

Spectral Analysis of Some Selected Hydrochemical Parameter Of Diyala River

Aqeel S. Al-Adili * & Qusay A. Al-Suhail **

Abstract

Some selected hydrochemical parameters of Diyala river including electrical conductivity (EC), Ca^{+2} , Mg^{+2} , SO_4^{-2} , Cl^{-1} , HCO_3^{-1} , total soluble solids ($T.S.S.$), discharge (Q) and total hardness (TH) were analyzed for their periodicities using monthly measurements for the period 1993-1997, to quantify and qualify surface water and investigate the periodicity behavior of these parameters. Results showed significant autocorrelation for all the studied series and therefore they were subjected to the Spectral (Fourier) analysis to investigate the main periodicities that contribute to the total variance of the observed data. Most of the selected parameters have strong (less frequent) semi-annual and biannual cycle, as well as seasonal cycle for, Cl , Mg , Ca , SO_4 , HCO_3 , TSS , and EC . These results reveal the variation of the factors affecting the river water quality including hydrological and meteorological conditions as well as the impact of human activities through the river catchments river.

Keywords: Periodicities - Spectral (Fourier) Analysis - Harmonic analysis- Autocorrelation

التحليل الطيفي لبعض العناصر الهيدروكيميائية المختارة في نهر ديالى

الخلاصة

تم اختيار عدة عناصر هيدروكيميائية لنهر ديالى شملت التوصيلية الكهربائية والملوحة والعسرة الكلية والتصرف وأيونات الكالسيوم والمغنيسيوم والكبريتات والكلوريد والبيكاربونات. حيث تم تحليل هذه المتغيرات لنهر ديالى للفترة من 1993 ولغاية 1997، وتم اخذ المعدل الشهري لكل واحد منها لغرض قياس ومعرفة نوعية وكمية التغيرات لتلك العناصر في مياه النهر، بالإضافة الى دراسة تصرف الدورية لتلك المتغيرات ومدى مساهماتها في التباين الكلي للمعطيات المشاهدة. وقد أظهرت الدراسة مضاهاة مميزة لكل العناصر المدروسة من خلال تحليل فوريير الطيفي. حيث ان معظم العناصر لها دورية نصف او شبه سنوية (اقل تردداً) بينما أظهرت متغيرات اخرى دورية فصلية (كما لأيونات Ca , Mg , Cl , SO_4 , HCO_3 و TSS و EC). وقد توصلت الدراسة الى ان التغيرات في العوامل المؤثرة على نوعية مياه نهر ديالى هي العوامل المناخية والهيدرولوجية بالإضافة الى التأثيرات المهمة الناتجة من فعل الانسان في جابية النهر.

Introduction

Diyala river is one of the main water resources of Iraq and one of the most important tributaries of Tigris river in Iraq. For this reason many cities are situated on it's banks, as well as, wastes fluids of agricultural and industrial activities in these cities are also concentrated directly to this river. It drains an area of about 32600 km² lying across Iraqi-Iranian frontiers. The river basin is widely varied through the entire catchments area from semi-arid

plain north of Baghdad to mountainous area of western Iran,[2]. The river catchments were divided into four parts; above Derbendikhan, Upper Diyala, Middle Diyala and Lower Diyala, each of these have different characteristics and different contribution to the main river flow. From geological view point, river catchments have different geological units; above Derbendikhan the catchments lies within thrust zone and the exposed rocks are of Jurassic age, whereas the Upper and Middle Diyala lie within the folded zone in

* Building and Construction Engineering Department, University of Technology/Baghdad

** College of Sciences, University of Basra/Basra

which the cretaceous strata are exposed, as well as Mukdadiya, Fatha formations and Quaternary terraces are dispersed. Lower Diyala is covered mainly by recent alluvium and lies within the unfolded zone [3].

The Climatic conditions vary so much in the river catchments in which the rainy season starting from November to April, the annual amount of precipitation varies from 800 mm near the northern parts to 250 mm near southern limits of the basin. The annual evaporation rate may reach as high as 2000 mm/year.[5]. These conditions have clear effects on alteration of wet and dry years and then on the variation of river water quality. However, the catchments area of Diyala river are lies within highly cultivated regions and have many canals and drainage channels, which contributing and affects river hydrochemistry and made variation of most of cations and anions, and this will effect on Diyala river as controlled river.

Many hydrochemical studies were achieved showing that water chemistry of the river are varied both spatially and temporally for the upstream river side,[1],[4],[6].

The main objective of the study is to quantify and qualify surface water as well as investigate the periodicity behavior of some selected parameters of Diyala river, using spectral (Fourier) analysis, linear regression, harmonic analysis, depending upon the monthly measurements for the period 1993-1997 available from the state of irrigation projects operation and maintenance. These include electrical conductivity (EC), Ca^{+2} , Mg^{+2} , SO_4^{-2} , Cl^{-1} , HCO_3^{-1} total soluble solids ($T.S.S.$), total hardness (TH) and discharge (Q),(table-1). Though discharge have less recording period (25 records) but, its importance for comparison purposes with the used parameters, reviles it's inclusion in the analysis.

Methodology

Autocorrelation

Autocorrelation can be defined as the measure of time dependence of a given time series for different lags. The values of autocorrelation coefficient for different lags and given confidence limits could be schematically shown using correlogram which indicates series trend and periodicity. Serial autocorrelation take the following form [8]:

$$r_L = \frac{Cov\{Y_i + Y(i+L)\}}{[VarY_i * VarY(i+L)]^{\frac{1}{2}}} \dots(1)$$

It can also be expressed using serial covariance as:

$$r_L = \frac{SerialCov(C_L)}{SerialCov(Lag C_0)} \dots(2)$$

Where $Y = average$; $0 < L < N$; $L = lag$ (represents the shift between any two compared series.

Spectral Analysis :

Spectral (Fourier) analysis is used for describing the structure of time series and explains the main components that contribute to the total variance in the observed data and defining the behavior using spectral density function. This function is the Fourier transform of the serial covariance as:[8];

$$g(L) = \int_0^{i\omega} e^{i\omega} df(\omega) \dots (3)$$

For continuous series :

$$g(L) = \int_0^{i\omega} e^{i\omega} f(\omega) d\omega \dots (4)$$

Where $\gamma(L) = variance$ at lag L , $f(\omega) = spectral$ density distribution function ,

$\omega = angular$ frequency ,

$t = time$,

$$i = \sqrt{-1}$$

Fourier transform is the method of transforming any function in term of time $Y(t)$ to another function in term of frequency $f(\omega)$, where the latter

function gives independent values with different frequencies as compared with time function which are strongly correlated leading to interpretation difficulties

Results And Discussion

Monthly readings of the selected parameters were plotted to define their trends, figures 1 to 3. As revealed by these figures, Discharge(*Q*), *Mg*, and *HCO₃* parameters shows noticeable increasing trend more than *T.H.* and *Cl* While *T.S.S.* and *EC* have slight decrease trends as compared with *SO₄* and *Ca*. Significant trends have clear effect on the analysis of time series especially if these series were taken on the basis of shorter period and less frequent sampling [7]. Accordingly they should be removed before carrying out the spectral analysis.

The average flow during the studied period reaches 160 m³/day (table-1), generally the flow increase with time, and most of discharge values fluctuated close to the mean, this is due to the effect of water flow regulation by dams [3]. However, The average monthly discharge showed that the maximum monthly flow of Diyala river occurs during February (Fig.-4).It should be consider here, that the flow of Diyala river is controlled by the Hemrin Dam along the year .

Correlogram of 95% confidence limit of the studied hydrochemical parameters Figures 5 to 7, shows clear periodicities (cycles), but they differ in their amplitude of the main components that contribute to the total variance of the observed data. Periodogram of the above parameters can be used to examine the main periodicities and their frequencies. According to the periodograms of the current data as depicted in the figures 8 to 10, it is clear that there exist a significant differences among the appeared periodicities. These periodicities can be classified as: strong clear (less frequent), clear, and

moderately clear (more frequent). Concerning *EC*, biannual cycle (5.1 months) and the cycle of 15.3 months which can called as semi-annual cycle are the most clear,(Table-2),(Fig-4-a). Other ions and total dissolved solids have strong clear semi-annual cycle but with less frequent occurrence. But *Ca*, *Mg*, *SO₄*, *Cl*, and *TSS* have clear biannual cycle, as well as, seasonal cycle for *Ca*, *Mg*, *SO₄*, *Cl*, *HCO₃*, *TSS*, and *EC*. However, Discharge(*Q*) clearly shows seasonal periodicity, the seasonal periodicity was confirmed by spectral analysis (Fig.8-d), and more frequent double annual cycles. This results is a reflection of both natural flow and meteorological conditions within the basin. As with regards to total hardness(*TH*) have an annual periodicity (11.5 months) as well as, biannual and seasonal but with moderately clear.

Most likely, the biannual cycle reflects the effect of time lag between the rainy and snow melt periods in the upper parts of the river catchments. Seasonal cycle reflects the impact of meteorological conditions on flow behavior whereas the semi-annual cycle exhibits the effect the overall natural conditions plus discharges release control through the dams installed upstream.

According to the aforementioned results there are significant variations in the periodicities of the studied parameters, however, it should be stressed here that the current results are restricted for the study period only and the real behavior of the river may be more clear if the measurements were taken for longer periods on the weekly or daily basis, [4].

Conclusions

1. Slight increasing trends in the studied hydrochemical parameters were noticed for *Q*, *Mg*, *T.H.*, *Cl* and *HCO₃*, while *T.S.S.*, *SO₄*, *Ca* and *EC* have slight decreasing, and high autocorrelation of the analyzed series were observed

indicating existence of different periodicities.

2. The study showed that the highest average monthly discharge for Diyala river is within February .

3. Semi-annual, biannual and seasonal cycles were found to be the most prominent periodicities contributing to the total variance of the most analyzed data. This reflects effects of the contributions for widely range of canals and drainage channels within the river basin.

4. Semi-annual cycle reflects the effect of wet and dry years fluctuation plus man made impact, whereas the biannual and seasonal cycles indicate the impact of flow and meteorological conditions throughout the entire river catchments area.

5. Measurements for Diyala river after 10 or 15 years from this date recordings will be very useful and effective to compare and evaluate this study results.

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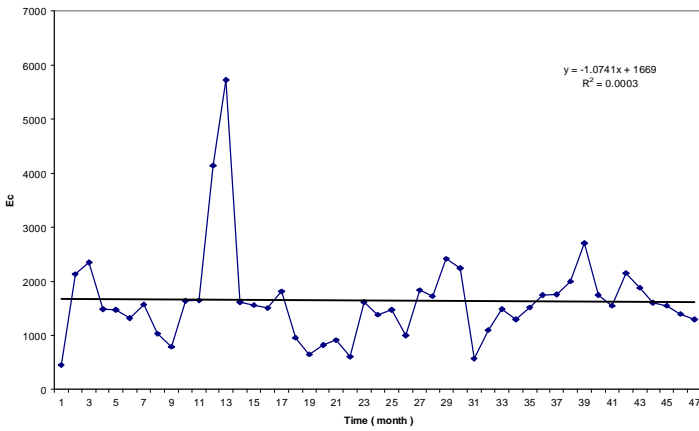
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Table(1) The results of analysis for Diyala river at Baquba station.

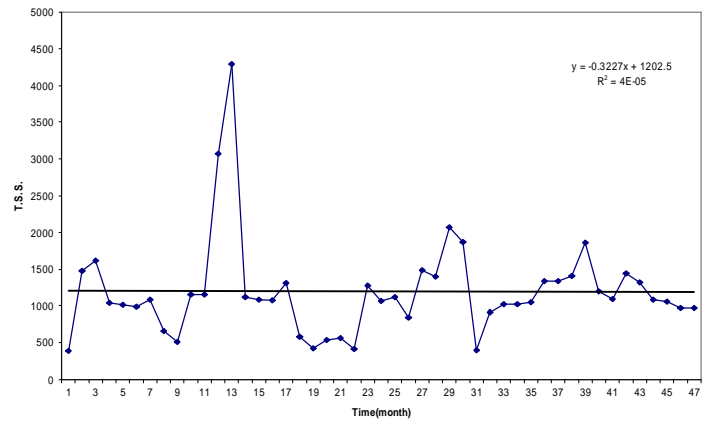
Samples	EC.10 ⁶	T.S.S(ppm)	Ca(mg/l)	Mg(mg/l)	Cl(mg/l)	SO ₄ (mg/l)	T.H.(mg/l)	HCO ₃ (mg/l)	Q(m ³ /day)
1	451	386	40	27	58	96	187	80	221
2	2130	1476	176	29	276	768	554	274	100
3	1480	1040	112	34	158	442	476	176	96
4	1470	1008	106	29	144	432	462	176	134
5	1320	990	104	29	152	371	436	116	130
6	1570	1086	112	43	168	448	479	188	130
7	1038	664	54	28	136	265	284	128	147
8	796	509	38	32	87	214	151	80	129
9	1640	1152	124	56	181	464	512	196	142
10	1650	1152	124	56	175	462	468	196	139
11	4140	3072	358	192	683	1105	1136	288	127
12	5720	4290	417	258	832	1588	1379	320	127
13	1610	1120	118	46	175	456	508	196	152
14	1560	1080	106	44	165	424	400	176	144
15	1510	1072	102	38	165	417	383	176	141
16	1810	1316	188	76	214	493	633	240	149
17	961	584	62	24	85	216	224	96	194
18	653	424	40	21	68	128	174	80	182
19	820	536	54	22	76	186	209	96	156
20	908	564	58	24	76	208	219	96	135
21	606	412	34	17	49	110	158	80	596
22	1610	1280	122	48	188	385	429	176	187
23	1390	1064	116	42	176	346	388	157	134
24	1470	1120	119	46	184	354	412	176	133
25	1001	846	76	38	132	245	327	137	----
26	1830	1488	153	76	216	497	596	213	----
27	1720	1400	149	72	202	476	556	196	----
28	2420	2068	288	115	486	576	943	248	----
29	2240	1864	248	91	452	568	852	248	----
30	571	398	54	29	88	116	256	131	----
31	1095	912	80	53	162	274	420	145	----
32	1480	1025	104	59	163	400	504	119	----
33	1300	1020	107	56	138	299	500	217	----
34	1520	1045	102	76	174	423	570	175	----
35	1750	1335	114	76	217	442	599	630	----
36	1760	1338	115	74	217	445	596	135	----
37	2000	1410	124	67	272	453	589	145	----
38	2700	1860	141	117	437	654	840	205	----
39	1750	1195	112	70	215	457	570	181	----
40	1550	1095	88	62	184	366	480	173	----
41	2150	1440	76	106	277	474	183	----	----
42	1880	1320	116	84	198	505	640	----	----
43	1600	1085	94	79	181	426	565	----	----

Table (2) The variables of Diyala river periodicities .

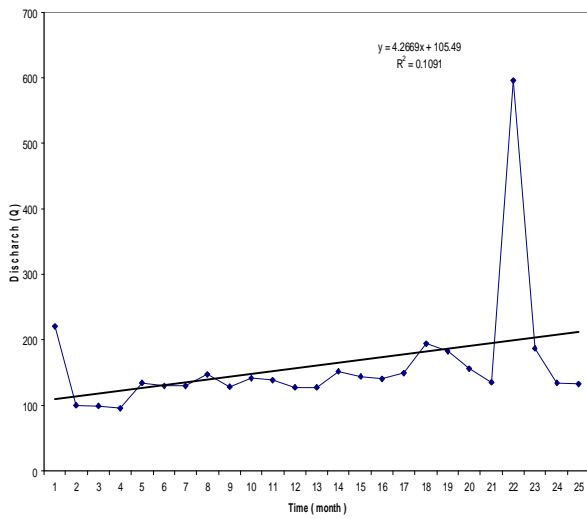
Variables	Frequencies	Periods (months)	Perodicities
EC	0.065	15.3	Smie – annual
	0.195	5.12	Biannual
	0.32	3.2	Seasonal
T.S.S.	0.065	15.3	Smie – annual
	0.195	5.12	Biannual
	0.32	3.2	Seasonal
Ca	0.042	15.3	Smie – annual
	0.17	5.12	Biannual
	0.33	3.2	Seasonal
Mg	0.065	15.3	Smie – annual
	0.195	5.12	Biannual
	0.32	3.2	Seasonal
cl	0.065	15.3	Smie – annual
	0.195	5.12	Biannual
	0.32	3.2	Seasonal
SO ₄	0.065	15.3	Smie – annual
	0.195	5.12	Biannual
	0.32	3.2	Seasonal
T.H.	0.085	11.5	Smie – annual
	0.195	5.12	Biannual
	0.32	3.2	Seasonal
HCO ₃	0.125	8	Smie – annual
	0.32	3.3	easonal
Q	0.04	24	Double annual
	0.29	3.4	Seasonal



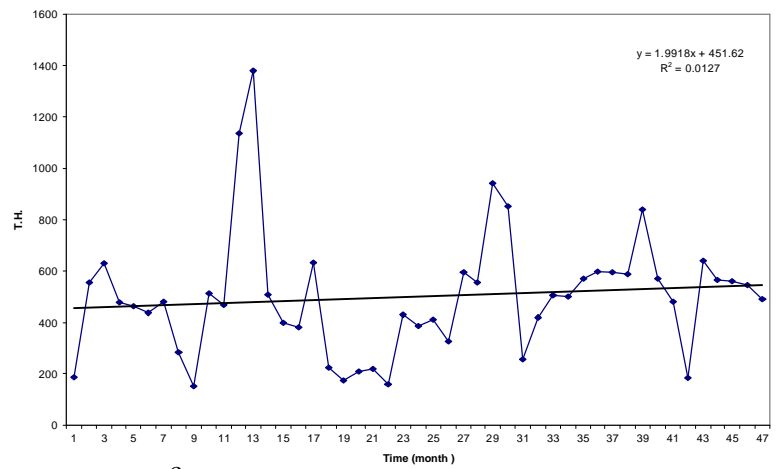
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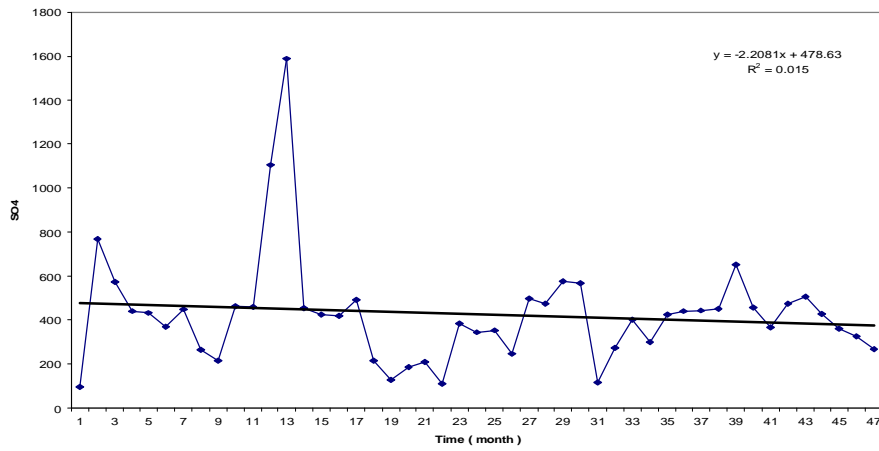


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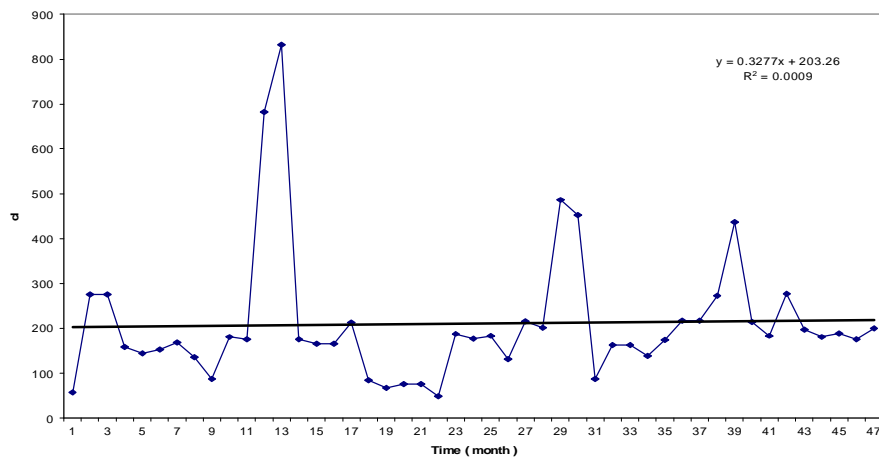


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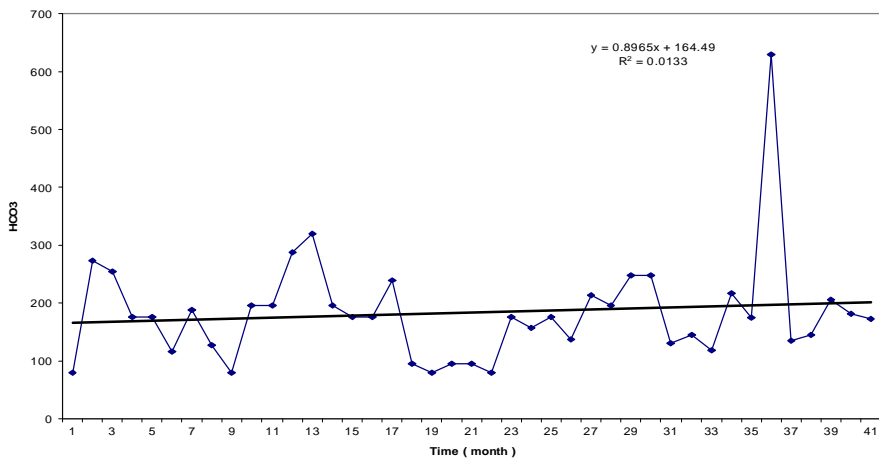
Figure (1) Variation of EC (a) , T.S.S.(b) , Q (c) , and T.H. (d) with time of Diyala river



- a -



- b -



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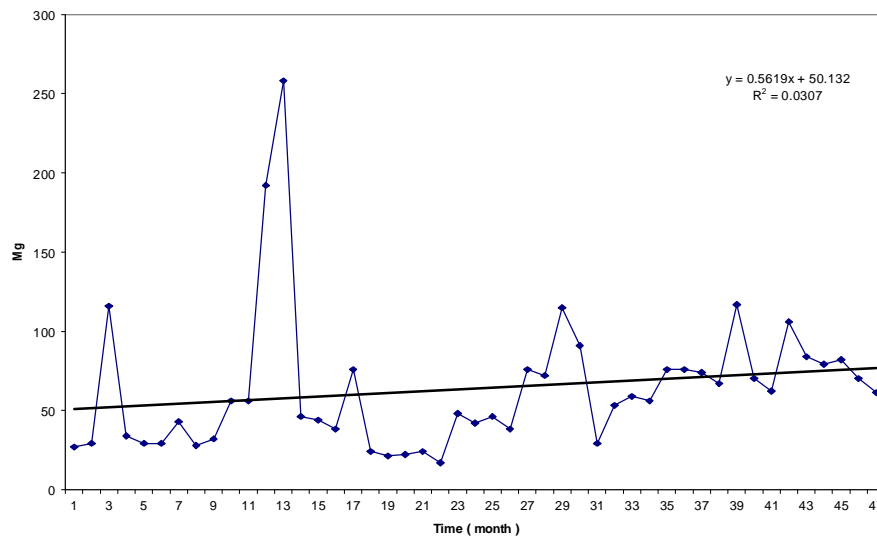


Figure (2) Variation of SO_4 (a) , cl (b) , and HCO_3 (C) ,with time of Diyala river .

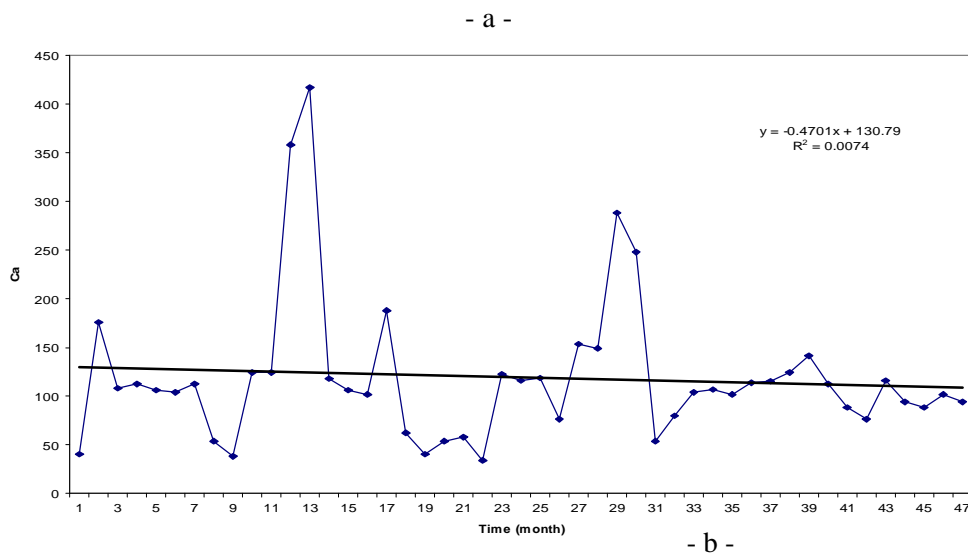


Figure (3) Variation of Mg (a) ,and Ca (b) ,with time of Diyala river .

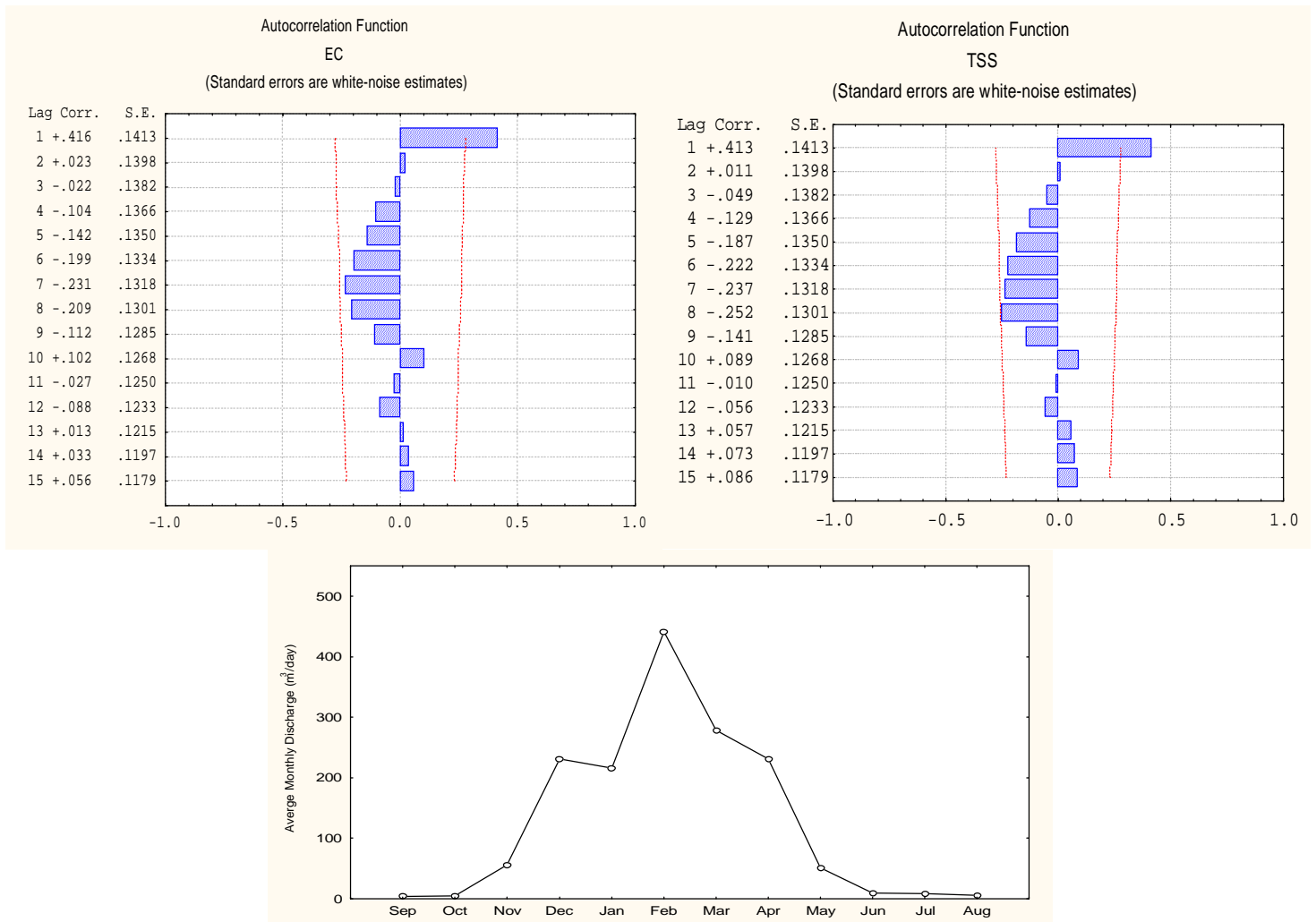


Figure (4) Flow Hydrograph of Diyala river at Baquba from 1993 to 1997 .

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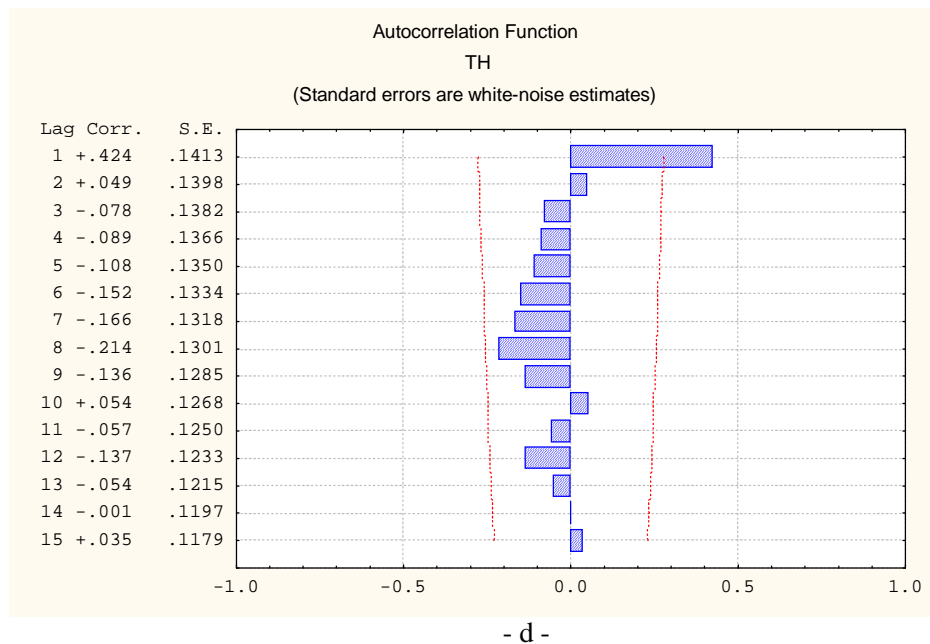
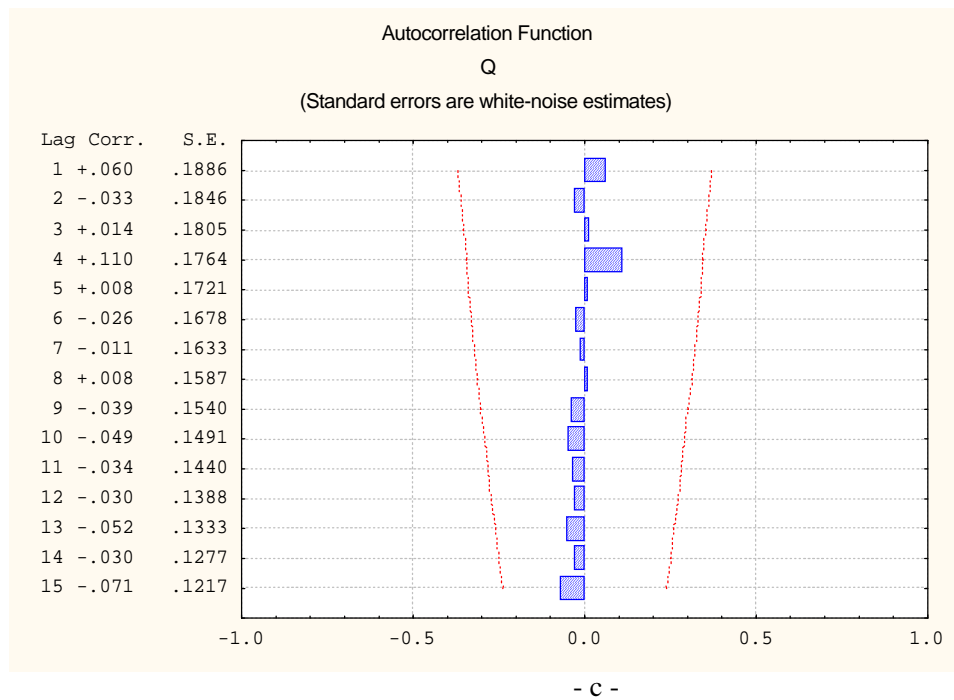
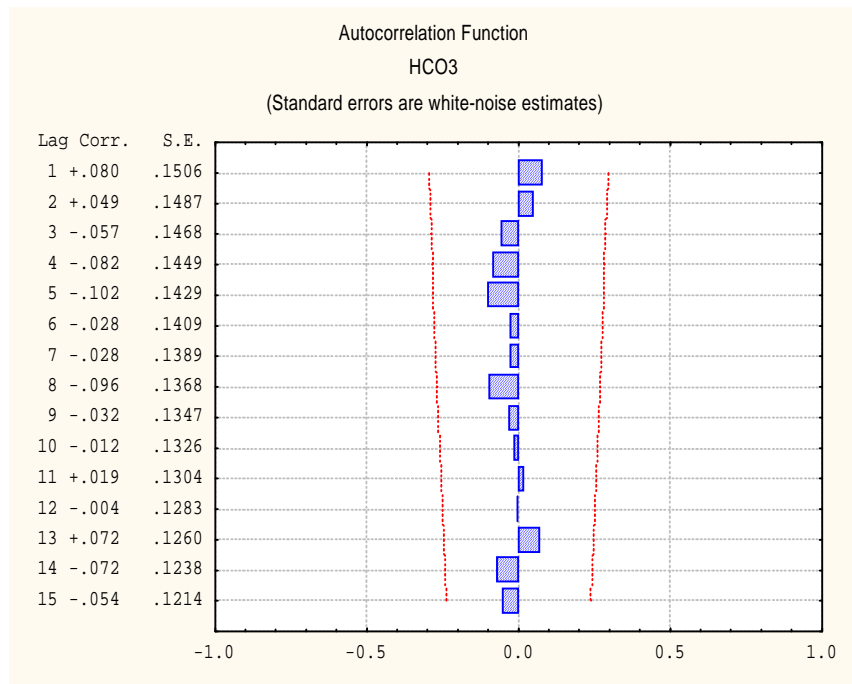
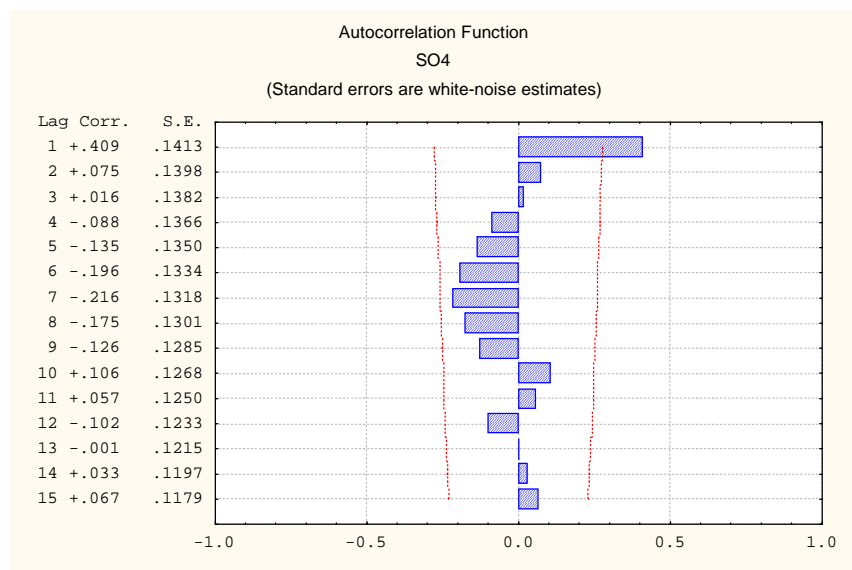


Figure (5) Correlogram(95% confidence limit) of EC (a) and TSS (b), Q(c), and TH (d) of Diyala river.



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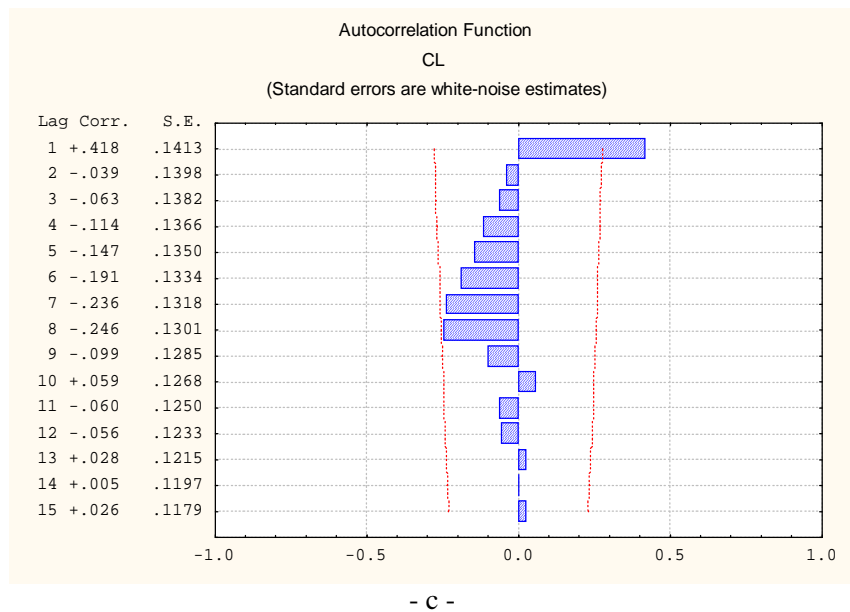
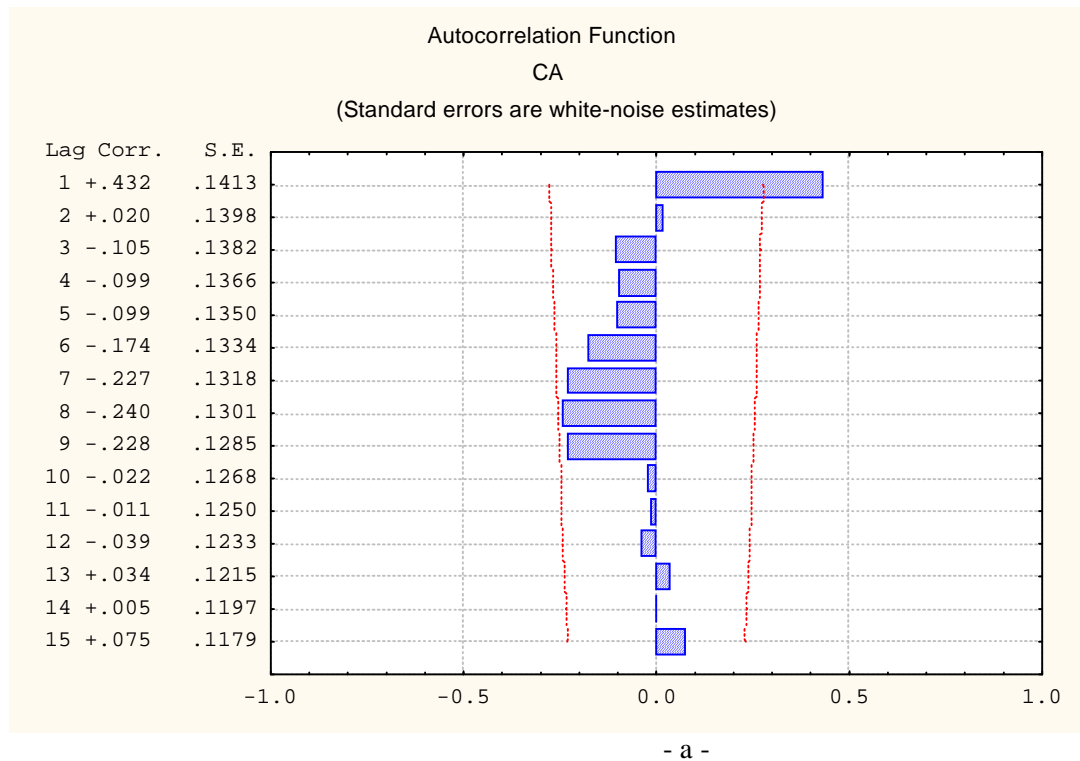


Figure (6) Correlogram(95% confidence limit) of HCO₃ (a) and SO₄ (b), and cl (c) of Diyala river



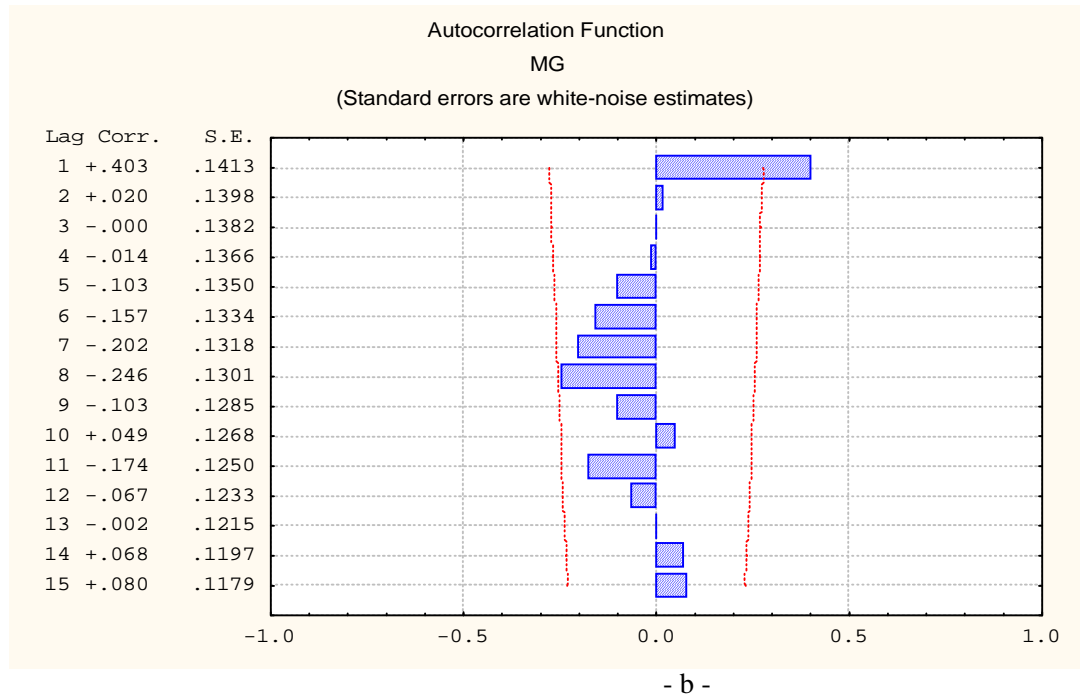
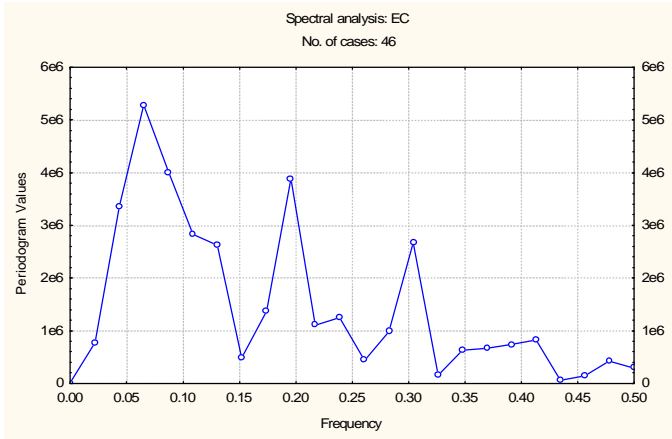
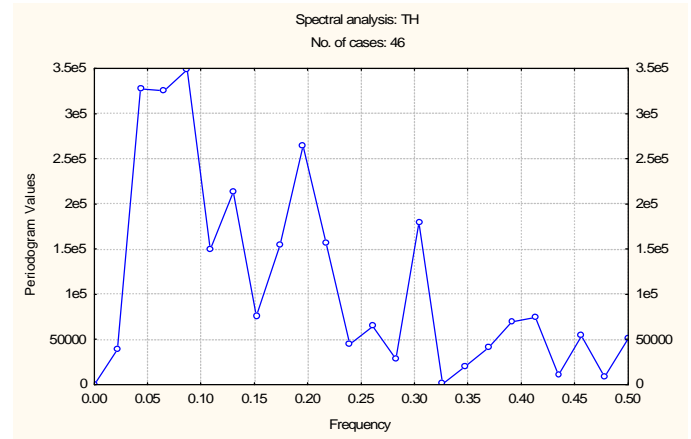


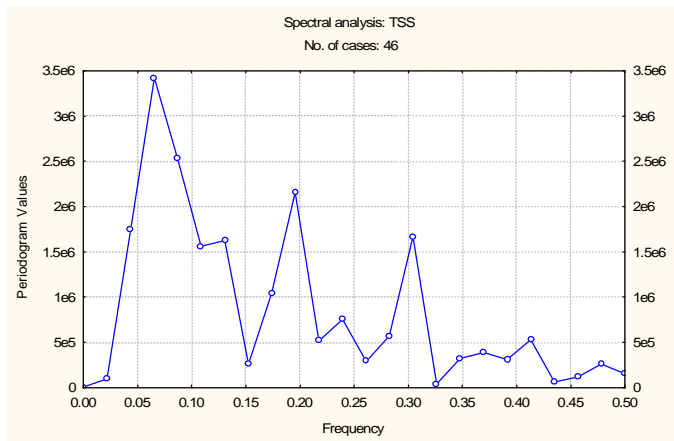
Figure (7) Correlogram(95% confidence limit) of Ca (a) and Mg (b) of Diyala River



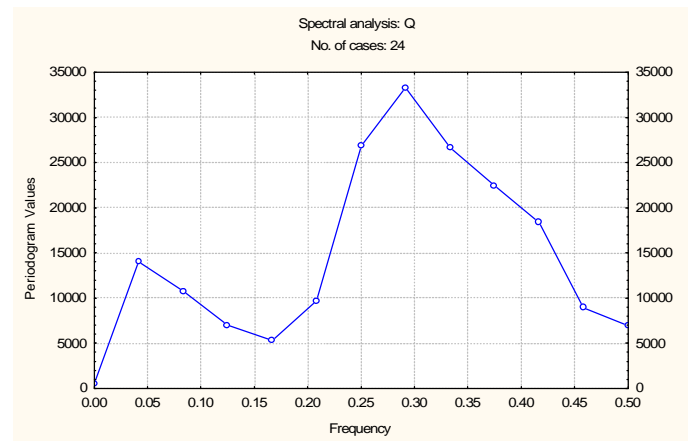
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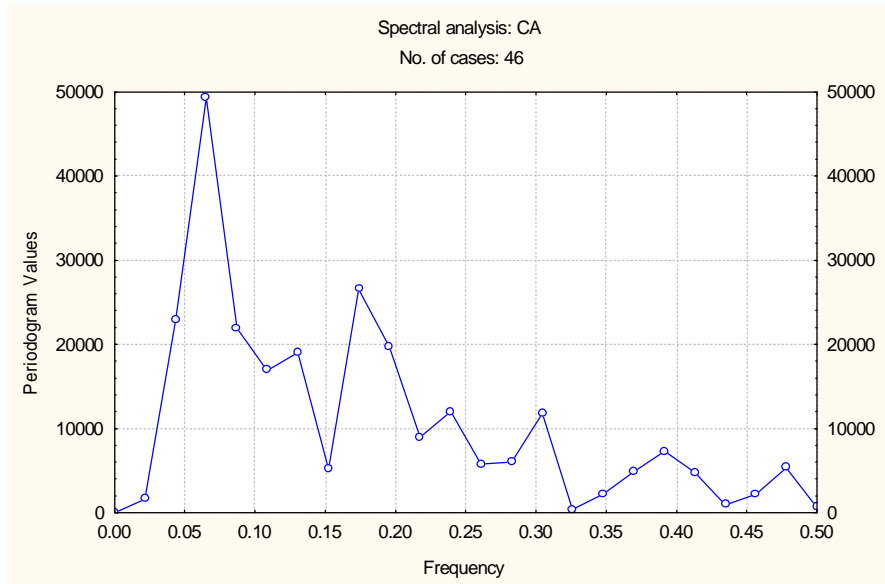


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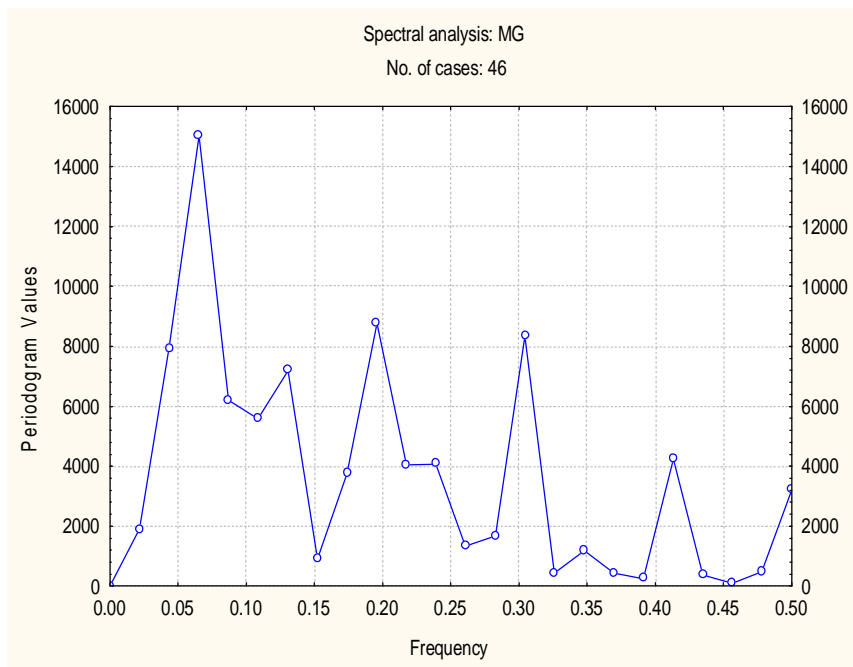


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Figure (8) Periodogram of ; EC (a) , T.H.(b) , TSS (c) and Q (d) for Diyala river.

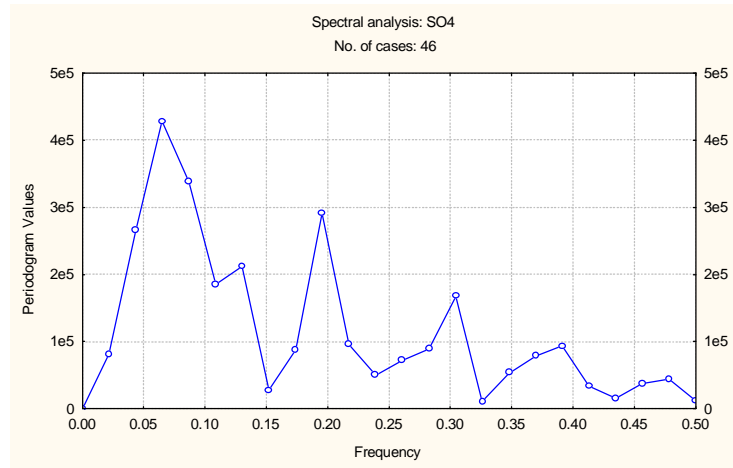


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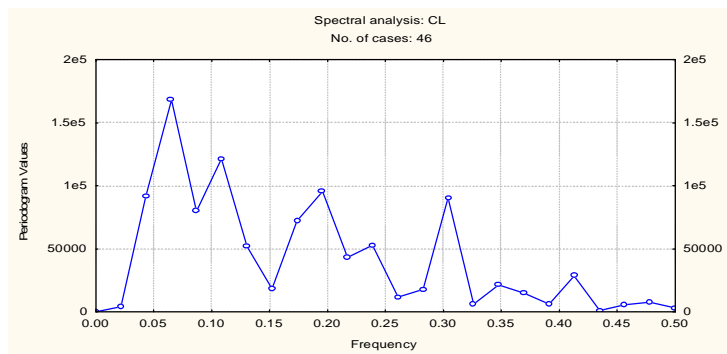


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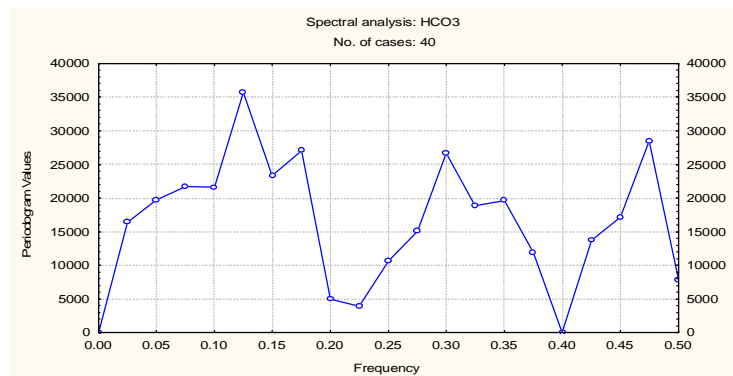
Figure (9) Periodogram of Ca (a) and Mg (b) for Diyala river.



- a -



- b -



- c -

Figure (10) Periodogram of SO₄ (a) , cl (b), and HCO₃ (c).