jaghjagh River within the Al-Qamishli region and to evaluate its potential impact on agriculture and irrigation.

2. Materials and Method

2.1 Study area

The Jaghjagh River is a small perennial in eastern North Syria, flowing from Turkey through the city of Al-Qamishli and continuing its path to the city of Al-Hasakah where it reaches its estuary at Khabur River. The sewage and solid wastes are dumped into the river from the cities of Nisibin and Al-Qamishli.

The climate in this region is semi-arid with an average annual rainfall of about 442 mm, a major part of which is received during the winter season.

2.2 River Water Sampling

Water samples were collected from three locations with a distance of 2 km between each sampling location (Figure 1), with coordinates illustrated in (Table 1), over a period of twenty-four months from January 2012 to December 2013. The monthly samples of the subsurface water were collected in triplicates during the first week of each month in the early hours of the day (7 a.m. to 9 a.m.). Iodine-treated double Stoppard polyethylene bottles were used for the collection of the water samples, which were kept in an ice bucket and brought to the laboratory for analysis. Some of the physicochemical characteristics of water, such as temperature and pH were measured using a mercury thermometer and digital pH-meter, respectively; other parameters including turbidity, electrical conductivity, total dissolved solids, nitrate-nitrogen, phosphates, biochemical oxygen demand, chemical oxygen demand, ammonia, were analyzed in the laboratory within six to eight hours using the methods of APHA (1985). Figure 2 illustrates the sampling locations selected for this study.

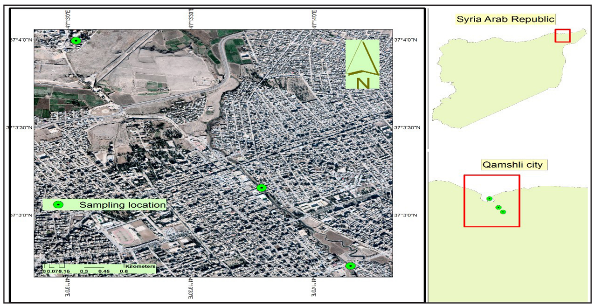

Figure 1. The sampling locations from Jaghjagh River in eastern North Syria.

Table 1. Coordinates of sampling locations

Sampling Location		Coordinates
1	river to the Syrian boundaries the beginning of entering the	Latitude: 37° 3’59.62”N Longitude: 41°13’32.07”E
2	2 km away from the previous location, the centre of the town, intensive sewage and industrial water is thrown into the river.	Latitude: 37° 3’9.35”N Longitude: 41°13’47.25”E
3	2 km away from the second location, industrial area.	Latitude: 37° 2’42.67”N Longitude: 41°14’8.94”E

Figure 2. Photos of some water sampling locations. (Source: Dr.Rami Kaba)

3. Results and Discussion

The range of variation and their annual mean along with a standard deviation of various physico-chemical characteristics of Jaghjagh River water are given in Table 2. Spatial variations are shown in Table 3. A seasonal variation is shown in Table 4. The monthly variations in water quality are depicted in Figures 3 to 12, while the correlation coefficients between different parameters are presented in Table 5. The high standard deviation indicates that the data are widely spread, due to the presence of temporal variations caused likely by natural and/or anthropogenic polluting sources.

Table 2. Range of variation, mean, and standard deviation of water quality parameters of the Jaghjagh River water

Parameters	2012			2013		
	Range of variation		Mean and Standard deviation	Range of variation		Mean and Standard Deviation
	Minimum	Maximum		Minimum	Maximum	
Ta	12	46	23.29±10.24	11.0	41.0	20.96±6.54
Tw	9.1	32.1	20.29±6.93	10.0	33.0	22.81±10.05
SS	7	124	26.94±26.11	8.0	129.0	33.78±30.58
pH	6.8	8.1	7.436±0.320	6.9	7.9	7.372±0.258
EC	370.0	1056.0	593.0±175.9	373.0	1022.0	594.3±178.5
TDS	171.0	500.0	282.1±79.6	220.0	509.0	292.1±59.9
COD_{cr}	4.0	290.0	71.7±75.8	14.0	367.0	60.5±70.5
BOD_5	2.00	155.00	40.36±43.51	3.00	150.00	29.94±32.94
Nitrate NO_3^-	0.00	16.90	2.856±4.535	0.100	11.00	1.978±2.382
PO_4^{-3}	0.13	29.10	5.69±6.94	0.200	22.40	6.395±6.139
Cl^-	4.0	410.0	44.7±73.9	17.0	519.0	53.0±87.7
NH_4^+	1.0	55.0	12.00±12.9	1.0	54.0	12.56±12.40

Where Ta is Air Temperature, °C , Tw is Water Temperature, °C, SS is Suspended Solids mg/l, EC is Electrical Conductivity, µS/cm, TDS is Total Dissolved Substance, mg/l, CODcr is Chemical Oxygen Demand, mg/l, BOD5 is Biological Oxygen mg/l, NO3- is Nitrate, PO4-3 is Phosphate, mg/l, Cl- is chloride, mg/l, NH4+ is Ammunium,mg/l.

Table 3. Spatial variations of water quality parameters during the study period.

	Sampling Locations			
Parameters	**1 Loc.**	**2 Loc.**	**3 Loc.**	**LSD 95%**
Ta	22.42a	22.52a	23.48b	0.721
Tw	20.37a	20.13a	21.36b	0.622
SS	16.3a	18.1a	56.6b	11.34
pH	7.48a	7.4a	7.39a	0.1254
EC	506a	531a	744b	60.5
TDS	267.6a	267.2a	326.5b	26.86
COD_{cr}	56.4a	49.6a	111.7b	29.96
BOD_5	22.9a	23.1a	59.4b	14.09
Nitrate	3.15a	2.40ba	1.70cb	1.252
PO_4^{3-}	3.74a	3.82a	10.57b	2.666
CL^-	22.6a	24.5a	99.4b	42.59
NH_4^+	7.53a	7.14a	22.17b	4.31

Table 4. Seasonal variations of water quality parameters during the study period

	Seasonal variations				
Parameters	Winter	Spring	Summer	Autumn	LSD 95%
Ta	13.05a	21.50b	35.92c	20.75b	4.346
Tw	14.24a	20.62b	28.13c	19.50b	3.027
SS	35.0a	24.1a	35.3a	27.1a	14.47
pH	7.36bc	7.59a	7.23c	7.42b	0.159
EC	479a	611b	670b	632b	88.6
TDS	242.4a	270.3b	329.4c	306.2bc	38.51
COD_{cr}	64.4a	51.9a	81.9a	92.1a	45.18
BOD_5	31.0a	32.3a	37.8a	39.5a	22.11
Nitrate	0.72a	1.08a	4.22b	3.64b	2.347
PO_4^{-3}	4.91a	4.45a	9.30b	5.52a	1.467
CL^-	27.1a	77.4b	49.7a	41.1a	49.10
NH_4^+	9.9a	11.1ab	15.0cb	13.2ab	5.75

Table 5. Correlation Coefficient (r) by Pearson among physicochemical parameters of the Jaghjagh river water.

	Ta	Tw	SS	pH	EC	TDS	CODcr	BOD_5	Nitrate	PO_4^{-3}	CL^-	NH_3-N
Ta	1											
Tw	0.878**	1										
SS	0.091	0.073	1									
pH	-0.234*	-0.247*	-0.057	1								
EC	0.363**	0.482**	0.537**	-0.115	1							
TDS	0.425**	0.558**	0.554**	-0.196	0.77**	1						
COD_{cr}	0.21	0.296*	0.640**	-0.065	0.553**	0.731**	1					
BOD_5	0.198	0.271*	0.628**	-0.072	0.655**	0.64**	0.874**	1				
Nitrate	0.26*	0.38**	-0.097	-0.082	0.084	0.198	0.059	0.013	1			
PO_4^{-3}	0.287*	0.306**	0.685**	-0.126	0.641**	0.628**	0.601**	0.635**	0.119	1		
CL^-	0.176	0.115	0.485**	-0.013	0.659**	0.494**	0.421**	0.579**	-0.05	0.436**	1	
$NH4^+$	0.194	0.286*	0.724**	-0.048	0.751**	0.647**	0.707**	0.827**	0.11	0.81**	0.55**	1

*** Correlation is significant at 0.05 significance level (2-tailed).*

3.1. Suspended solids (SS)

Clay, silt, organic matter, plankton, and other microscopic organisms cause turbidity in natural waters (Kishor and Joshi, 2005). The average measured SS varied between 7-124 mg/l and 9-129 mg/l in 2012 and 2013 respectively. Spatial variation among the locations was demonstrated clearly at location 3, where the concentration of 56.6 mg/l has a significant difference compared to other locations (Table 3). No temporal variation was noticed, and the seasonal average SS increased apparently in winter and summer with values of 35.0 and 35.3 mg/l (Table 4). Additionally, its values displayed a positive correlation with the values of EC, TDS, CODcr, BOD5, PO43-, chloride, NH4+ and a negative correlation with nitrate (Table 5).

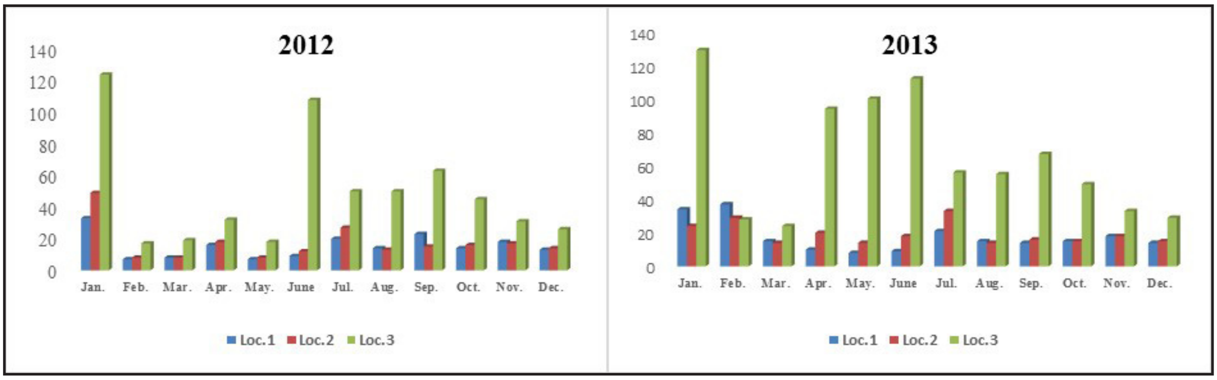

Figure 3. Monthly variations in Suspended solids (SS).

3.2. pH

pH is an important factor for realizing the nature and extent of pollution. pH values of Jaghjagh River water varied during the study period from slightly acidic to slightly alkaline levels of 6.8 and 8.1 (Table 2). Khadse et al. (2008) reported that higher pH values are often caused by bicarbonates and carbonates. The average pH values did not show a statistically significant difference among the sampling locations (Table 3). According to the seasonal variation, pH varied between 7.23 and 7.59 in summer and spring respectively; moreover, there was a significant difference among them (Table 4). In accordance with the correlation matrix, it was observed that pH was negatively related to the temperature (Table 5). The pH values ranged from 6.8 in July to 8.1 in March of 2012 and ranged between 6.9 in May and 7.9 in April of 2013 (Figure 4). The pH increase is related to rainfall runoff which brought waste with, but it did not exceed the acceptable standards of sewage water for irrigation proposes (Syrian Standards limitations, 2008).

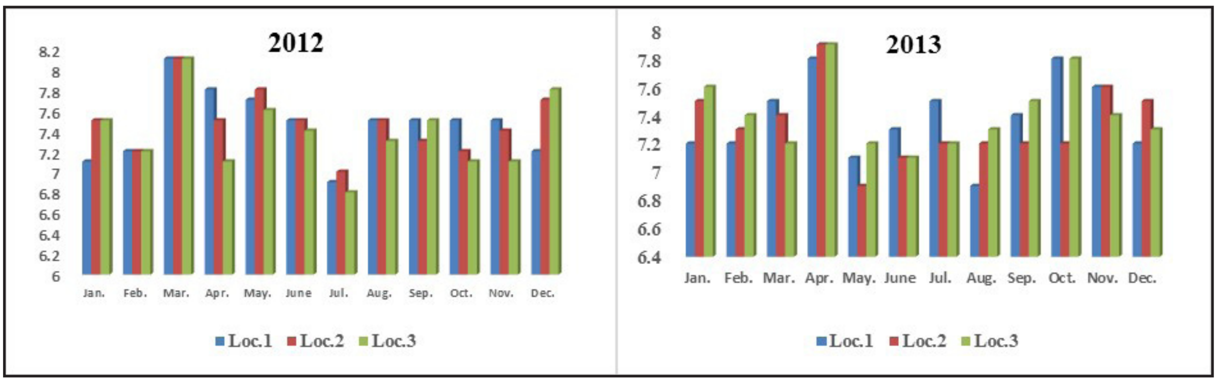

Figure 4. Monthly variations in water pH.

3.3. Electrical Conductivity

Spatial variation of EC showed a rage of values between 506 and 744 µS/cm. The values observed at location 3 varied significantly compared to the sampling locations 1 and 2 (Table 3). However, seasonal variation showed significant differences in the values in spring, summer, and autumn compared to winter with values of 611, 670, 632 and 479 µS/cm respectively (Table 4). This was because of the wide variety of inorganic salts and organic matter resulting from natural conditions and agricultural runoff (Basu and Lokesh, 2013). In accordance with the correlation matrix, EC demonstrated a positive correlation with temperature, SS, TDS, CODcr, BOD5, PO43-, chloride, and NH4+ and a negative correlation with pH. According to the Syrian Standardization, the parameter EC was within the acceptable standards for irrigation purposes.

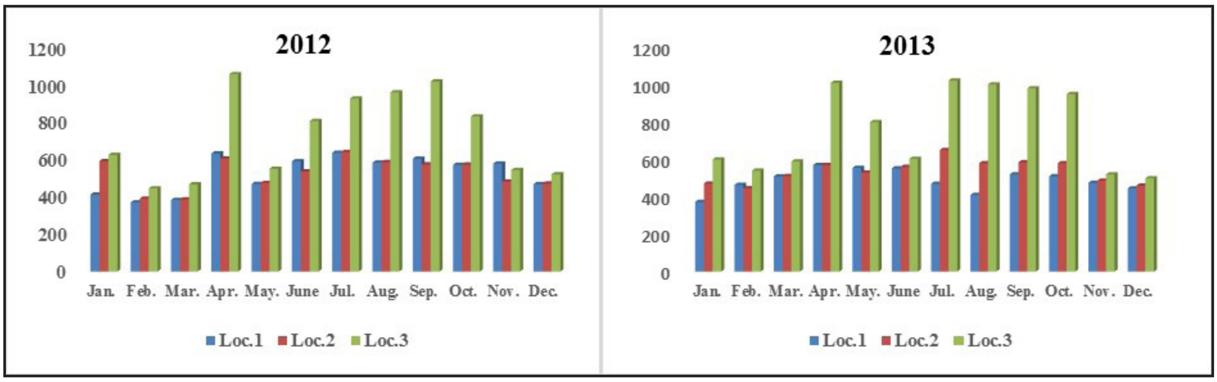

Figure 5. Monthly variations in electrical conductivity of water.

3.4. Total Dissolved Substance

The average TDS value varied between 267.6 mg/l and 326 mg/l at the sampling locations, especially location 3 which showed a significant difference compared the other sampling locations. A higher value of TDS was observed in summer (the dry season) and lower values were observed in winter (the rainy season) with values of 3 29.2 and 242.4 mg/l demonstrating a significant difference between them, because the seasonal variation in the major ion concentrations and TDS of the water are usually governed by river runoff variations (Khazheeva et al., 2007). The TDS parameters showed a positive correlation with the parameters of temperature, SS, EC, CODcr, BOD5, PO43-, chloride and NH4+, and a negative correlation with pH (Table 5).

Figure 6. Monthly variations in TDS of water.

3.5. Chemical Oxygen Demand

The Chemical Oxygen Demand (CODcr) is the measurement of oxygen required for the oxidation of organic matter in the samples, and being a reliable parameter for judging the extent of pollution in water (Amirkolaie, 2008), it is widely used for determining the waste concentration (Kazi et al., 2009). In the present study, CODcr ranged from 4 mg/l (March 2012) to 367 mg/l (January 2013) (Figure8). According to the results presented in Table 3, there was a significant spatial variation demonstrated at location 3 with values of 111.7 mg/l compared to locations 1 and 2. This reflects the observations made by Garg et al. in a reservoir in India (2010). The highest value was obtained at sampling location 3 (367 mg/l), where there were intensive discharges of domestic and industrial wastewater dumped into the river. Furthermore, the COD_{cr} values demonstrated a positive correlation with the parameters of temperature, SS, EC, TDS, BOD5, PO_4^{3-}, Chloride and NH_4^+ (Table 5), indicating that the COD^{cr} could be related to the leaching and transport of natural, domestic sewage, agricultural and industrial pollutants as observed by Barakata et al. (2016). The mean consternation of COD_{cr} was higher than the maximum limit permitted by the Syrian Standardization for the irrigation of cooked vegetables.

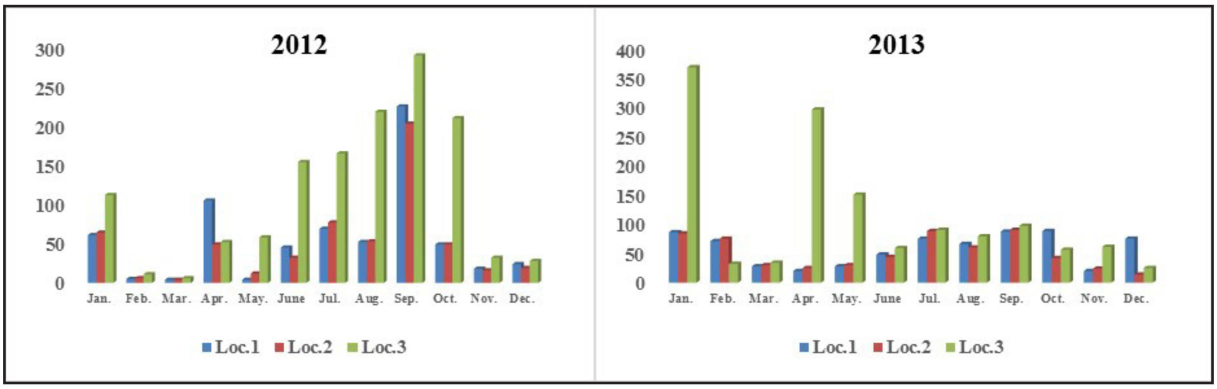

Figure 7. Monthly variations in chemical oxygen demand (CODcr)

3.6. Biochemical Oxygen Demand

The significant spatial variation was noticed at location 3 with values of 59.4 mg/l compared to values at locations 1 and 2 (Table 3). No significant temporal variation was noticed according to the results in (Table 4). The highest BOD5 was recorded during the months of January, April, July, August, and September, and the lowest values were recorded in the months of February, March, November, October, and December in all of the sampling locations (Figure 8). This may be related to the high biological activity stimulated by the rising temperature. Similar results were reported by Sreenivasulu et al. (2014) and Issa (2013). BOD5 values demonstrated a positive correlation with water temperature, SS, EC, TDS, COD, PO43-, Chloride and NH4+ (Table 4). Compared to the Syrian standards, all locations showed a moderately to highly polluted quality in more than 50% of the samples, especially at location 3.

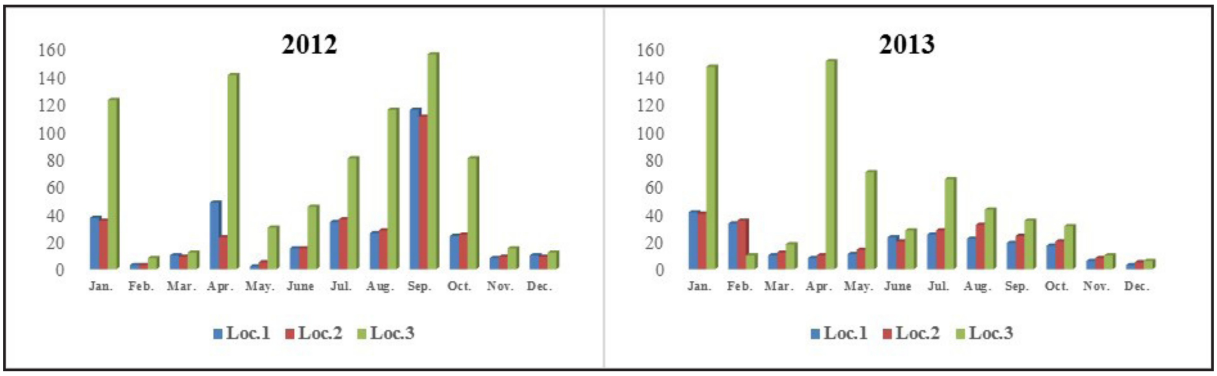

Figure 8. Monthly variations in biochemical oxygen demand (BOD5)

3.7. Nitrate

Nitrate concentrations varied at locations from 1 to 3 with a maximum value of 3.15 mg/l at location 1 which demonstrated a significant difference compared to the values at location 3 (Table 3). This is related to the intensive fertilization processes of the agricultural lands adjacent to location 1. Significant Seasonal variations in the nitrate concentration were noticed in summer and autumn with the values of 4.22 and 3.64 mg/l respectively, compared to lesser concentrations in winter and spring (Table 4). Pejman et al. (2009) stated that nitrate values should be of higher values in warm seasons, which may be justified by the relatively more agricultural and husbandry activities, as is clearly demonstrated by Figure 9. According to the Syrian Standardization, the nitrate content in all of the water samples were within the allowable concentrations for irrigation purposes.

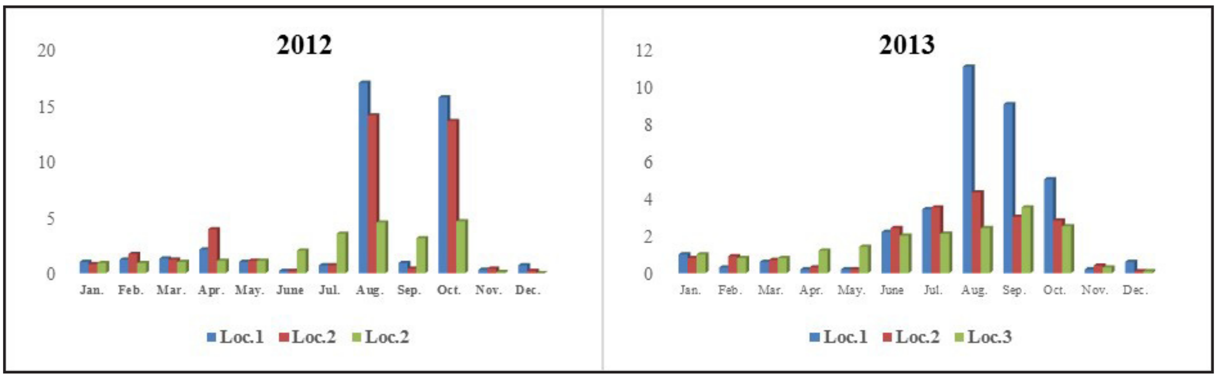

Figure 9. Monthly variations in nitrate (NO3-)

3.8. Phosphate

Phosphate concentrations ranged from 0.13 to 29.1 mg/l in 2012, and from 0.2 to 22.4 in 2013, with the highest value (10.57 mg/l) being recorded at the location 3 demonstrating a significant difference compared to locations 1 and 2 (Table 3). This is due to the mixing of domestic waste and different industries' effluents with agriculture runoff from the farmlands (Groupement ADI/CACG, 2010). From a season-based evaluation, it was noticed, that due to high evaporation, the Phosphate value of 9.30 mg/l shows a significant difference in summer compared to the values in other seasons, and this is well-matched with the findings of Garg et al. (2010). Phosphate correlated reasonably well with temperature, SS, EC, pH, TDS, CODcr, BOD5, Nitrate, Chloride and NH4+. According to the Syrian Standardization of wastewater for irrigation, the higher values of Phosphate observed at location 3 during the months of January, August, and October of 2012 and 2013 respectively (Figure 10) have exceeded the maximum limits allowed for irrigation.

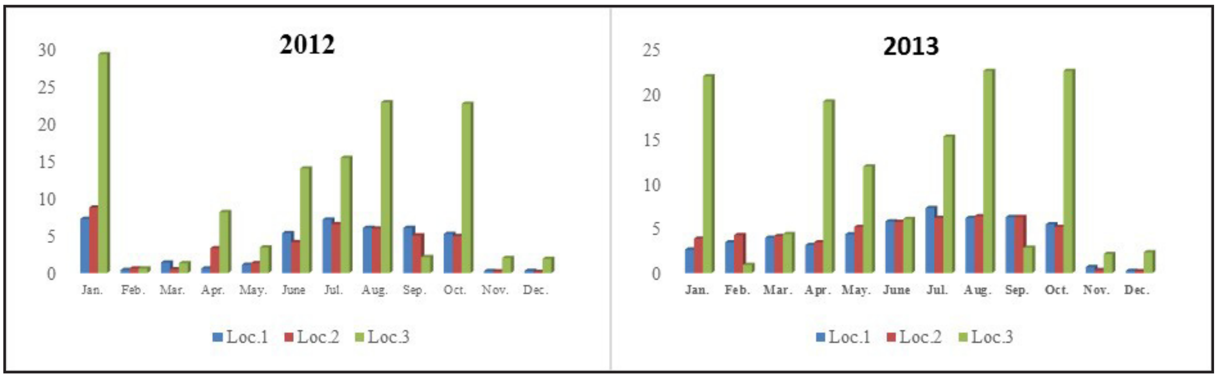

Figure 10. Monthly variations in Phosphate

3.9. Chloride

Chloride spatial variation was clearly observed among locations, where the average value of 99.4 mg/l recorded at the location 3 exhibit a significant difference in comparison to other locations. Seasonal variation, which was clearly demonstrated in spring when domestic and industrial wastewater inlets are the highest, showed a statistically significant difference with the value of 77.4 mg/l compared to the values in winter only. This can be explained in terms of the climatologic and hydrologic characteristics associated with the wet (cold or temperate) and dry (warm) seasons (Zare et al., 2011). The chloride concentration had not exceeded the maximum limit allowed by the Syrian Standards for irrigation at sampling locations 1 and 2 in 2012 and 2013. However, the concentration of chloride obtained at location 3 in April of 2013 (Figure 11) had exceeded the allowable irrigation limits of all crops, vegetables, trees and the surfaces of green types.

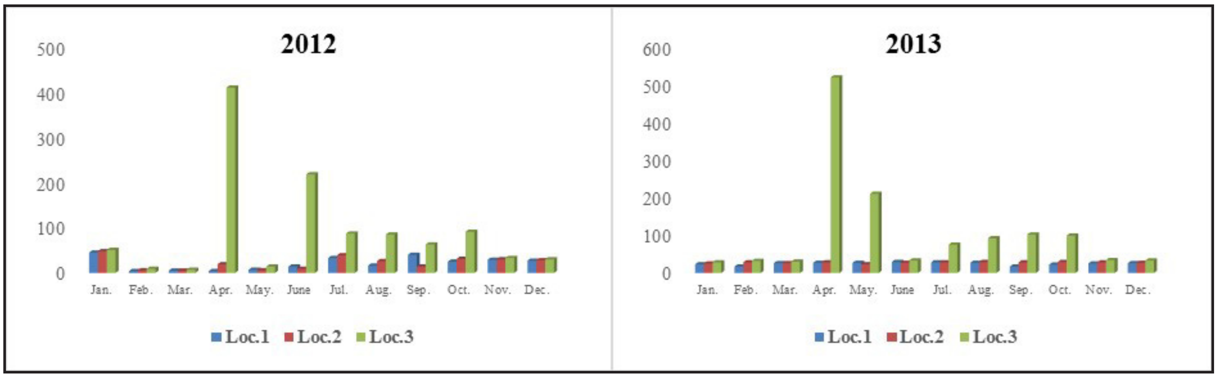

Figure 11. Monthly variations in Chloride.

3.10. Ammonium

Ammonium (NH4+) values varied spatially among locations with the highest value of 22.1 mg/l being recorded at location 3, where the downstream of Al-Qamishli region wastewater discharges are situated indicating a moderate to high pollution of the riverwater; this showed the negative impact of discharges from the city on the quality of the water of the studied river (Barakata et al., 2016), with significant differences compared to others. However, temporal variations were not observed during the study period. In accordance with the correlation matrix, ammonium displayed a positive correlation with SS, EC, TDS, CODcr, nitrate, BOD5, PO4-3, and Chloride, (Table 5). The Ammonium concentrations exceeded the allowable Syrian limits for irrigation concerning all type of crops being forest or fruit trees or cereals and forage and also cooked vegetables during the months from July to September in 2012 and 2013 respectively at location 3 (Figure 12).

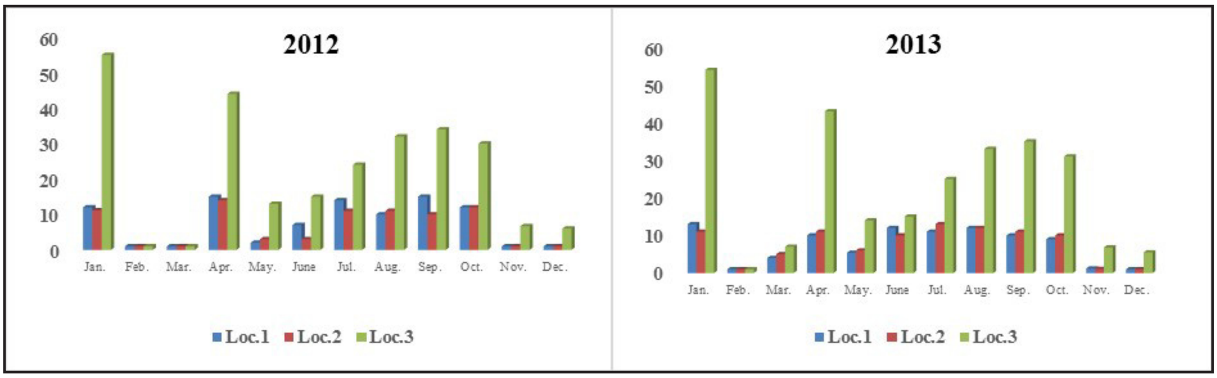

Figure 12. Monthly variations in Ammonium

4. Conclusions and Recommendations

According to the Syrian standards for pH, electrical conductivity, total salts, chloride, and nitrate, there were no restrictions on the use of water for irrigation purposes. However, there was a rise of CODcr and BOD5 values in all three locations, as a result of the industrial waste, fertilizers, and agricultural pesticides, dumped directly into the river without treatment. Due to the high values of ammonium NH4+, the water of the river at the third location in the runoff season was close to being a threatening water quality for the irrigation of cooked vegetables, fruits, fodder, and grains. Therefore, it is critical to monitor water quality and the river discharge continuously. This study recommends controlling the cultivation of vegetable crops especially freshly eaten crops, which are directly irrigated by the water of the river. This study also recommends raising environmental awareness and guiding farmers on adjacent territories to grow more fodder crops, which increase their income and strengthen the environmental cleanness. Moreover, more works on modeling and the prediction of the spatial and temporal variability of the river water quality are required.

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