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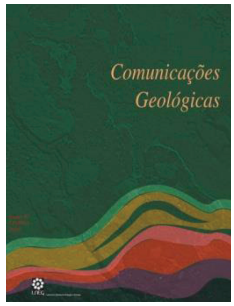
Study of superficial waters quality in a post-wildfire scenario in Portugal Central Region



Estudo de qualidade de águas superficiais em cenário de pós-incêndio na Região Centro de Portugal

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Abstract: Following the major wildfires that affected the Central region of Portugal in 2017, a watercourse monitoring campaign was initiated in November 2017 to determine changes in water proprieties in a post-fire scenario, and establish the persistence of these effects. In the Mondego River basin, 10 points, from 6 watercourses, were chosen based on the size of the watershed and the percentage of burnt area. Monthly water monitorization featured in situ parameters and major ions analysis. A higher electrical conductivity was found in water in November 2017, before the first runoffs. Major ions have, in generally, decreased from December to January. However, the Cavalos brook showed an increase in NO_3 concentration, and the downstream of Mondego River showing increase in Ca, HCO_3 and NO_3.

Keywords: Superficial water quality, wildfires, Mondego River.

Resumo: Posteriormente aos incêndios que afetaram a região Centro de Portugal em 2017, foi iniciada em novembro desse ano uma campanha de monitorização dos cursos de água para determinar as alterações nas propriedades da água num cenário pós-incendio, e a persistência dos seus efeitos. Na bacia do Rio Mondego, foram escolhidos 10 pontos, de 6 cursos de água, com base nas dimensões da bacia de drenagem e percentagem de área ardida. A monitorização mensal da água contemplou parâmetros *in situ* e determinação de iões maiores. A condutividade elétrica mais elevada foi encontrada em novembro, antes dos primeiros escoamentos. Os iões maiores, em geral, diminuíram de dezembro para janeiro. No entanto, a ribeira de Cavalos mostrou um aumento na concentração de NO_3, e a jusante do Rio Mondego mostrando um aumento em Ca, HCO_3 e NO_3.

Palavras chave: Qualidade de águas superficiais, fogos florestais, Rio Mondego.

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1. Introduction

The Central Region of Portugal was affected, in 2017, by two major wildfire events that contributed to the largest burnet area of the last 10 years, the second one, in mid-October, was responsible for 51% of all the burnt area of 2017 (DGAPPF, 2017).

Wildfires can directly lead to soil erosion, as the loss of vegetation exposes the soil to the rainfall increasing its erodibility (Fredriksen and Harr, 1981). The decrease in evapotranspiration also diminishes infiltration and consequently increases runoff. Furthermore, wildfires may produce hydrophobic behavior on the soil (Letey, 2001), which also contribute to increase the runoff. In a post-fire scenario, it is expected that the runoff may result in impacts on superficial waters, with the introduction of sediments ashes and other debris. Ashes have been also linked to the input of nitrogen and phosphate in watercourses following wildfires (Earl and Blinn, 2003).

After the second major wildfire event a monitoring campaign was developed in Portugal's central region in order to, 1) compare, in a post-fire scenario, water proprieties before and after the first runoffs, 2) determine the water quality in subsequently months after the wildfire events, 3) understand what are the effects of the runoff in an intense post-fire scenario, and 4) determine the persistence, if any, of these same effects.

The study area in the Mondego River Basin, which has an area of 6 659 km^2. All sampling points were located in the Central Iberian Zone (CIZ), which has various metamorphic units, an extensive area of granites and the Ordovician quartzites. The metamorphic zone, occupies the center of the study area, while the granitoids occupy the Northeast portion of Mondego's catchment. A Cretaceous to Cenozoic sediment cover is found in several continental basins. The area presents high contrast of reliefs with flatter upstream areas, high slopes with embedded valleys to the South and in the contact with the Meso-Cenozoic basin, and the latter characterized by its level and nearly level planes. It's limited in the South-East by the Central Mountain Range, corresponding to a horst with direction ENE-WSW. While to the North, the basin is limited by the Caramulo Massif and the Nave Plateau.

2. Methodology

From the Mondego River basin, 10 monitoring points were selected (Fig. 1). The points were chosen based on the size of the watershed and the percentage of burnt area, creating 3 categories (Tab. 1): 1) the Mondego River, 2) drainage basins with areas between 100 to 1000 km² and burnt area superior to 50%, and 3) drainage basins with areas between 10 to 100 km² and burnt area superior to 75%.

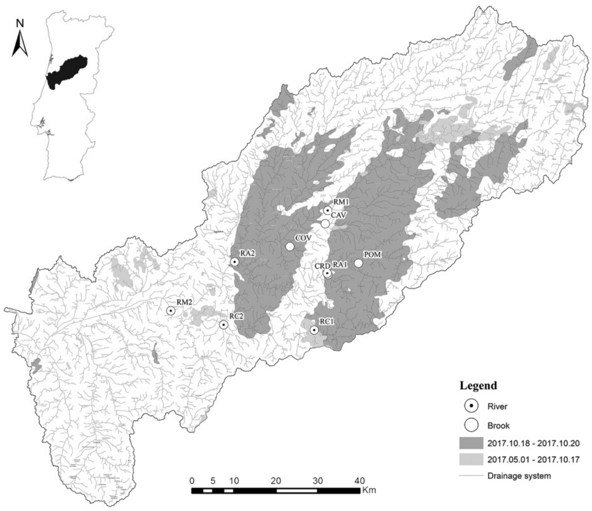

Figure 1. Monitoring points and burnt area in the study area.

Figura 1. Pontos de monitorização e área queimada na área de estudo.

The water monitorization feature *in situ* analysis. Temperature, pH, ORP, electrical conductivity (EC), O_2 and turbidity, were measured using portable meters, while CO_2 and alkalinity were determined titration. Samples were also collected for major constituent analysis. The determination of Cl, NO_3, SO_4, Br, Ca, Mg, Na, and K was through ion chromatography and inductively coupled plasma - optical emission spectrometry, while the PO_4 and NO_2 was through molecular absorption spectroscopy.

The periodicity chosen for water monitoring was monthly, due to the expected short-term fluctuations in the watersheds.

3. Results

Data obtained so far, has shown the EC tends to be higher on Mondego River, Covelo and Cavalos brooks (Tab. 2). Covelos and Cavalos brooks, do indeed have burnt percentages above 75%, and as Tiedemann, *et al.* (1978) observed, EC of water in burnt areas tend to be higher for a short period of time, due to the presence of ash in the water. However, the water of these 3 watercourses is also the most mineralized (Tab. 3), which could also indicate that the water's signature could be related to the basin's geology or land-use. A general observed trend was a decrease in EC with the increase of precipitation, most likely to dilution. The sampling point RM2 which has presented an increase in EC rather than a decrease. The precipitation of December, 107.3 mm in Coimbra and 167.5 mm in Viseu, seemed to influence in some way the pH of the waters, since it seems to exist a trend of diminished pH during this month. An exception is in the Ceira River and Cavalos Brook.

When observing the major ions in December and January (Tab. 3), the sample points POM, CRD, RA1 and RC1 display very low mineralized waters. This low mineralization can be related to the basin's geology, which is mostly constituted by metamorphic rocks, and the residence time of the water in these basins. All these basins sampling points showed dilution from December to January, however, it was visible an increase in NO_3 in CAV. While the increase of NO_3 in soils, with further transport to watercourses, has previously been linked to forest fires (Khanna and Raison, 1986),

Table 1. Sampling locations and references.

Tabela 1. Localização e referências da amostragem.

	Ref.	Latitude	Longitude
Mondego River (upstream)	RM1	N 40.40260º	W 7.98590º
Mondego River (downstream)	RM2	N 40.20094º	W 8.42773º
Drainage basins w/100 to 1000 km² and burnt area > 50%			
	Ref.	**Latitude**	**Longitude**
Alva River (upstream)	RA1	N 40.27023º	W 7.98851º
Alva River (base level)	RA2	N 40.29513º	W 8.24554º
Ceira River (upstream)	RC1	N 40.15035º	W 8.02658º
Ceira (base level)	RC2	N 40.16191º	W 8.27780º
Drainage basins w/10 to 100 km² and burnt area > 75%			
	Ref.	**Latitude**	**Longitude**
Cavalos Brook	CAV	N 40.37465º	W 7.99312º
Covelo Brook	COV	N 40.32784º	W 8.09358º
Cerdeira Brook	CRD	N 40.16617º	W 7.98728º
Pomares Brook	POM	N 40.29226º	W 7.90367º

Table 2. Results of *in situ* analysis.

Tabela 2. Resultados das analyses *in situ*.

Ref.	Camp.	E.C. (µS/cm)	pH	Eh (mV)	pE	Turb. (NTU)	CO_2 (mg/l)	Alk.
RM1	2017-11	176.40	7.90	–	–	–	–	–
RM2	2017-11	97.00	7.85	–	–	–	–	–
RA1	2017-11	69.10	7.65	–	–	–	–	–
RA2	2017-11	67.30	7.56	–	–	–	–	–
RC1	2017-11	88.20	6.83	–	–	–	–	–
RC2	2017-11	131.10	7.22	–	–	–	–	–
CAV	2017-11	420.00	6.78	–	–	–	–	–
COV	2017-11	155.00	7.28	–	–	–	–	–
CRD	2017-11	81.20	6.13	–	–	–	–	–
POM	2017-11	75.70	7.17	–	–	–	–	–
RM1	2017-12	164.00	6.88	447.00	7.98	91.30	23,80	47.00
RM2	2017-12	144.60	6.80	458.00	8.10	18.08	3.60	32.00
RA1	2017-12	49.80	6.31	521.20	9.39	25.92	–	4.00
RA2	2017-12	90.00	6.60	433.00	7.72	20.85	18.00	–
RC1	2017-12	79.60	7.11	483.70	8.73	4.58	2.20	6.00
RC2	2017-12	122.00	7.19	461.00	8.17	8.91	4.60	19.00
CAV	2017-12	289.00	7.03	432.60	7.70	4.71	30.80	19.00
COV	2017-12	224.00	6.74	495.00	8.76	2.05	33.20	29.00
CRD	2017-12	89.10	6.04	483.40	8.55	6.26	1.00	9.00
POM	2017-12	83.20	6.49	497.60	8.93	3.29	–	12.00
RM1	2018-01	107.10	6.11	504.50	9.07	10.14	11.00	28.00
RM2	2018-01	155.30	7.79	470.00	8.35	36.60	17.60	93.00
RA1	2018-01	36.90	6.75	494.00	8.90	0.71	7.60	11.00
RA2	2018-01	59.60	6.95	512.00	9.23	8.12	13.60	13.00
RC1	2018-01	53.10	6.99	455.00	8.15	1.28	11.60	21.00
RC2	2018-01	89.00	7.22	406.70	7.25	3.41	21.20	32.00
CAV	2018-01	229.00	6.77	489.00	8.80	2.83	27.20	51.00
COV	2018-01	155.60	7.00	455.00	8.17	3.01	13.80	29.00
CRD	2018-01	89.80	6.98	428.00	7.60	1.82	11.80	36.00
POM	2018-01	66.40	6.67	460.50	8.26	3.49	16.80	31.00

the introduction of this molecule can also be linked to agriculture through the use of fertilizers.

The base level equivalents of RA1 and RC1, RA2 and RC2 respectively, are more mineralized then their upstream counterparts. From December to January both these sample points showed dilution from the rainfall, with a particular decrease in HCO_3 for both samples. The upstream of Mondego River did displayed dilution from rainfall, particularly in terms of HCO_3, contrary of the downstream sampling point where an increase of HCO_3, NO_3, and Ca. This increase in the amount of suspended materials in RM2, which could also be seen through the EC and turbidity, can be possibly linked to the transport of particles by runoff. These particles can be related to clay particles as result of erosion after the forest fires, however ash can also have a high content of $CaCO_3$ and NO_3.

4. Conclusions

While some it could exist some evidences that link the forest fires of 2017 to changes in water quality in the studied basin, these are not yet very clear. One reason can be related to ash having the ca-

Table 3. Results of major ions.

Tabela 3. Resultados dos iões maiores.

Ref	Camp.	HCO_3 (mg/l)	Cl (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	PO_4 (mg/l)	Br (mg/l)	Na (mg/l)	K (mg/l)	Mg (mg/l)	Ca (mg/l)
RM1	2017-12	57.31	16.50	5.60	10.00	0.21	0.04	16.00	4.00	2.50	7.90
CAV	2017-12	23.17	33.00	10.50	15.40	1.20	0.05	33.00	8.30	4.40	12.00
COV	2017-12	35.36	20.80	7.50	19.80	<d.l.	0.07	18.00	2.80	8.30	7.20
POM	2017-12	14.63	6.80	5.00	6.00	<d.l.	0.05	6.60	0.68	1.90	2.20
RA1	2017-12	4.88	5.90	2.60	2.50	<d.l.	0.02	4.70	0.74	1.00	2.20
CRD	2017-12	10.97	10.10	2.40	8.00	<d.l.	0.05	9.20	0.84	2.80	2.50
RA2	2017-12	29.26	8.70	2.10	6.10	<d.l.	0.05	7.40	1.40	2.60	3.50
RC1	2017-12	7.32	6.80	4.50	6.80	<d.l.	0.06	6.50	0.77	3.20	2.90
RC2	2017-12	23.17	7.60	0.00	5.60	<d.l.	<d.l.	4.40	0.86	1.80	2.80
RM2	2017-12	39.02	9.30	2.80	8.90	<d.l.	0.04	9.20	1.90	4.10	8.50
RM1	2018-01	34.14	13.00	6.10	8.00	0.03	0.18	11.00	2.00	1.60	4.70
CAV	2018-01	62.18	32.00	16.00	15.20	0.05	0.77	24.00	5.00	3.40	8.60
COV	2018-01	35.36	25.00	4.10	12.20	0.08	<d.l.	16.00	1.60	5.10	4.30
POM	2018-01	37.80	5.70	4.60	4.70	0.04	<d.l.	6.10	0.61	2.00	2.30
RA1	2018-01	13.41	4.60	1.60	2.10	0.02	<d.l.	4.10	0.44	0.79	1.40
CRD	2018-01	43.89	9.10	4.90	6.90	0.05	<d.l.	9.40	0.80	2.90	1.40
RA2	2018-01	15.85	6.90	3.10	4.40	0.03	<d.l.	5.50	0.72	1.90	2.40
RC1	2018-01	25.60	5.00	1.90	4.50	0.04	<d.l.	5.00	0.41	2.10	1.60
RC2	2018-01	39.02	8.80	4.80	6.70	0.04	<d.l.	7.50	0.92	2.70	4.00
RM2	2018-01	113.39	11.00	4.60	13.20	0.04	<d.l.	9.20	1.50	4.40	14.00

pacity of increase infiltration and prevent or delay the runoff up to a certain thresholds of rainfall quantity and intensity (Cerdà and Doerr, 2008). The precipitation of the hydrological year of 2017/2018 in the study are up until February were very low compare to the normal precipitation of the last 30 years. Further results of the campaigns in the next, rainier periods, may contribute to clearly understand the effects of forest fires in water quality. Further analysis should also consider the study of some metals and compounds such as polycyclic aromatic hydrocarbons which have also been linked to forest fires.

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