Impact of olive oil industry on benthic macroinvertebrates in the Kabylia region

Article *in* Journal of Materials and Environmental Science · January 2020

Hassina Merabet
Université de Béjaïa

Fatah Zouggaghe
Université de Bouira, Algérie

Lotfi Mouni
Université de Bouira

Journal of Materials and Environmental Sciences
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2018, Volume 9, Issue 9, Page 2753-2767

http://www.jmaterenvironsci.com

Impact of olive oil industry on benthic macroinvertebrates in the Kabylia region

H. Merabet[1,2*], L. Mouni[2], F. Zouggaghe[2]

[1] *Department of Environmental Biological Sciences, Faculty of Nature and Life Sciences, University of Bejaia, 06000 Bejaia, Algeria.*

[2] *Laboratory of Management and Valorisation of Natural Ressources and Quality Assurances,University of Bouira, Algeria.*

Received 18 Oct 2017,
Revised 26 May 2018,
Accepted 28 May 2018

Keywords
- ✓ *Olive mill wastewaters,*
- ✓ Water courses,
- ✓ Benthic macroinvertebrates,
- ✓ Physicochemical,
- ✓ Kabylia

merabethassina@yahoo.fr;
Phone: +213770708120;
Fax: +21326847651

Abstract

To study the effect of olive mill wastewaters on benthic macroinvertebrates, we opted to carry out a biological and physicochemical study in three rivers in the Kabylia region . A series of water and wildlife was affected over three periods for two years ; from october 2015 to May 2017. The results relating to aquatic fauna during the olive period show a total disappearance of all taxa downstream from the point of discharge in theWadi Bougdoura. As well as a decrease in the number of taxa at the point of discharge with a high number of pollu- resistant taxa such as Diptera, at the point of discharge and down-stream in the Wadi Arkham during the olive period. We have also seen a disappearance of taxa sensitive to pollution such as Trichoptera at the point of discharge and down-stream after the olive period. In the Wadi Bousselam, thermal and industrial pollution leads to a low number of all taxa at the point of discharge and downstream throughout the study period.The physicochemical study revealed a drop in dissolved oxygen up to 3.10 mg/l downstream discharge point and important mineralization at stations at the point of discharge and downstream where discharged olive mill wastewater, during the olive period. High concentrations of sulphates (265mg/l to 1012.5mg/l), chlorides (201.1 mg/l to 6922.5 mg/l), salinity (0.72 PSU to 6.83 PSU) and electrical conductivity (1.737 ms/cm to 14.92 ms/cm). Nutritional salt (nitrate and nitrite) levels remain low in all study stations, ranging from 0.49 mg/l to 2.39 mg/l for $NO3^-$, and from 0.03 mg/l to 1.66 mg/l for $NO2^-$.

1. Introduction

The Mediterranean countries producing olive oil are confronted with the problem of the disposal of their particular sewage called olive mill wastewater, a mixture of oil and water [1]. Olive mill wastewaters are effluents toxic by their phenolic compounds [2-3-4], a lot of acid with a very high saline and organic load [5] contain significant quantities of mineral salts [6] which particularly affect the quality of water in which they are dumped. Algeria is one of the main Mediterranean countries whose climate is the most favorable to the cultivation of the olive trees [7]. The increase in olive production as well as the introduction of modern techniques for oil extraction has placed the olive tree in a sensitive position as a potential polluter.

Kabylia is a mountainous and Mediterranean region located in the north of Algeria. It is characterized by its olive-growing activities, whose olive trees cover an important part of its territory [8]. The olive mill wastewaters are most often rejected in natural receptors and watercourses without any previous treatment. This latter, seriously harm the quality of these surface waters. The structure of benthic macroinvertebrate communities is often used as an indicator of the effects of human activities river ecosystems. It also provides a wealth of information on water and habitat quality [9-10].

Thus, these benthic macroinvertrbrates constitute one of the most widely used tools for the definition from the types of system an the assessment of the state of health of fresh water, mainly running water [11]. In addition, the development of certain populations, regression or disappearance of other populations leads to the establishment of lists of species indicative for the level of pollution, according to their polluo-sensitivities [12]. Research studies focus on the impact of different types of pollution and anthropogenic disturbance on benthic macroinvertebrates in aquatic ecosystems. On the one hand, these studies generally show a decrease or even disappearance of certain taxa or faunal groups downstream of the discharge points, on the other hand, they show a satisfactory diversity noted at the reference stations situated upstream of these discharges [13-14-15-16-17-18]. However, knowledge of the effects of olive mill wastewater on benthic invertebrates in lotic ecosystems is very limited. Indeed, a rigorous monitoring of the current situation of olive oil pollution and its evolution in aquatic ecosystems is of a great importance for the conservation of the biocenosis of these ecosystems.

In this perspective, our work is concerned to study the impact of olive mill wastewater as well as effluents of olive oil mill on the biological quality of three rivers in the kabylia region; using the communities of Macro-invertebrates benthic as bio-indicators of the health status of these aquatic ecosystems.

2. Material and Methods

2.1.Study area and sampling stations

Kabylia is a mountainous and coastal region located in the center-east of Algeria. Two distinct geographical areas compose the relief of its territory namely the Kabylia of Djurdjura and the Kabylia of the Babors and the Bibans. The aim of this study is based on the southern part of the Kabylia of Djurdjura (Figure 1), which extends 150 km from the Issers Plain in the west to the Soummam valley East and over 100 km from north to south between the Mediterranean and Wadi Sahel / Soummam [8]. The Djurdjura massif climate is considered as being cold and wet because of the abundant rainfall (over 800 mm/year). The hydrographic network of the Kabylia of Djurdjura is very dense. It is composed of three (03) major Wadis (rivers) which are: Wadi Isser, Wadi Sébaou and Wadi Soummam. These wadis draining stormwater into the sea are fed by an important large hydrographic scalp composed of small wadis (wadi and coastal wadis of the hinterland and some important tributaries) [19]. Three rivers were chosen during this study which belongs to three different watersheds: Wadi Arkham (Isser Watershed), Wadi Bougdoura (Coastal Watershed Algerian) and Wadi Bousselam (Watershed of the soummam).

Figure 1: Location of the study area

The choice of the stations was conditioned by the various direct sites of the olive mill wastewater in the three rivers, where a total of 9 stations were retained (Table 1, Figure 2). The study was conducted between 2015 and 2017 with six sampling campaigns; two in the months of October 2015 and 2016 (before the olive-growing period), two others in January 2016 and 2017 (during the harvest period) and two more in May 2016 and 2017 (after the harvest period). Harvesting of water and fauna from macroinvertebrates were collected from three samples in each watercourse, with nine samplings in each year, a total of 18 levies taken between 2015 and 2017. In each watercourses, three studies stations were targeted, one at the point of direct discharge of the olive mill wastewater and two stations upstream and downstream of this point of rejection.

2.2. Sampling and analysis

2.2.1.sampling: After completing a field record, benthic macroinvertebrates and water samples are collected from each study site:

•*Water sampling*

Samples were taken at each station, in 1.5 liter polyethylene bottles facing the current, these bottles were rinsed with the water to be analyzed. To avoid oxidation and formation of air bubbles the bottles must be filled on board and closed. The samples are transported to the laboratory in a cooler at a temperature of 4°C.

Table 1: The study stations and their geographical coordinates.

Stations*	Geographical coordinates	Location
Ar1	N 36 ° 25'53.5" E 003 ° 48'33.3"	located 2 km upstream from the point of discharge, in front of viaduct (bridge) in Ain El Turk (Wilaya of Bouira), chosen as a reference station.
Ar2	N 36 ° 26'20.7" E 003 ° 49'53.8"	located at the direct discharge point of the oil mill at Ain El Turk.
Ar3	N 36 ° 26'25.6" E 003 ° 50'00.2"	located 500 m downstream from the discharge point at Ain El Turk, 100 m before its confluence with Wadi Djemaa.
Bg1	N 36 ° 35'23.6" E 003 ° 51'03.1"	located 8 km upstream of the discharge point and 2 km downstream of the Draa El Mizan dam (Wilaya of Tizi ouzou), this station was chosen as a reference station.
Bg2	N 36 ° 38'32.0" E 003 ° 53'42.2"	Located at the direct discharge point of the oil mill, in the commune of Ait Yahia Moussa (Wilaya of Tizi-ouzou).
Bg3	N 36 ° 38'47.7" E 003 ° 54'12.9"	located at a distance of 1 km downstream from the point of discharge, in the commune of Ait Yahia Moussa.
Bs1	N 36 ° 24'34.4" E 004 ° 35'14.5"	located 2 km upstream of the discharge point and 2 km downstream of Tichy-Haf dam in the municipality of Tamokra west of Akbou (Wilaya of Béjaia), this station was chosen as a reference station.
Bs2	N36°24'41.1" E 004 ° 35'07.4 "	located at the direct discharge point of the oil mill, opposite the thermal station of Hammam Sidi Yahia in the municipality Tamokra.
Bs3	N 36 ° 24'36. 9" E 004 ° 35'00.2"	located at a distance of 500 m downstream from the point of discharge, and 3 km upstream of its confluence with the wadi Sahel in the area of Akbou.

(*) Ar, Wadi Arkham; Bg, Wadi Bougdoura; Bs, Wadi Bousselam.

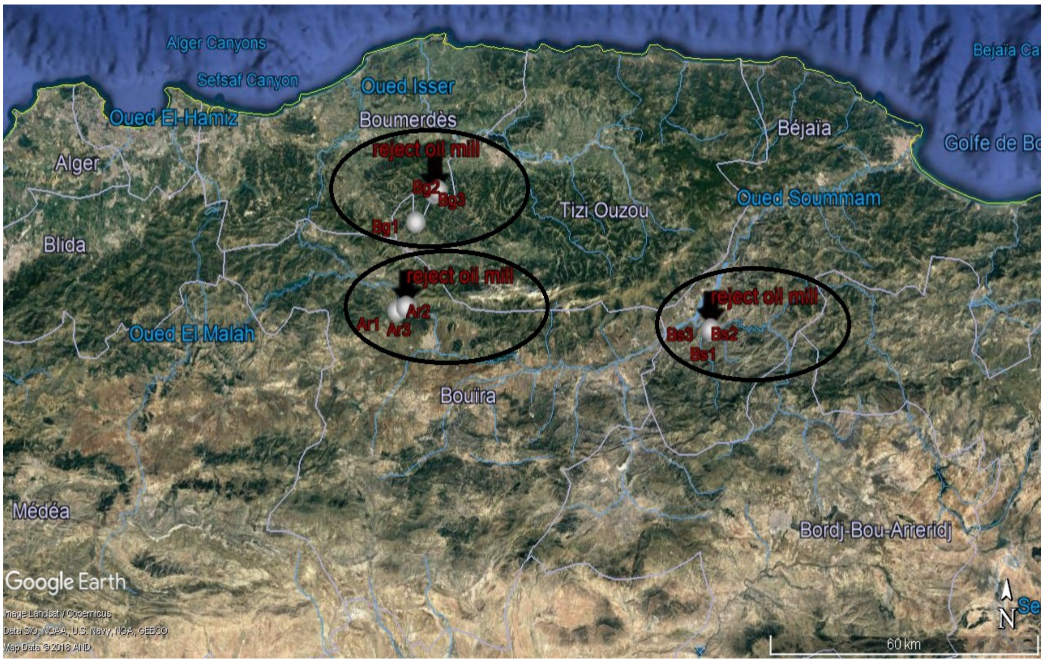

Figure 2: Location of the sampling station

•Benthic macroinvertebrates sampling

The benthic fauna were removed using a disturbed mesh, placed against the current; the lower substrates (rock, sand, mud ...) are mixed with the hands in shallow water or with the Feet in deeper water. The collected samples are sorted to remove large organic debris and the individuals trapped in the net are recovered. Each sample is fixed immediately by addition of 10% formalin. In the laboratory, the samples are then transferred into sieves at different meshes. The selected part is then sorted. The ultimate goal is to recover the greatest number, see the totality of individuals. The different faunal groups are then identified using a binocular lens, up to the family or gender level using a guide to identification freshwater invertebrates [20].

2.2.2 Physicochemical and biological analyzes

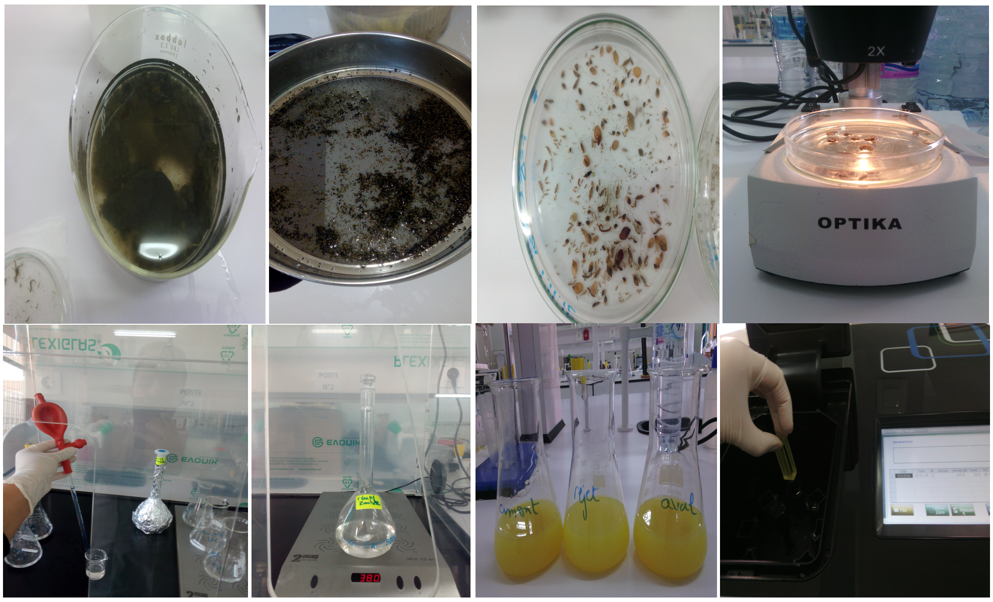

Figure 3 : Photos identification of macroinvertebrates and physicochemical analyzes

a. Physicochemical parameters

Temperature (T), conductivity (Cond), PH, dissolved oxygen (O2) and salinity were measured in situ using a multi parameter (HANNA, HI 9829). They are very sensitive to environmental conditions and are likely to change to significant proportions if they are not measured on site [21]. The other physicochemical parameters are measured in the laboratory; the chlorides (Cl-) are measured by Mohr volumetric method in the presence of silver nitrate [22]. Nitrates (NO3-), nitrites (NO2-) and sulphates ($SO4^{2-}$) were determined by the following methods: sodium salicylate, Zambelli reagent method [23] and turbidimeter method [22], Using a UV-Visible spectrophotometer of the Optizen POP type.

b. Biological parameters

In order to facilitate the interpretation of the results obtained from the determination of benthic invertebrates in the samples, the abundance and taxonomic richness of the two years of study are calculated. The values of the taxonomic richness and abundance of each of the stations are represented by histograms and curves, which allows us to compare between study stations and rivers.

3. Results and Discussions

3.1.Physicochemical parameters

Physicochemical parameters provide information on water quality. The mean values of the physicochemical analyzes of the two years of study were calculated. The results in Wadi Arkham, Wadi Bougdoura and Wadi Bousselam are shown in Tables 2, 3 and 4 respectively.

Table 2: Mean values of the physico-chemical parameters in the Wadi Arkham (Oct 2015 / May 2017)

Parameters	Before the olive period October 2015-2016			During the olive period January 2016-2017			After the olive period May 2016-2017		
	Upstream (Ar1)	Reject (Ar2)	Down-stream (Ar3)	Upstream (Ar1)	Reject (Ar2)	Down-stream (Ar3)	Upstream (Ar1)	Reject (Ar2)	Down-stream (Ar3)
T (°C)	17	16	16	12.5	10.5	3.5	23	22.5	21.5
PH	8.3	8.2	8.22	8.29	8.16	8.23	8.03	8.57	8.18
Cond. (ms/cm)	1.466	1.437	1.475	1.683	1.749	1.751	1.471	1.461	1.472
O_2 (mg/l)	11	12	12.5	11.07	12.43	13.52	8	9.45	8.20
Salinity (PSU)	0.7	0.71	0.69	0.74	0.77	0.78	0.75	0.73	0.73
Cl^- (mg/l)	176	186	184	177.5	205	201.5	95.5	120	109
SO_4^{2-}(mg/l)	332	292	380	580	502	560	425	380	392.5
NO_3^-(mg/l)	1.67	1.72	1.36	1.66	1.53	1.47	1.44	1.63	1.725
NO_2^-(mg/l)	0.35	0.12	0.12	0.055	0.155	0.13	0.545	0.11	0.085

Table 3: Mean values of the physicochemical parameters in the Wadi Bougdoura (Oct 2015 / May 2017)

Parameters	Before the olive period October 2015-2016			During the olive period January 2016-2017			After the olive period May 2016-2017		
	Upstream (Bg1)	Reject (Bg2)	Down-stream (Bg3)	Upstream (Bg1)	Reject (Bg2)	Down-stream (Bg3)	Upstream (Bg1)	Reject (Bg2)	Down-stream (Bg3)
T (°C)	16.5	15.5	12.5	10.5	10	11	19	21	21
PH	7.92	7.76	8.14	7.68	7.54	7.26	7.56	7.83	8.06
Cond. (ms/cm)	1.608	1.653	1.642	1.706	1.737	1.749	1.637	1.392	1.399
O_2 (mg/l)	7.52	8.85	10.02	3.42	5.17	3.10	3.36	6.32	6.72
Salinity (PSU)	0.89	0.47	0.74	0.68	0.72	0.75	0.80	0.65	0.66
Cl^{-}(mg/l)	212.6	220.1	166.67	245.5	393.5	355	192.5	188.5	161
SO_4^{2-}(mg/l)	352.5	268.5	274.75	310	306.5	265	330	243.5	257.5
NO_3^-(mg/l)	0.9	3.525	2.15	2.335	0.49	0.64	0.27	3.815	3.69
NO_2^-(mg/l)	0.765	0.545	0.64	0.425	0.57	1.66	0.62	1.4	1.55

Table 4: Mean values of the physicochemical parameters in the Wadi Bousselam (Oct 2015 / May 2017)

Parameters	Before the olive period October 2015-2016			During the olive period January 2016-2017			After the olive period May 2016-2017		
	Upstream (Bs1)	Reject (Bs2)	Down-stream (Bs3)	Upstream (Bs1)	Reject (Bs2)	Down-stream (Bs3)	Upstream (Bs1)	Reject (Bs2)	Down-stream (Bs3)
T (°C)	16	23.5	25	9.5	22.5	21.5	18	32	32.5
PH	8.25	6.86	7	8.46	6.93	6.96	7.84	6.70	7.04
Cond. (ms/cm)	1.511	14.055	17.02	1.566	14.92	14.56	1.543	17.69	19.03
O_2 (mg/l)	9.40	7.62	7.60	11.7	7.98	6.96	6.75	4.39	5.41
Salinity (PSU)	0.77	8.05	8.20	0.63	6.81	6.83	0.77	15.47	15.53
Cl^{-}(mg/l)	161.45	5005.5	6272.6	193	6851.5	6922.5	146.5	6006	7081.5
SO_4^{2-}(mg/l)	352.5	781.25	681.25	405	981	1012.5	330	578.5	632.5
NO_3^-(mg/l)	0.355	0.25	0.27	0.45	2.39	2.18	0.825	0.62	0.54
NO_2^-(mg/l)	0.06	0.07	0.1	0.515	0.195	0.19	0.013	0.045	0.48

Comparison of the results at the 9 stations studied in the three rivers allowed to detect high concentrations of chloride (Cl-), sulphates (SO_4^{2-}) and electrical conductivity (Cond) contents and salinity during the olive period in the discharge points and downstream. Other research by several authors on the impact of these releases on different watercourses is presented in Table 5.

Table 5: average values of physicochemical parameters obtained in different studies on the impact of Olive mill wastewaters on rivers

Country	Period			T (°C)	PH	Cond (ms/cm)	O2 (mg/l)	Cl- (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)	NO_2^- (mg/l)	Reference
Greece Evrotas river 11/2006 to 05/2008)	1st year	Before	Up-stream	n.d	7.90	0.560	9.64	8.73	n.d	0.36	0.01	[24]
			Down-stream	n.d	8.08	0.506	10.84	14.20	n.d	2.65	0.04	
		During	Up-stream	n.d	8.01	0.554	8.81	7.80	n.d	0.44	0.01	
			Down-stream	n.d	8.06	0.465	9.17	12.17	n.d	1.79	0.01	
		After	Up-stream	n.d	7.91	0.472	8.63	8.20	n.d	0.71	0.01	
			Down-stream	n.d	7.89	0.418	8	11.34	n.d	2.07	0.01	
	2nd	Before	Up-stream	n.d	7.92	0.551	7,02	11.05	n.d	1.60	0.01	
			Down-stream	n.d	8	0.511	7.56	15.20	n.d	0.80	0.01	
		During	Up-stream	n.d	8.18	0.436	7.45	8.77	n.d	1.06	0.01	

	year		**Down-stream**	n.d	7.82	0.475	5	18.17	n.d	1.50	0.26	
		After	**Up-stream**	n.d	8.10	0.488	7,89	11.41	n.d	0.22	0.01	
			Down-stream	n.d	7.89	0.445	5.01	15.02	n.d	0.16	0.01	
Greece 09/2008 to 05/2011	**Belikas river**	**During**	**Up-stream**	n.d	n.d	n.d	n.d	n.d	n.d	1.51	0.002	[25]
			Down-stream	n.d	n.d	n.d	n.d	n.d	n.d	2.07	0.015	
	Pamisos river	**During**	**Up-stream**	n.d	n.d	n.d	n.d	n.d	n.d	2.03	0.001	
			Down-stream	n.d	n.d	n.d	n.d	n.d	n.d	5.19	0.08	
Morocco 2009/2010	**Boufek rane river**	**During**		18.5 4	7.58	0.85	6.03	314.45	14.67	3.33	0.82	[26]
Greece 05/2006 to 12/2007)	**Evrotas river**	**During**		n.d	n.d	n.d	6.8	n.d	n.d	1.4	0.024	[27]

n.d. no determined

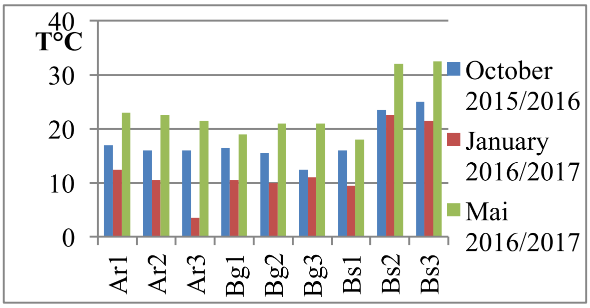

Figure 4: Variation of temperature during sampling campaigns in the three rivers.

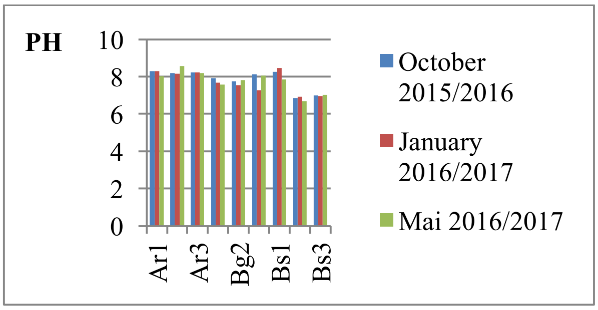

Figure 5: Variation of PH during sampling campaigns in the three rivers.

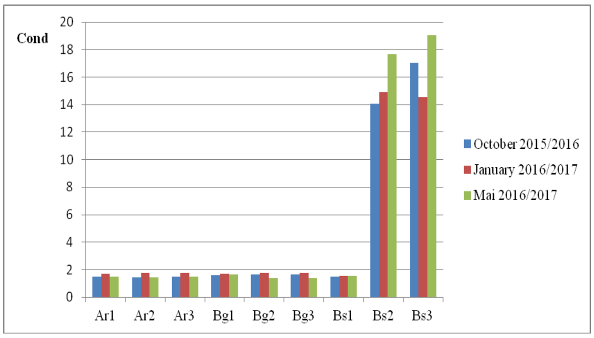

Figure 6: Variation of electrical conductity during sampling campaigns in the three rivers.

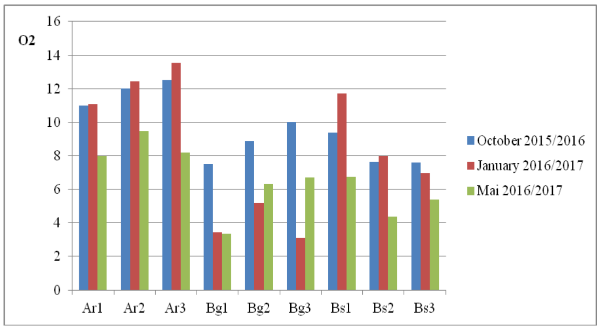

Figure 7: Variation of O2 during sampling campaigns in the three rivers.

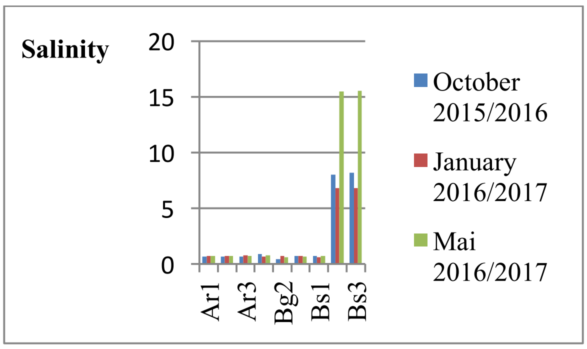

Figure 8: Variation of Salinity during sampling campaigns in the three rivers.

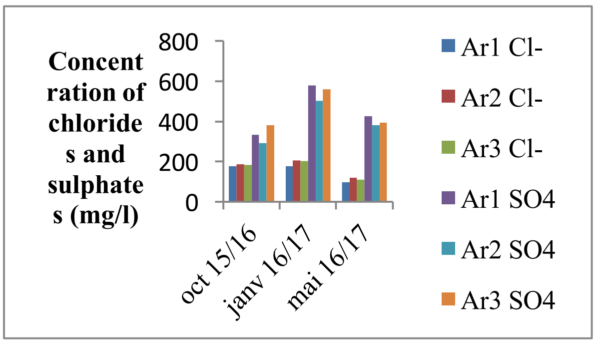

Figure 9: Variation of chlorides and sulphates in the wadi Arkham.

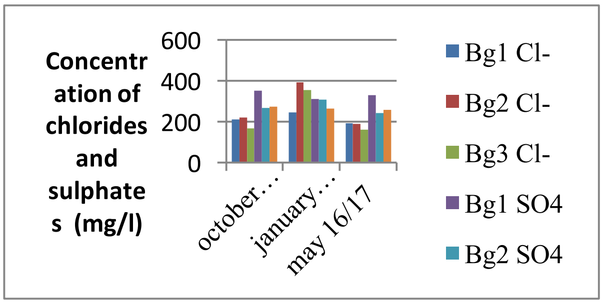

Figure 10: Variation of chlorides and sulphates in the wadi Bougdoura.

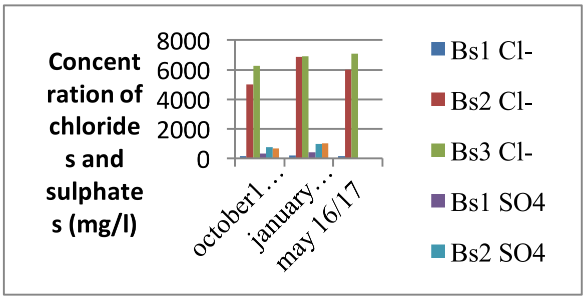

Figure 11: Variation of chlorides and sulphates in the Wadi Bousselam.

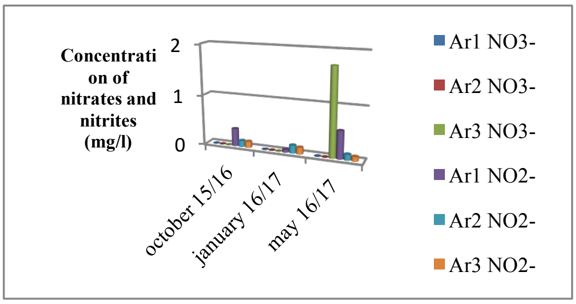

Figure 12: Variation of nitrates and nitrites in the wadi Arkham.

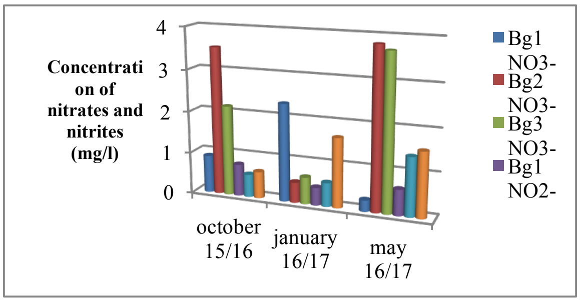

Figure 13: Variation of nitrates and nitrites in the wadi Bougdoura.

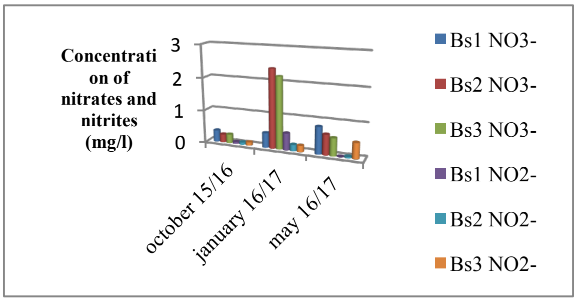

Figure 14: Variation of nitrates and nitrites in the Wadi Bousselam.

Temperature

The temperature of a watercourse plays a fundamental role in the dynamics of aquatic ecosystems and is highly sensitive to environmental factors and the impacts of human activities [28].

Temperature values at the Wadi Arkham follow seasonal variations during the three sampling seasons. In the Wadi Bougdoura, the temperature decreases from upstream to downstream before the olive period (October), and follows a growing gradient after the olive period. The increase of these values at the Bg2 to Bg3 station during the olive period is due to the oil mills rejections in this region. Large variations in temperature are observed in the Wadi Bousselam at the Bs2 and Bs3 stations due mainly to the confluence of the Wadi with the thermal station of Hammam Sidi Yahia, and particularly to the olive oil rejections at the level of station Bs2 during the olive period (January) reaching 22.5°C at the point of discharge (Figure 4).

The PH

The pH of the water indicates its acidity and alkalinity [29], PH values are between 6 and 8.5 in natural waters [30]. Olive mill wastewaters have an acid pH [31,32,33,34,35,36,37,38,39,40,41,42]. This can be explained by self-oxidation and polymerization reactions that convert phenolic alcohols into phenolic acids [43]. These reactions are manifested by a change in initial staining of olive mill wastewaters to a very dark black [32]. The average values of PH in the Wadi Arkham during the olive period varied between 8.16 and 8.23 in Ar2 and Ar3, these values are slightly basic and not significant; this corresponds to the dilution of volumes Spilled in this watercourse. In the Wadi Bougdoura, a decrease in PH values is recorded during the olive period compared to the values recorded in October and May, with a minimum value of 7.26 in the station located downstream of the Bg3, this explains a large volume of effluents discharged which are characterized by their acidity. In the Wadi Bousselam the PH values are basic in the Bs1 stations and slightly neutral in the Bs2 and Bs3 stations (6.70 to 7.04) during the three periods. Low PH changes are recorded during the olive period, with a minimum value of pH 6.96 (Figure 5), which can be explained by the high water flow in January. same results are found by [24,26] (table 5).

Conductivity

The conductivity of water indicates its ability to conduct electric current. This ability depends on the water content of dissolved salts [44]. Olive mill wastewaters contain significant levels of electrical conductivity [36,45,46], They generally have a high salinity due to the important addition of salt for the conservation of olives (conductivity greater than 10mS.cm-1) [33,35,37,38,39,47,48].

The highest values of conductivity were recorded after the olive period in the Wadi Bousselam and during the olive period in the Wadi Arkham and Wadi Bougdoura. They reach respectively the values: 1.749 ms/cm and 1.751 ms/cm in the stations Ar2 and Ar3. In the Wadi Bougdoura, we recorded high levels of conductivity during the harvest period at the two stations (Bg2 and Bg3), whose maximum value was 1.749 ms/cm in the Bg3 station and 1.739 ms/cm In the station Bg2.

Olive oil releases explain these high values in these stations. In the Wadi Bousselam, the conductivity values remained stable during the three sampling campaigns at station Bs1 (1.511 ms/cm at 1.566 ms/cm). Very significant variations are recorded in stations Bs2 and Bs3 before the olive period (October) following the discharges from the thermal station. An increase in these values during the olive period at the point of discharge (Bs2) is recorded, this increase being explained by the effluents of the olive mill wastewater at this watercourse. The maximum value is 19.03 ms/cm in Bs3 after the olive period; this value can be explained by the high temperatures recorded at this station at 32.5 ° C (Figure 6).

The dissolved oxygen (O2)

In the aquatic environment, oxygen is an essential element for living organisms. the concentration of oxygen in water is the result of many processes. Above all, the dissolving capacity of oxygen is a function of the temperature by the water; cold water contains a greater quantity of oxygen than hot water [49]. dissolved oxygen is the degree of self-purification in storage basin olive oil mill wastewater or in a stream [33] .

In the Wadi Arkham high concentrations of dissolved oxygen are recorded during the olive period, with a maximum value of 13.52 mg/l in Ar3. The low temperature value Ar3 (3.5°C) explains the good oxygenation of water during this period. A decrease in dissolved oxygen is recorded during the month of May compared to the months of October and January.

the same results obtained by [24] in the first year of study, the concentrations of dissolved oxygen are not significant during the olive period. this is related to the rainfall that occurs by dilution of organic matter, and the fixation of pollutants in sediments and aquatic organisms.

In the Wadi Bougdoura we noted a low concentrations of dissolved oxygen during the olive period, the minimum value is recorded in Bg3 (3.10 mg/l), and a value of 5.17 mg/l in Bg2, this can be expressed by the evacuation of organic matter to downstream. It is estimated that the high organic loading of olive mill wastewater has suffered a drop in oxygenation at this station. this drop in dissolved oxygen can be explained by the effect of sedimentation of olive mill wastewater on oxygen availability. By clogging the interstices of the gravel, fine sediments reduce the exchange of oxygen between the surface and the interior of the gravel [50].

the same results obtained by another study [24] a value of 7.45 mg / l upstream and 5 mg / l downstream. In the Wadi Bousselam high oxygenation is recorded in Bs1 during the olive period, dissolved oxygen decreases from upstream to downstream, reaching 6.96 mg/l in Bs3, dilution is explained by these small variations. Low values are recorded after the olive period in Bs2 and Bs3; this is explained by the fact that hot water contains less oxygen than cold water (Figure 7).

Salinity

Salinity is defined by the total amount of dissolved elements in the water. The presence of salt in water is very important and determines some of its properties [18].

In the Wadi Arkham, salinity follows an increasing gradient from upstream to downstream, and records high values in Ar2 and Ar3 during the olive period. Compared to the results obtained in May, a decrease is recorded from the upstream towards the downstream, confirming the effect of olive mill wastewater in January on this watercourse. In the Wadi Bougdoura the same trends are recorded during the olive period, upstream to downstream, it is estimated that olive oil effluents are responsible for these high values, a slight decrease is observed after the olive period in the Stations Bg2 and Bg3 compared in January. Similar values are recorded in the Wadi Bousselam in the Bs1 station during the three studies periods, with large variations recorded in Bs2 and Bs3 in May. This confirms that salinity evolves in parallel with conductivity (Figure 8).

Mineral salts

Chlorides

Chlorides (Cl-) are widely distributed in nature, usually in the form of sodium (NaCl) and potassium (KCl) [51]. They do not participate in the biological process (decomposition of organic matter), and the increase in its content is considered as an index of industrial pollution [44].

Olive mill wastewater contain high concentrations of chlorides [31, 39,40,52] This high chloride content is due to the practice of salting (adding salt in large quantities) for the conservation of olives before the extraction process. Chloride levels are higher during the olive period at the discharge points and downstream in the three rivers. The evolution of these concentrations in Wadi Arkham shows that station Ar2 records the highest value during the month of January (205 mg / l). During the month of May we recorded a decrease in these concentrations (figure 9). The results obtained in the Wadi Bougdoura determine significant concentrations in the Bg2 and Bg3 stations (393.5 mg/l, 355 mg/l) respectively during the olive period, whereas during the month of May these concentrations decreased, At 161 mg/l in the station Bg3 (figure 10). Very high concentrations of chlorides recorded in the Bs2 and Bs3 stations during the olive period, which gives information on the effect of these releases on these two stations. An increase in these levels after the olive period was recorded in the Bs3 station (7081.5 mg/l) (Figure 11).

The Sulphates

Sulphates (SO_4^{2-}) exist in running water at varying concentrations depending on the geological nature of the lands traversed. The increase in its contents is considered as an index of industrial pollution [44].The sulfates concentrations in the olive mill wastewaters are varied with process type of trituration of olive [33]. The sulphates showed the same changes in concentrations as chlorides and conductivity during the olive period in the Wadi Bougdoura and the Wadi Bousselam. In the Wadi Arkham, the highest values are recorded in the Ar1, Ar2 and Ar3 stations (580 mg/l, 502 mg/l and 560 mg/l respectively) (Figure 9).

In the Wadi Bougdoura, the sulphate concentrations recorded the same variations before and after the olive period. A decreasing gradient from upstream to downstream is recorded during the olive period. The highest value is recorded at station Bg2 (306.5 mg/l) (Figure 10). In the Wadi Bousselam, the concentration of sulphates increases during the olive period. The values recorded in the Bs2 and Bs3 stations are very high, reaching respectively (981 mg/l, 1012.5 mg/l) during the month of January (Figure 11). Compared to the values recorded during the olive period, the concentrations obtained in the discharge points and downstream experienced a significant decrease in the concentration of this parameter after this period (sampling campaign in May). Concentrations of conductivity, chlorides and sulphates evolve in parallel, with high concentrations due to the use of salts for the preservation of olives. These are parameters which determine a mineral pollution of the waters.

Nutritional salts

Nitrates and nitrites are forms of nitrogen that naturally exist in the environment [53]. The nitrates concentrations are varied with process type of trituration of olive, for the press process, it is 0.36 to 1.39 ppm, the continuous process three-phases, it is 0.25 to 1.34 ppm, and for the continuous process two-phases, it is 0.06 to 0.95 ppm [33,41,54]**.**

In our study nitrates and nitrites have low concentrations and do not show significant differences between upstream and downstream. Nitrate and nitrite levels recorded during the three sampling campaigns in the three rivers remain small and less (Figures 12, 13 and 14).

The Nitrates

In the Wadi Arkham, the highest concentration is in Ar3 in May, reaching 1.725 mg/l, between 0.36 mg/l and 1.725 mg/l during the months of October and May, this explains the natural phenomenon of self-purification of these rivers. A slight decrease is observed during the olive period in Ar2 stations, reaching a value of 1.53 mg/l (Figure12). In the Wadi Bougdoura, a significant decrease in the nitrate concentration is recorded in the

Bg2 and Bg3 stations during the harvest period compared to the results obtained during the months of October and May. A low value is recorded in the direct discharge point (0.49 mg/l) (Figure 13). On the other hand, in the Wadi Bousselam, an increase of these concentrations in the Bs2 station is observed during the olive period, which is 2.39 mg/l (Figure14).

The Nitrites
The evolution of the nitrite concentration during the study period shows an increase in these values at the point of release during the olive period. In Wadi Arkham, values are stable during the three sampling seasons and range from 0.055 mg/l to 0.545 mg/l in study stations (Figure12). An increase in nitrite concentrations during the olive period compared to the concentrations obtained in October in the Wadi Bougdoura. The highest concentration during the month of January is recorded in the downstream point (Bg3: 1.66 mg/l) (Figure 13).The high concentration is recorded in upstream station during the olive period in the Wadi Bousselam, the maximum value being to the order of 0.515 mg/l in Bs1 (figure 14). The decrease in nitrate and nitrite concentrations and the low values recorded by these two parameters in the discharge points of olive mill wastewater; during the olive period can be explained by the saturation of the self-purification capacity of living organisms under the effect of too concentrated organic matter and the presence of toxic substances. Under anoxic or even anaerobic conditions, denitrification of nitrate is reduced to nitrite and then to nitrogenous nitrogen (nitric oxide: NO, nitrous oxide: N_2O and diazote: N_2) released into the atmosphere, which reduces the nitrogen load of the system Aquatic life [55].

Same results of nitrates and nitrites are referred by several authors such as [24,25,26,27], they vary between (5.19 mg/l to 0.44 mg/l NO_3^-) and (0.26 mg/l to 0.001 mg/l NO_2^-) during the olive growing season. The main physicochemical results show the degradation of the rivers studied, this degradation exists more exactly at the points of discharge of the oil mills and downstream of these oil mills.

3.2. Benthic macroinvertebrates

Macroinvertebrate communities are highly sensitive to environmental variability. Therefore the diversity of the species present and their abundance can provide important indications on the quality of aquatic environment [56]. The presence or absence of benthic macroinvertebrates may constitute a biological marker of aquatic ecosystems of running water [57]. The average abundance and taxonomic richness of benthic fauna during the two years of study of the three rivers studied are presented in Tables 5, 6 and 7.

Table 5: Taxonomic list of benthic macroinvertebrates present in the Wadi Arkham

	October 2015/2016			**January 2016/2017**			**May 2016/2017**		
	Ar1	**Ar2**	**Ar3**	**Ar1**	**Ar2**	**Ar3**	**Ar1**	**Ar2**	**Ar3**
Turbellaria									
Planariidae		1					1		1
Cnidarians									
Hydridae	1								
Nemathelminthes								1	
Isopods									1
Gastropods									
Physidae									
Physa			1			1			
Plecoptera									
Leuctridae									
Leuctra	1			2					
Ephemeroptera									
Baetidae									
Baetis	15			11	1	1	39		2
Baetopus	3								
Acentrella	4	5	117	2	19	30	19	1	35
Caenidae									
Caenis		3	3	3	1	1	2	2	1
Odonata									
Gomphidae									
Onychogomphus		1		1		2	1	2	2
Ophiogomphus									1

Heteroptera									
Mesoveliidae									
Mesovelia			1						
Hydrometridae									
Hydrometra								1	
Coleoptera									
Dytiscidae									
Hygrotus		4						3	
Gyrinidae									
Aulonogyrus							2		2
Trichptera									
Hydropsychidae									
Cheumatopsyche	2	10	8		8	1	1		
Hydroptilidae									
Agraylea							1		
Diptera									
Chironomidae	2	1	22	34	13	24	11	5	5
Empididae	2			2					
Simulidae	1		14	11	3	10	1	2	7
Limoniidae								1	1
Hexatoma				1		1			
Athericidae									
Atherix						1			
Blephariceridae									
Hapalothrix						14			
Tipulidae				4			3	8	3
Ceratopogonidae							1		
Ephydridae						1			
Total number of individuals	31	25	166	71	45	87	82	26	61
Total number of taxa	9	7	7	10	6	12	12	10	12

Table 6: Taxonomic list of benthic macroinvertebrates present in the Wadi Bougdoura

	October 2015/2016			**January 2016/2017**			**May 2016/2017**		
	Bg1	**Bg2**	**Bg3**	**Bg1**	**Bg2**	**Bg3**	**Bg1**	**Bg2**	**Bg3**
Nemathelminthes								1	
Gastropods									
Hydrobiidae									
Lithoglyphus	1								
Ancylidae			4						
Physidae		35	1						
Planorbidae								1	
Lumbricidae							1		
Ephemeroptera									
Baetidae									
Baetis	5				3			23	21
Acentrella		82	85					48	77
Caenidae									
Caenis		22	17		10			2	2
Heteroptera									
Corixidae									
Mecronecta			1						
Coleoptera									
Gyrinidae									
Aulonogyrus		1							
Trichoptera									
Hydropsychidae									1
Hydropsyche			5						

Cheumatopsyche			1						
Hydroptilidae									
Hydroptila			1						
Diptera									
Chironomidae	268	27	3	15			52	60	36
Simulidae	25	25	5					20	
Blephariceridae			34						
Psychodidae	115		1						
Ceratopogonidae			1		1				
Tipulidae									1
Total number of individuals	414	192	159	15	14	0	53	155	138
Total number of taxa	5	6	13	1	3	0	2	7	6

Table 7: Taxonomic list of benthic macroinvertebrates present in the Wadi Bousselam

	October 2015/2016			**January 2016/2017**			**May 2016/2017**		
	Bs1	**Bs2**	**Bs3**	**Bs1**	**Bs2**	**Bs3**	**Bs1**	**Bs2**	**Bs3**
Ephemeroptera									
Baetidae									
Baetis	2		1				1		
Acentrella	2								
Ecdyonurus	1								
Odonata									
Gomphidae									
Gomphus	1			1					
Ophiogomphus				1			2		
Libellulidae									
Orthetrum		1	1		1				
Coleoptera									
Gyrinidae									
Gyrinus	1								
Trichoptera									
Hydropsychidae	5			1					
Diptera									
Chironomidae	1	10	10		8				
Thaumalidae	1								
Limonidae				1					
Total number of individuals	14	11	12	4	9	0	3	0	0
Total number of taxa	8	2	3	4	2	0	2	0	0

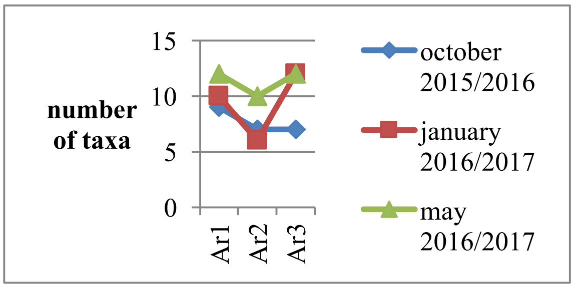

Figure 15: Taxonomic Wealth in the Wadi Arkham.

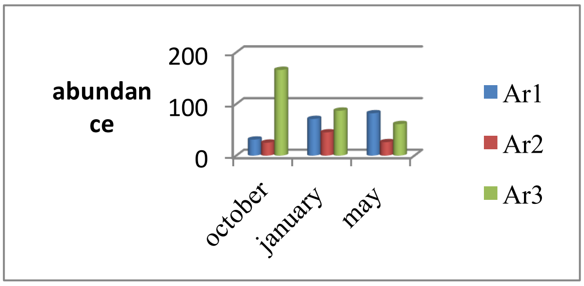

Figure16: Abundance in the Wadi Arkham

In the Wadi Arkham, taxonomic richness decreases at the point of release (Ar2) during the olive period and a high abundance of benthic invertebrates is observed downstream of the discharges (Ar3) during the same period. The genus Acentrella and the families Blephariceridae, Chironomidae and Simulidae are the most abundant families in this station (Ar3) (Table 5). A low abundance is recorded after the olive period at the stations Ar2 and Ar3, characterized by the disappearance of the trichoptera which is a pollu-sensitive order. This means a gradual restoration of taxa during the May (Figure 15 and 16). The maximum abundance values are observed during the month of October, which indicates the effect of these rejections even after the olive period.

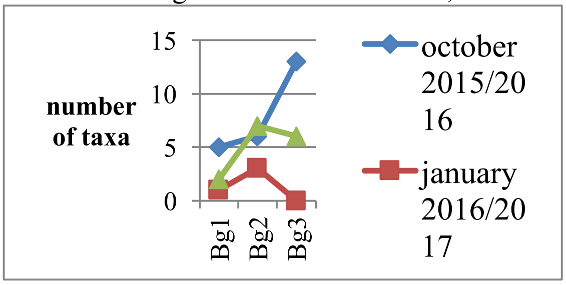

Figure 17: Taxonomic Wealth in the Wadi Bougdoura.

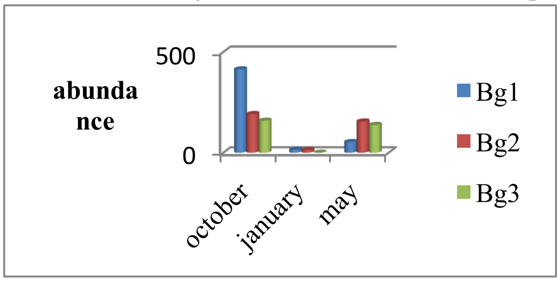

Figure18: Abundance in the Wadi Bougdoura

In the Wadi Bougdoura, benthic invertebrate taxa disappear completely downstream from the point of discharge during the olive period. And they reappear in May with a high population for the genus Acentrella and the Chironomidae family (Table 6). The trichoptera disappear in the station (Bg3) after the olive period compared to the results obtained in October. The distribution of individuals in the Wadi during May highlights an increase in taxon numbers and abundance from upstream to downstream. Indeed, during the month of October the various wastewater discharges from the non-functional sewage treatment plant contributes to the absence of sensitive taxa and the proliferation of taxa tolerant to organic pollution composed mainly by Chironomidae with a population high of 268 individuals in the station (Bg1) (Figure 17 and 18).

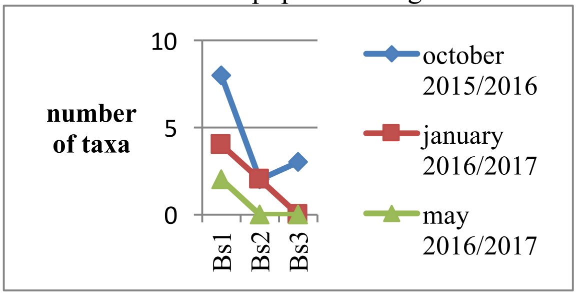

Figure 19: Taxonomic Wealth in the Wadi Bousselam.

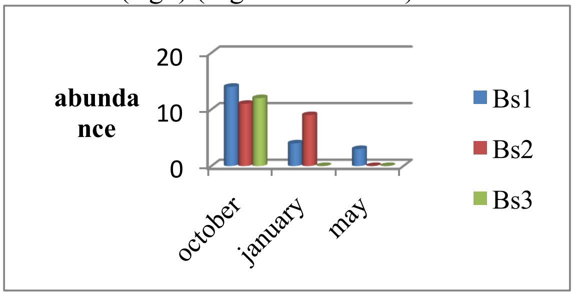

Figure20: Abundance in the Wadi Bousselam.

Minimum abundance values are recorded in the station (Bs1) with two individuals that survive during May in the Wadi Bousselam, this can be explained by its situation downstream from a dam, a low Taxonomic richness immediately downstream of a dam [58]. Absence of all benthic invertebrate taxa at Bs3 during the olive period following discharges from oil mills and the effect of the thermal station (Hammam Sidi Yahia), the high salinity of these waters and the high temperatures Organisms (Figure 19 and 20). Liquid effluents from oil mills lead to the death or reduction of benthic invertebrate populations downstream from the point of discharge in Kabylia rivers, and the return to normal conditions is much longer.

Conclusion

This study shows that olive oil releases in the Kabylia region cause a significant degradation of the aquatic ecosystem by causing a decrease in biodiversity, the disappearance of the most sensitive benthic organisms to pollution as well as the proliferation of tolerant taxa downstream olive oil rejects. These results show that the effects of the same pollution can be different depending on the duration of the discharge, the volume of the discharge, the concentration and nature of the effluent, and the dilution power of the watercourses. It is also noted that the restoration of biological quality after these releases is slow. Degradation of water quality is observed at stations located just at the point of discharge and downstream of these points, characterized by a high mineral load. However, olive oil industries are probably the most important but not the only sources of pollution for the study area, point sources of discharges have been identified as the various wastewater from the non-functional wastewater treatment plant in the wadi Bougdoura and the thermal station of Wadi Bousselam, which can explain the biological quality disturbance of these rivers even before the harvest period. The physicochemical results are significantly different between the upstream stations in relation to the discharge point and the two stations located just at the point of discharge and the one downstream, significant mineralization and a drop in dissolved oxygen are recorded during the olive growing season that affect the taxonomic richness and abundance of the benthic community studied. It high time to fight against this pollution by adopting measures for the preliminary treatment of liquid effluents from the olive industry before they are released into the environment.

References

1. N. Benyahia, K. Zein, 2nd International Conference *Swiss Environmental Solutions for Emerging Countries (SESEC II*). (2003).
2. L. Echihabi, L. Foutlane, L. Bourchich, *Economic and Social Review: newsletter of the Society for Economic and Social Studies*. 60 (2002) 77.
3. M. Hamdi, doctoral thesis, University of Provence Aix Marseille1, (1991) 180.
4. Amic, C. Dalmasso, institute PYTHEAS, Observatory of sciences of the universe, university of Aix-Marseille. (2013) 1.
5. M. Cadillon, J.C. Lacassin, Society of the Canal de Provence and Provençal Region. (2002) 2.
6. M. Aggoun, B. Duriot, A.Arhab, Cornu, A., Barkat, M., Graulet, B., *Renc. Rech. Ruminants*. 20 (2013) 111.
7. E. Tsagaraki, H.N. Lazarides, K.B. Petrotos, *Springerlink*. 8 (2007) 133.
8. R. Toubal, M. Dahli, *The Tunisian-Mediterranean Association for Historical, Social and Economic Studies*. (2013).
9. T.S. Woodcock, A.D. Hurny, *Freshwater biology*, 52 (2007) 177-196.
10. D. Touzin, Use of benthic macroinvertebrates to assess the deterioration of river water quality in Quebec, university of Laval. (2008) 20.
11. J. Verneaux, *Proceedings of the national seminar, Hydrosystems, Cermagref Editions, Paris*. (1994) 215.
12. E. Angelier, ecology of running waters. *Tec et Doc éditions*, (2000) 170.
13. R.Kaiser, National R.D. *Program on Environment-Water*, University of Liège. (1976) 110.
14. B. Bouchaud, P. Clavel, Y. Hamon, C. Romaneix, *Bull.Fr.Piscic*. 273(1979) 138-139.
15. B. Faessel, M.C. Roger, B. Cazin, *Annls Limnol*. 29 (3-4) (1993) 307-323.
16. B. Alhou, Y. Issiaka, A. Awaiss, J.C. Micha, *Hydroécol. Appl*. 18 (2014) 139-163.
17. P. Vivier, I.N.R.A. Continental Hydrobiology Station of Paris. (1970)91.
18. J.N. Beisel, M.C. Peltre, P. Usseglio-polatera, *Final report. LIEBE – CNRS UMR 7146*. University of Paul Verlaine Metz. (2011) 2-3.
19. Direction of the environment of the wilaya of tiziouzou, Study on the delimitation and characterization of the mountain areas and mountains of Djurdjura, Final report *Rapport*, Vol 3. (2010)40-41.
20. H. Tachet, P. Richoux, M. Bournaud, P. Usseglio-polatera, Freshwater Invertebrates: Systemic, Biology, Ecology. *CNRS Editions*, (2000).
21. K. Barki, end of studies project, University of Sidi Mohamed Ben Abdellah, Maroc. (2014) 15.
22. M. Tardat-Henry, J.P. Beaudry, water chemistry. *Le Griffon d'argile inc, première édition*, (1984) 252-254.
23. J. Rodier, Water analysis: natural waters, wastewater, seawater. *8 th edition DUNOD*, *Paris*, (2008) 1578.
24. I. Karaouzas, N.T. Skoulikidis, U. Giannakou, T.A. Albanis, Water Research. 45(2011) 6334-6346.
25. A. Pavlidou, E. Anastasopoulou, M. Dassenakis, I. Hatzianestis, V. Paraskevopoulou, N. Simboura, E. Rousselaki, P. Drakopoulou, *Science of the Total Environment*. 497-498 (2014) 38-49.
26. M. Larif, A. Soulaymani, A. Elmidaoui, *J. Mater. Environ. Sci. 4 (3) (2013) 432-441.*
27. O. Tzoraki, D. Moraetis, F.Stamati, S. Navrozidis, E. Kouseri, N. Kalogerakis, N.P. Nikolaidis, *1st International Conference "Hazardous Waste Management", Chania (Greece)*. (1-3 October 2008).
28. A.Beaufort, B .Augeard, F. Moatar, F. Curie, *ONEMA*. final report. University François-Rabelais of Tours. (2015) 5.
29. E.G. Nisbet, O. Verneau, *Annls Limnol*. 6 (2) (1993) 161-190.
30. D. Chapman, V. Kimstach, a guide to the use of biota, sediments and water in environmental monitoring, *2nd ed. E & FN Spon,* ISBN : 0-419-21590-5 (HB), 0-419-21600-6 (PB) (1996) 84.
31. A. Esmail, H. Abed, M. Firdaous, N. Chahboun, Z. Mennane, E.H. Berny, M. Ouhssine, *J. Mater. Environ. Sci.5 (1) (2014) 121-126.*
32. N. Assas, L. Ayed, L. Marouani, M. Hamdi, *Process Biochemistry.* 38 (2002) 361-365.
33. D. Bouknana, B. Hammouti, R. Salghi, S. Jodeh, A. Zarrouk, I. Warad, A. Aouniti, M**.** Sbaa, *J. Mater. Environ. Sci.* 5 (4) (2014) 1039-1058.
34. F. Hanafi, N. Sadif, O. Assobhei, M. Mountadar, *Revue des sciences de l'eau.*4 (22) (2009) 473-485.
35. M. El yamani, N. Ghabbour, E.H. Sakari, Y. Rharrabti, *J. Mater. Environ. Sci.* 8 (8) (2017) 2667-2378.
36. N. Slimani Alaoui, N. Jbari, M. Stitou, F. El Yousfi, A. El Laghdach, *J. Mater. Environ. Sci.* 7 (9) (2016) 3125-3132.
37. M. Panizza, G. Cerisola, *Water Research*.40 (2006) 1179 – 1184.
38. H. Zaier, W. Chmingui, H. Rajhi, D. Bouzidi, S. Roussos, A. Rhouma*, Journal of new sciences, Agriculture and Biotechnology*. 48(2) (2017) 2888-2897.

39. M. M. Rguiti, A. Baddouh1, K. Elmouaden, Lh. Bazzi, M. Hilali, L. Bazzi, *J. Mater. Environ. Sci.* 2 (9) (2018) 551-558.
40. I. Bouhssine, A. Tazi, M. Azzi, *J. Mater. Environ. Sci.* 4 (3) (2013) 354-361.
41. A. Ait-hmane, N. Ouazzani, L. Latrach1, A. Hejjaj, A. Assabbane, M. Belkouadssi, L. Mandi, *J. Mater. Environ. Sci.* 4 (9) (2018)1223-1233.
42. S. Ntougias, F. Gaitis, P. Katsaris, S. Skoulika, N. Iliopoulos, G.I. Zervakis, *Chemosphere.* 92 (2013) 399–405.
43. M. Hamdi, Thèse de l'Université de Provence. Marseille, France (1991).
44. P. Le pimpec, Pollution of aquatic environments: practical guide of the sampling agent. *Edition CEMAGREF*, (2002) 32.
45. M.G. Di Serio, B. Lanza, M.R. Mucciarella, F. Russi, E. Iannucci, P. Marfisi, A. Madeo, *International Biodeterioration & Biodegradation*. 62 (2008) 403–407.
46. C. Paredes, J. Cegarra, M.P. Bernal, A. Roig, *Environment International* .31 (2005) 305– 312.
47. A. Tsioulpas, D. Dimou, D. Iconomou, G. Aggelis, *Bioresource Technology.* 84 (2002) 251–257.
48. N. Haouache, A. Bouchaleta, *J. Mater. Environ. Sci.* 7 (7) (2016) 2288-2294.
49. S. Herbert, S. Legre, Monitoring the water quality of rivers and small streams. State of the Environment Monitoring Department, Ministry of the Environment Gouvernement du Québec. (2000) 5.
50. I.S. Onge, P. Bérubé, P. Magnan, *le naturaliste canadien.* 125 (2001) 81-95.
51. Nechad, K. Fadil, F. Fadil, *Larhyss Journal*. 20 (2014) 127-146.
52. H. Aissam, thèse de doctorat, Faculté des sciences, Dhar El Mehraz ,Fes (2003) 64,67.
53. Manitoba Water Stewardship and Manitoba Health, The presence of nitrate in Manitoba's water supply. (2011).
54. M. Arienzo, R. Capasso, *J. Agric. Food Chem.* 48 (2000) 1405-1410.
55. Y. Zhang, doctoral thesis, University of Lorraine, France. (2014) 58-59.
56. L. Karrouch, A. Chahlaoui, *Biomatec Echo.* 3(2009) 6-17.
57. F. Zouggaghe, L. Mouni, M.Tafer, *Larhyss Journal.* 17 (2014) 21-33.
58. N.J. Voelz, J.V. Ward, *J.Fish.Aquat.Sci.* 48 (1991) 2477-2490.

(2018) ; http://www.jmaterenvironsci.com