Comparative Analysis Of Results Obtained From 3 Indexes (SEQ-Eau, IBD, IPS) Used To Assess Water Quality Of The Berdawni, A Mediterranean Stream At The Beqaa Region - Lebanon

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Abstract: In Lebanon, for water managers, the quality of water is apprehended under the only aspect of the physicochemical quality. This analysis presents some operational limit, because of specific information which it brings in space and time. In this context, It appeared interesting to us to carry out a study specilaized to evaluate the trophic quality of Berdawni, principal affluents on right bank of Litani (Mediterranean Eastern, Lebanon), and to take into account, parallel to the chemical analyses of water and with the application of the index SEQ-Eau (MEDD & France water agency, 2003), the diatomic study of the communities of Berdawni and to analyze the various results got from the calculation of 2 biological indices I.B.D.(AFNOR, 2000) and I.P.S. (Cemagref, 1982). The comparison of the indications provided by these 3 indexes clarifies divergences, sometimes important in the analysis of the quality of fesh water and made it possible to discuss the limits of their applications.

Keywords: biological index, chemical index, IBD, IPS, Mediterranean river, SEQ-Eau, water quality.

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INTRODUCTION

For water managers, the quality of a river is often understood by the only aspect of the physico-chemical quality of water. This analysis has some limitations, due to the timely information it provides in space and time; so it is not really suited to the analysis of some insidious or very short pollutions. In reality, the rivers, like any ecosystem, are "a system of complex interactions between species and of these with the environment" (Frontier & Pichod-Viale, 1995). Functional knowledge of the ecosystem that incorporates interactions between species and environment, enables, in case of modification in the environment, to perceive the effects of this modification (Cairns et al., 1993). It follows that any change of a compartment will influence the function of other compartments (Lair et al., 1998; Lougheed et al., 1998; Mc Collum et al., 1998) by acting in particular on the structures of biological communities (Bernez, 1999). The use of biological communities, to analyze the health status of aquatic ecosystems, has been thus gradually imposed because aquatic organisms amplify discrete pollution and integrate spatial and temporal variability by their prolonged or constant presence in the water. In this context, Prygiel and Coste (2000) and the "Center of Study of Agricultural Mechanization and the Rural Engeneering of water and Forestry" in France (Centre d'Étude du Machinisme Agricole et du Génie Rural des Eaux et Forêts = Cemagref) (1982) respectively created two indices based on the algae: Biological Index of Diatoms (Indice biologique des Diatomées = IBD) and the Polluo-specific Sensitivity Index (Indice de Polluo-sensibilité Specifique = IPS). The IPS rises from work of Descy (1980) and especially of Coste (1978) on Meuse and Sambre (two Belgian river) and it was applied by the Cemagref in 1982. So, it seemed interesting to consider, in parallel with chemical analyzes of water, the study of various biotic compartments of an hydrosystem and to analyze the different results. This work develops the results obtained from the calculation of 3 indexes, applied to three different compartments of the "Berdawni", a mountain stream at the Bekaa region (Lebanon, Eastern Mediterranean) subjected to natural and anthropogenic disturbances. The Quality Evaluation System of water for rivers (Système d'évaluation de la qualité de l'eau des cours d'eau = SEQ-Eau) developed by a French water agency (MEDD & Water Agency, 2003), IBD (AFNOR 2000) and the IPS (Cemagref, 1982) were simultaneously calculated at 4 stations of the Berdawni stream, surveyed over 10 campaigns since July 2010 to June 2011 inclusive, and their indicative values were compared.

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STUDY SITE

The "Berdawni" is the main tributary on the right bank of the Litani River (Figure 1). It has it source at an altitude of 1236 m. After a course of 12 km it flows into Litani River at an altitude of 890m. The slope is strong and the substratum is generally coarse. From the source to the confluence with Litani river 4 stations have been studied 1 station (B1, B2, B3 and B4) (Figure 1).

B1 is located at the source of Berdawni. It is fully anthropized. It is in the form of a concrete channel of 1 to 3 m in height and 5 m wide. It is bordered on its right bank by a provincial road. The left bank is lined with a series of restaurants during the summer. The ripisylve is well developed and the macrophytes are totally absent in this sector.

B2 is located at 3 km from the source at 1150 m altitude. The average width of the river bed at this point is 6 m. Upstream of this station, a dairy products factory and a large paper factory are present. This station is located in a groove with a steep slope. The right bank is bordered by a mountain that rises up to 1300 m altitude. The ripisylve is well developed. The presence of macrophytes is limited to a few macro-algae and phanerogams.

B3 is located at 1000 m altitude upstream of Zahle town (70,000 inhabitants), 6 km from the source. Strongly anthropized, this station is bordered on the left bank, by a series of restaurants and on the right bank by a large cars parking. The ripisylve is well developed. The presence of macrophytes is limited to few phanerogams located at both banks and to macro-algaes which colonize the river.

B4 is located at 900 m altitude, at 8 km from the source (downstream of the city of Zahle). It is highly anthropized. It is in the form of a 6 m wide concrete channel. The right side of B4 is bordered by a local road and the right one is bordered with a deposit of sand and gravel used in construction. The ripisylve is absent which promotes the development of macrophytes during the summer.

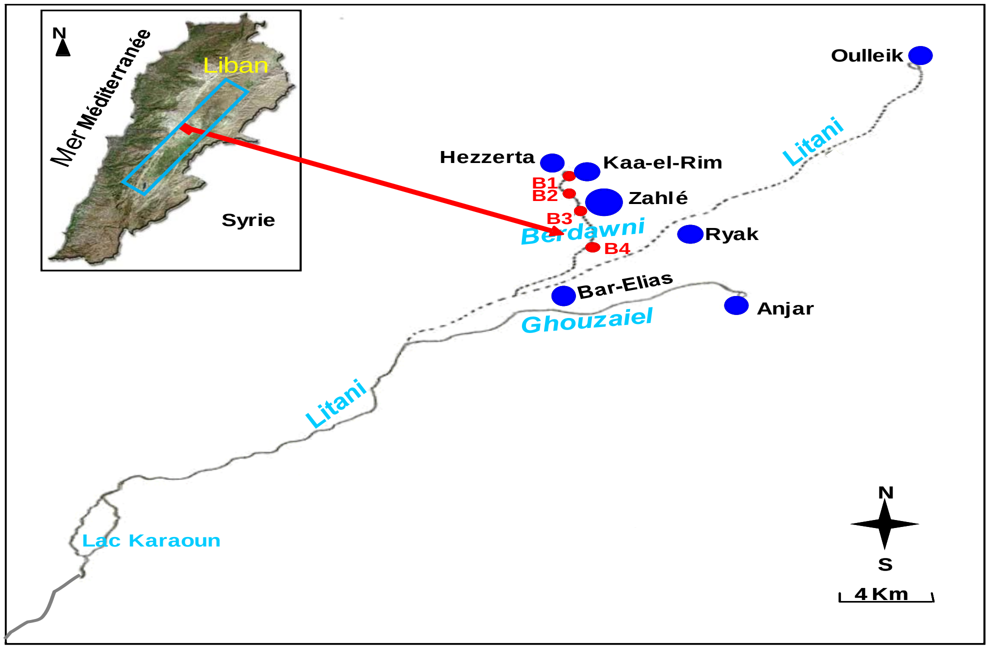

Fig.1 *showing the location of Berdawni and the 4 river stations included in this study.*

	B1				B2				B3				B4			
	Moy	σ	Min	Max	Moy	σ	Min	Max	Moy	σ	Min	Max	Moy	σ	Min	Max
T (°C)	8.0	0.4	7.3	8.8	11.5	2.2	9.2	15.0	12.8	2.1	10.5	16.0	16.1	6.6	11.0	28.0
Cond (µS/cm)	243	23	200	285	301	56	230	420	328	63	240	450	345	46	300	420
TDS (mg/l)	138	9	120	150	191	28	145	230	195	34	135	250	203	29	160	240
O2 (mg/l)	9.4	1.5	7.0	12.0	9.2	1.5	7.0	11.0	8.2	0.6	7.0	9.0	7.2	1.5	4.0	8.5
NO2()mg/l)	0.2	0.0	0.2	0.2	0.8	0.4	0.2	1.5	1.4	0.3	1.0	2.0	5.1	1.1	4.0	7.0
NO3 (mg/l)	1.3	0.1	1.1	1.4	12.1	0.6	11.0	12.9	23.0	1.6	20.0	25.0	51.9	10.0	41.0	70.0
NH4 (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1
PO4 (mg/l)	0.0	0.0	0.0	0.0	0.5	0.1	0.4	0.6	0.9	0.2	0.5	1.1	2.2	0.4	1.7	2.7
DBO5 (mg/l)	2.3	0.6	1.4	3.3	4.8	1.8	3.0	7.7	5.6	0.4	5.0	6.2	8.5	2.0	6.0	12.3
M.E.S.mn.(mg/l)	2.0	0.3	1.3	2.5	4.6	0.8	3.8	6.0	2.2	0.3	2.0	2.8	10.3	3.2	6.5	14.0
M.E.S.org.(mg/l)	0.8	0.1	0.7	1.0	3.3	1.0	2.0	5.0	1.2	0.2	1.0	1.5	5.4	1.0	4.0	6.7
pH	8.3	0.2	8.0	8.5	8.5	0.1	8.3	8.6	8.7	0.1	8.5	8.9	8.7	0.4	7.8	9.0
V.moy. (m/s)	1.4	0.8	0.4	2.5	1.8	0.7	0.8	2.8	1.4	0.7	0.5	2.5	1.1	0.7	0.2	2.0
Prof.moy. (cm)	27	8	20	40	29	13	15	45	32	14	15	50	29	14	8	45

Table.1 *Mean values (10 campaigns from July 2010 to June 2011), standard deviations, minimum and maximum of 14 physicochemical parameters analyzed at B1, B2, B3 and B4.*

PS: *With the exception of pH and dissolved O2, all the physicochemical parameters differed significantly from one station to another (p <0.01, Friedman test).*

MATERIALS AND METHODS

The following physical parameters were determined in situ in each station: depth (with a ruler) and the current velocity (FLO-MATE, portable Model 2000). In addition, 10 abiotic parameters of the water were analyzed either on the field (pH, Dissolved Oxygen, Temperature, Conductivity and Total Dissolved Solids with a multiprobe WTW analyzer) or at the laboratory such as NO2, NO3, NH4, PO4, DBO5, Mineral Suspension Matter (M.E.S.min.) and and Organic Suspension Matter (M.E.S.org.), using the SEQ-Eau protocol recommended by the French Water Agency (SEQ-Eau 2003). Indications for I.B.D. (AFNOR NF T90-354 2000) and I.P.S. were observed during the study to assess the water quality of these different streams. The identification of diatoms is performed under an optical microscope (magnification 1000 X immersion) with Süβwasserflora Krammer & Lange-Bertalot (1986, 1988, 1991a and 1991b), Germain (1981) and Bourrelly (1966, 1968 and 1970) and some other specific flora. Ten sampling campaigns were carried out at each station from July 2010 to June 2011, at monthly intervals, from April to October, and every two months from the end of November to February.

RESULTS

1. Physical chemistry of waters and the SEQ-EAU index

The average and extreme values of the physico-chemical descriptors analyzed at stations B1, B2, B3 and B4 are shown in Table 1. In **B1**, the temperature is low with an average of 8.8°C. The current speed is fast, the pH indicates moderately alkaline waters and the degree of mineralization is strong. This is probably related to the geology of the area which is mainly composed of limestone. In **B2**, the temperature increases by 3.5°C compared to B1. The current velocity increases compared to B1. The pH indicates moderately alkaline waters. The observation in pH variation over time may be related to industrial waste from factories located in this area that seems slightly reducing the alkalinity of water, especially during the summer. The degree of mineralization is high; it increases compared to B1. O2 levels reveal, outside dryness, good water oxygenation in this sector. Concentrations values of nitrogenous substances and orthophosphates, BOD5 values, of mineral and organic suspension matter (M.E.S.mn, and M.E.S.org.) increased with respect to B1 with maximum concentrations of these parameters during the summer. For **B3**, changes in water quality are similar to what was described in B2 with a decrease in the content of M.E.S.mn, and M.E.S.org. and a significant increase in concentration of nitrogen substances and orthophosphates. The degree of mineralization is high; it increases slightly compared to B2. **B4** is characterized by a dryness period from July to September. Dryness period is more related to the tourism and agriculture activities than to the hydraulic regime of the Berdawni. The water temperature increases by 3.3 °C compared to B3 while the current velocity and depth decrease compared to B3. The mineralization is high. The levels of orthophosphates and different forms of nitrogen show a sharp deterioration in water quality compared to crenon (B1) and rithron (B2 and B3) stations and always indicate a critical stage of pollution showing a strong disturbance of the nitrogen cycle. The substrate granulometry reveals a coarse substrate at the source (B1) (65%), the rithral B2 (85%) and B3 (70%) and becomes fine (80% to 90%) at the Potamal (B4). The SEQ Water Index (SEQ-Eau) is calculated from the values of 14 physical and chemical components obtained after analysis in the field and in the laboratory (according to the standards recommended by this method of analysis). The index grades range from 0 to 100. The water quality is described with 5 quality classes: 80 <very good ≤100; 60 <good ≤ 80; 40 <acceptable ≤ 60; 20 <bad ≤ 40; 0 ≤very bad ≤ 20. Grades obtained after index calculations are presented in Table 2.

	Grades/100												Water quality
	J0	**A0**	**S0**	**O0**	**D0**	**F1**	**M1**	**A1**	**M1**	**J1**	**Mean**	**S.D.**	
B1	76	76	75	75	77	78	78	80	78	76	**77**	**1.6**	Good
B2	58	58	54	60	62	61	66	65	65	59	**61**	**3.8**	Good
B3	62	62	60	62	64	65	65	63	63	60	**63**	**1.8**	Good
B4	40			52	52	52	54	55	54		**51**	**5.0**	Acceptable

Table 2. *Spatio-temporal variation of the water quality of the 4 surveyed stations (from the index SEQ-EAU 1999). J0: July 2010, A0: August 2010, S0: September 2010, O0: October 2010, D0: December 2010, F1: February 2011, M1: March 2011, A1: April 2011, M1: May 2011, J1: June 2011)*

The water quality varies from acceptable to good (grades of index varies from 40 to 80). The crenon (B1) has good quality water throughout the year (grades of index varies from 75 to 80). The rethron (B2, B3) have water of acceptable to good quality (grades of index varies from 54 to 66) with temporal variations occurring especially at B2 with acceptable quality water at the winter and spring periods, and poor quality water at the summer and fall periods. The Potamon (B4) has a degradation of the quality of water which is manifested by acceptable water quality during the whole year (grades of index varies from 52 to 55) excepting for July with bad water quality (grade index = 40).

2. Diatoms and I.B.D.

Diatomic populations of Berdawni consist of 91 species. The I.B.D. is calculated using data of number of species of epilithic diatoms. This index was calculated for these populations of all stations from July 2010 until June 2011. The index grades range from 0 to 20. The quality of water is described with a number belonging to the 5 following quality classes: 17 ≤ very good ≤20; 13≤ good ≤ 16.9; 9≤ acceptable≤ 12.9; 5≤ Poor ≤ 8.9; 1≤ bad ≤5. Grades obtained after index calculations are presented in Table 3. The crenon (B1) has good quality of water to very good (rating index range from 14 to 17.8) with slight variations according to time. The rithron (B2, B3) has acceptable to good quality waters (index grades ranged from 9.8 to 15.9) with temporal variations that occur especially at B2 by good quality water in April 2011 (grade = 15.9) and acceptable quality in August and September 2010 (12.8 and 9.8, respectively) and February and June 2011 (12.6 and 12.9, respectively). Temporal variations in B3 are low; it showed generally good quality water (grades ranging from 13.5 to 15.4) with a slight deterioration in August-September 2010 and February 2011, which showed an acceptable quality water (12.6 and 12 respectively). The potamon (B4) showed a degradation of the quality of the water represented by average quality waters during the whole year (index grades ranged from 9.6 to 12).

3. Diatoms and I.P.S.

The I.P.S. (Cemagref, 1982) is calculated from the data of actual numbers of species of epilithic diatoms. This index was calculated for populations of all stations from July 2010 until June 2011.Index grade ranges from 0 to 20. The quality of water is described with a number belonging to one of the 5 following quality classes: 17 ≤ very good ≤20; 13 ≤ good <17; 9 ≤ acceptable <13; 5 ≤ bad <9; 1 ≤ very bad <5. Grades obtained after indexes calculations are presented in Table 4.

	Grades/20												Water quality
	J0	**A0**	**S0**	**O0**	**D0**	**F1**	**M1**	**A1**	**M1**	**J1**	**Mean**	**S.D.**	
B1	16.5	17	17.8	14	16	16.8	17	16.5	16	16.8	**16**	**1.0**	Good
B2	15.5	12.8	9.8	14.3	15	12.6	14.2	15.9	15.5	12.9	**14**	**1.9**	Good
B3	14.2	12.6	12.4	13.5	13.7	12	14.8	15.4	14.5	14	**14**	**1.1**	Good
B4	10.9			12	10.4	10.4	11.8	12	11.7	9.6	**11**	**0.9**	Acceptable

Table 3. *Spatio-temporal evolution of the water quality of the 4 surveyed stations (according to the index IBD, AFNOR 2000).*

	Grades/20												Water quality
	J0	**A0**	**S0**	**O0**	**D0**	**F1**	**M1**	**A1**	**M1**	**J1**	**Mean**	**S.D.**	
B1	19	18.7	18.7	17	16.4	17.7	18.5	19	19	18.7	**18.3**	**0.9**	Very good
B2	15.5	11.5	6.5	13	14	13.5	14.8	16	16.1	13	**13.3**	**2.8**	Good
B3	13.3	13	10.8	14	12	14	14.8	15.5	14.2	14.5	**13.7**	**1.4**	Good
B4	10.3			9.4	8	12.5	13	13	13.2	7.5	**10.9**	**2.4**	Acceptable

Table 4*. Spatio-temporal evolution of the water quality of the 4 surveyed stations (according to the index IPS - Cemagref, 1982).*

The crenon (B1) has generally very good water quality (maximum grade of 19 in June 2010, April-May 2011) with the exception of December 2010 when water quality deteriorated slightly and becomes good with a grade of 16.4. We can talk about a high stability during different periods of the year. Unlike B1, B2 water quality varies greatly with time. It presents degradation according to the months and seasons with a minimum of 6.5 in September 2010 and a maximum of 16.1 in May 2011. For B3, water quality varies from acceptable to good (index grades ranged from 10.8 to 15.5) with too low temporal variations represented by deterioration in water quality during the summer and by an improved quality during the spring period. At B4, water quality showed temporal variations represented by a deterioration in water quality during the summer (7.5 in June 2011) and by an improvement during the spring period (13.2 in May 2011). These temporal variations are related to discharge and to the use of water for agricultural, which reduces the flow rate and degrades the quality of water in this sector subject to intense agricultural and urban activities.

4. Comparison of the 3 indexes

The comparison of the three indexes (SEQ-Water, I.B.D., I.P.S.) showing changes in the water quality of the 4 studied stations is represented in figure 2. Analysis of these graphs show that the index SEQ-Water reveals differences in space with a degradation of the quality of water from upstream to downstream and masks at the same time the temporal variations; contrary to biological indexes that show both spatial and temporal variations especially during summer and autumn periods. By comparing the results obtained by I.B.D. and I.P.S. we notices differences according to the notes which result in an underevaluation of the grades of the I.D.B. compared to the I.P.S. on the level of the crenon (B1) and an overvaluation on the level of the rithral (B2, B3) and the potamal (B4.) In addition the temporal variations are much more visible by the I.P.S. especially with the level of the rithral and the potamal.

DISCUSSION

According to the SEQ-Water index, the physico-chemical quality of the studied area and their aptitude to natural functions of aquatic environments vary little over time, with a trend towards improvement in winter while the spatial variations are more remarkable according to the studied sectors. This confirms the results indicated by Ismail H. (2008) with a slight decrease in the observed grades. Furthermore, contrary to what was shown on Southeast rivers in France (Cazaubon et al., 2005; Abou-Hamdan, 2004), these variations describe an upstream-downstream gradient. Based on the assessments and the water quality of river ecosystems established by Nisbet & Vernaux (1970), aptitudes obtained by the SEQ-Water for different sectors seem to over-estimate the quality of rithron and Potamon waters and underestimate that of the crenon. Thus, in terms of biological potential and usage and according to the notes of the SEQ-Water and with reference to the significance of suitability classes of this index (SEQ-Water Report, 2003), crenal water is suitable for irrigation but it requires a simple treatment to be suitable for drinking. According to diatoms indexes (I.B.D. and I.P.S.) based on the ecology of diatomic taxa including their sensitivity to pollution degree (Rimet et al., 2006), the evaluation of the quality of Berdawni goes in the same direction of results obtained by Ismail H. (2008) on the same stream with a slight decrease in the observed grades. Analysis of the results showed little difference between the two indices. These differences confirm, firstly, that the IPS is the best method (Cemagref, 1982) to assess the quality of rivers subjected to different perturbations mainly organic and secondly, the presence of problems with the standard method I.B.D. (Lenoir & Coste, 1996; AFNOR, 2000) which is manifested by an under-evaluation of the quality of the source (B1) and an overestimation of the quality of rithron (B2, B3). This underestimation by I.B.D. of the quality of the source of Berdawni (unpolluted source characterized by a high conductivity due to the limestone substrate) can be explained by the fact that the I.B.D. has a better correlation with the conductivity rather than organic and trophic pollution parameters and by the fact that the conductivity is incorporated in the design of I.B.D. as a pollution indicator parameter (Rimet et al., 2006; Ismail, 2008). Furthermore, the results of these biological indexes also show the ability of I.P.S. to identify the temporal variations much better than I.B.D. They confirm the performance of I.P.S. in assessing the biological quality of European rivers (Tudesque & Ector, 2002), the Eastern Mediterranean (Gomà et al., 2004; 2005; Abou Hamdan et al, 2010), the Swiss (Hürlimann et al., 1999), Finland (Eloranta, 1999) and Poland (Kwandrans et al., 1998) and highlight the problems associated with the application of I.B.D. in assessing the quality of some rivers in Lebanon (upper basin of the Litani) (Ismail, 2008; Abou-Hamdan et al, 2010) and Lorraine (France). (Rimet et al, 2006) showing, firstly, an overestimation of the quality of rivers characterized by high organic pollution and secondly, a discriminating capacity of quality, lower by IBD that I.P.S.

CONCLUSION

The comparison of information provided by these 3 different indexes highlights divergences, sometimes significant, in the analysis of water quality. It shows in particular a contradiction between the grades of a chemical index (SEQ-Eau) on one hand, and biological indexes (I.B.D. and I.P.S.) not only by obtained grades, but also at the level of the temporal variations, on the other hand. These differences are accentuated for rhithron and Potamon, areas where there is a tendency to overestimate water quality by the SEQ-Eau index. This result can be interpreted, through the integrative power of organisms of the physico-chemical characteristics of the environment, over a long period of time; the SEQ-Eau reflecting the instantaneous values of these parameters. The performance of the I.P.S. in the assessment of water quality in European and Mediterranean rivers (western and eastern) raises the question about the need to standardize this index. Besides, the differences in grades on the same stream with the same indexe between 2008 and the results of this work, which show deterioration in the water quality of the river, raise questions about the management of the river and the measures that must be taken to protect it. Without drawing final conclusions about it, these results raise the question about the reliability of these indexes, in particular, their use for the investigation of small Mediterranean rivers. This work highlights the need to use, for this type of streams, each of these indexes wisely, and not to analyze just a single ecosystem compartment for water quality Assessment, otherwise a misinterpretation will occur.

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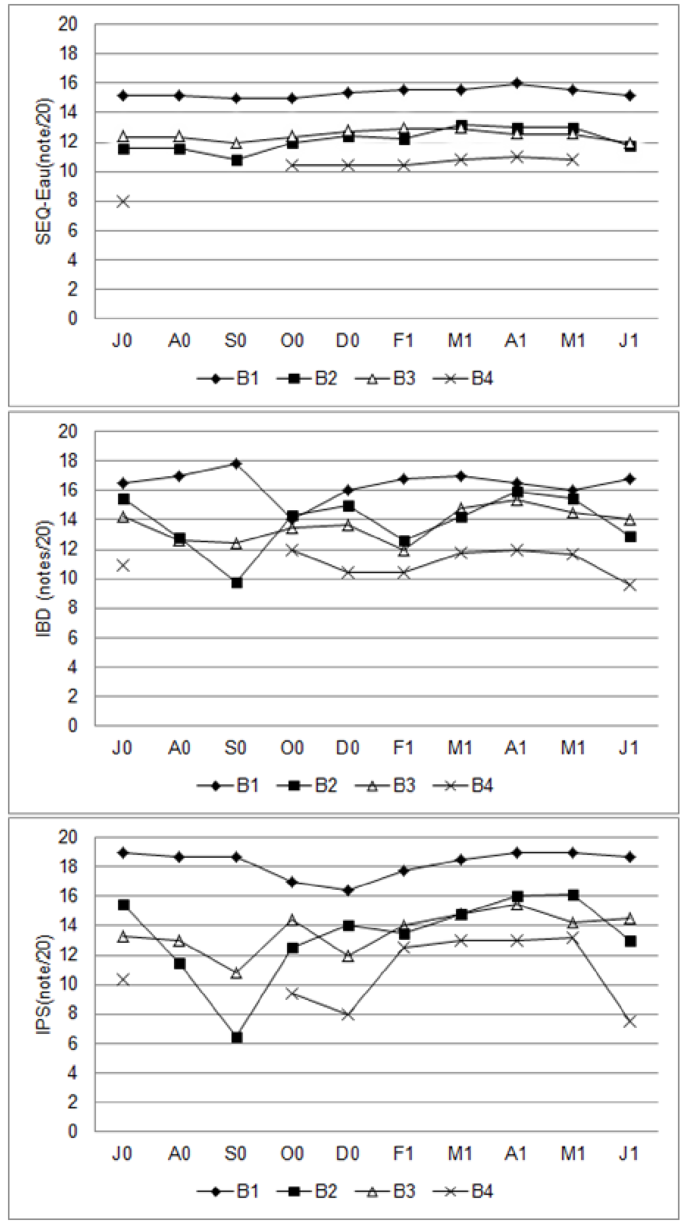

Fig.2 *Comparative Graphs of the 3 indexes grades (SEQ-Water, IBD, IPS) showing the evolution of the water quality of the 4 studied stations at the Berdawni.*

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