THE USE OF CULTIVATED PLANTS IN WATER QUALITY MONITORING

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Abstract

Water contamination is the most complex global environmental problem. Any pollution that is emitted into the environment at a certain time reaches the groundwater, rivers, lakes and seas. Nowadays aquatic ecosystems around the world are increasingly threatened by different pollutants. Rivers and lakes are under constant pressure from urban wastewater pollution, chemical waste from industry and transport, pesticides from agricultural areas, etc. By applying various methods in the laboratory were tested quality and impact of the water, characteristic for its high content of certain pollutants, to the test plants: buckwheat (*Fagopyrum esculentum*) and cabbage (*Brassica oleracea*). The analyzed water was taken from two locations of the River Lesa in Portugal. Physico-chemical analysis of water indicates that nitrates, nitrites and ammonium were detected in values exceeding maximum allowable concentration, according to Portuguese regulations of water quality. Also, in the analyzed water samples cadmium (Cd), magnesium (Mg) and iron (Fe) were found in quantities that exceed the MAC values, as well as some pesticidal substances (MCPA, fonofos). In the tested samples, long list of pharmaceuticals were detected. The obtained results indicate differences in tolerance of the test plants according to the parameters which have been detected in the water. Physiological parameters (germination energy and germination) have not been proven to be good indicators of water quality, while the more reliable may be considered some morphological parameters (length of shoot), that reacted by stimulation of the shoot.

Introduction

Water pollution is a problem of global proportions which refers both to drinking and water used for irrigation of agricultural crops. The biggest polluter of the environment, in addition to industry, is agriculture. Pesticidal residues carried by water from agricultural areas pose an environmental threat as a result of intensive agricultural production and irrigation. In order to prevent and reduce environmental pollution, it is essential to carry out the continuous monitoring of water quality. Methods that involve the use of cultivated plants as test organisms are extremely important for assessing the contamination of water used in agricultural production, because its results reflect the benefits of the area for cultivation of plants and the use of water for irrigation. The aim of the study was to by using test plants buckwheat (*Fagopyrum esculentum*) and cabbage (*Brassica oleracea*) determine the degree of water pollution through morphological (germination energy, germination) and physiological parameters (length of roots and shoots, fresh and dry weight of roots and shoots).

Experimental

Water sampling was conducted in 2014, by experts from "Northern Region Water Institute"-IAREN (Instituto da Água da Região do Norte) from Portugal. Water was sampled from two sites along the River Lesa in Portugal. Physico-chemical analysis of water was also conducted in Portugal and includes the following parameters: general parameters of water quality, organic

compounds, heavy metals, pesticides, pharmaceuticals. For chemical analysis, the following techniques were used: Atomic Adsorption Spectrometry-Flame Technique (EPA Method 7000B), Liquid Chromatography-Tandem Mass Spectrometry (LC-MS-MS), Gas Chromatography Mass Spectrometry (GC-MS) and Inductively Coupled plasma Mass spectrometry (ICP-MS). For the extraction that preceded detection of the presence of pollutants Solid Phase Extraction (SPE) and Accelerated Solvent Extraction (ASE) were used. The maximum allowable quantities (MAC) used in this experiment are stipulated by Portuguese regulations Decreto-Lei nº 103/2010, D.-Lei nº 236/1998 and the EU Directive 2008/105/EC. Water quality was evaluated using physiological (germination energy and germination /%/) and morphological parameters (length of roots and shoots of seedlings /cm/, fresh and dry weight of roots and shoots of seedlings /g/) of the test plants. A filter-paper method by ISTA (International rules for seed testing) for 2013 was used. Results for physiological parameters are expressed in percentages. The values of morphological parameters are shown as average values and are processed using the Analysis of Variance and Duncan's multiple comparison test, in the statistical software R ver. 3.2.2.

Results and discussion

According to the results of the physico-chemical analysis (Tab. 1.), in water sample Lesa I a high concentration of ammonia nitrogen (exceeding maximum allowable concentration for 126x) and nitrite (3x) was established, while the other test parameters were in allowable limits. In water sample Lesa II was found that nitrate values exceed the MAC for 2.5x and ammonia nitrogen (184x), so this water sample is also polluted and does not meet the required quality for irrigation. Water containing a high concentration of nitrogen and nitrogen compounds can adversely affect the yield and quality of barley, sugar beet and some vegetable crops, causing excessive growth of vegetative organs (Bauder et al., 2014). The results indicate that the shoot length of cabbage was significantly stimulated by water from the sample Lesa I and Lesa II (found to have a high concentration of nitrate, nitrite and ammonia) which is consistent with the allegations of Bauder et al. (2014).

Table 1. Physico-chemical analysis of the general parameters in analyzed water samples

Location	Detected values of general parameters							
	pH	EC (mS/cm) at 20˚C	t°C	NO_3^- mgN/l	NO_2^- mgN/l	NH_3 mgN/l	P mgP/l	B mgB/l
Lesa I	7.5	463	21.4	0.6	**3.0**	**6.3**	<0.1	<0.1
Lesa II	7.3	423	22.3	**25.0**	0.7	**9.2**	0.9	<0.1
MAC*	**5-9**	**≤1000**	**30.0**	**10.0**	**1.0**	**0.05**	**1.0**	**1.0**

The results from analysis of heavy metals and other elements from the list of priority pollutants indicate an extremely high amount of cadmium (Cd), three times higher than the MAC and also the increased amount of molybdenum (Mo) and magnesium (Mg) in the water sample Lesa I. Iron (Fe) is found in high quantities in a water sample Lesa II (2.5x more than the MAC). In the sample Lesa II a higher concentration of manganese (Mn) was also detected, but values were below the MAC (Tab. 2). Heavy metals are very harmful because of their non-biodegradable nature, long biological half-lives and their potential to accumulate in different body parts. Cadmium is toxic to many plant species. High concentrations of cadmium cause the inhibition of plant growth, development and to the occurrence of deformities. The shoots are shortened, the root is reduced and becomes brown, stiff (Rascio & Navarre-Izzo, 2011). Iron is one of 16 essential elements for plant growth and reproduction. Although required by plants in small amounts, Fe is involved in many important compounds and physiological processes in plants.

Toxicity of iron has not been reported under most aerobic plant production systems (Hochmuth, 2011).

Table 2. The content of heavy metals and elements from the list of priority pollutants in water

Location	Detected values of heavy metals and other elements									
	Cd (µg/l)	Se (µg/l)	As (µg/l)	Mo (µg/l)	Cr (µg/l)	Pb (µg/l)	Mn (µg/l)	Fe (µg/l)	Zn (µg/l)	Mg (mg/l)
Lesa I	**16**	<2.5	<1.0	33	<0.5	<0.2	<1.0	<0.1	<10.0	**75**
Lesa II	<0.5	<2.5	<1.0	<0.01	5	<0.2	72	**250**	24	9,6
MAC	**5**	**10**	**10**	**50**	**50**	**50**	**100**	**100**	**500**	**50**

Chemical analysis of pesticide content in the tested waters showed the presence of pesticide substances MCPA and fonofos. The highest concentration of these substances was found in water sample Lesa I. In the sample Lesa II listed pesticides were below the limit of detection (Tab. 3.). Fonofos represents a highly toxic organophosphate insecticide. In plant tissues it is rapidly metabolized to non-toxic compounds. It is extremely dangerous and toxic to bees, birds, fish and other aquatic organisms (Wagner, 1983). MCPA is a selective herbicide for control of broadleaf weeds. Applied in small quantities, it stimulate growth like natural hormones. Moderate amounts stimulate cell division and elongation, while large amounts inhibit grow (Konstantinović, 2008). The research results are consistent with this these, as the test plant cabbage had a growth stimulation in the treatment with water from sample Lesa I, where it is detected an increased amount of MCPA.

Table 3. The content of pesticides and organic compounds in water samples

Location	Parameters (µg /l)						
	Endosulfan	MCPA	Alachlor	Simazin	Fonofos	Aldrin	Benzene
Lesa I	<0.009	**5.9**	<0.01	<0.05	**670.0**	<0.01	<0.28
Lesa II	<0.009	<0.05	<0.01	<0.05	<0.01	<0.01	<0.28
MAC	**0.01**	**0.5**	**0.7**	**4.0**	**10.0**	**30.0**	**50.0**

Chemical analysis of the content of pharmaceuticals in tested water samples showed that the drugs, such as paracetamol, naproxen, ibuprofen, hydrochlorothiazide, azithromycin, diclofenac, furosemide and ciprofloxacin, were over the limit of detection. Water sample Lesa II contained the highest concentrations of these drugs, so it can be considered more polluted compared to Lesa I. The main sources of pollution of surface and ground-waters with these compounds are urban and agricultural waste waters or households, hospitals and agricultural lands. Also, the significant source of pollution are wastewaters from the pharmaceutical industry.

*Bioassay results - test plants buckwheat and cabbage:*The obtained results indicate differences in tolerance of the test plants according to the parameters which have been detected in the water. Physiological parameters (germination energy and germination), in both cases, have not been proven to be good indicators of water quality, while the more reliable may be considered some morphological parameters of cabbage (length of shoot), that reacted by stimulation (Tab. 4.). Shoot length of cabbage was significantly stimulated by water from Lesa I (by 22%) as compared to control, and from Lesa II by 14%. Differences between the treatments are statistically significant ($F=11.78^*$, $p < 0.05$). Other morphological parameters (length of root, fresh and dry weight of root and shoot), were not affected by water quality and all values are on the same level of significance, compared to the control. Buckwheat has not proved to be a good indicator of

water quality, which is contaminated with specified pollutants. More reliable can be considered the results obtained from the test plant cabbage.

Table 4. Impact of water quality on morphological parameters – Root and Shoot

Root				Shoot			
Parameters	Water sample	Buckwheat Values	Cabbage Values	Parameters	Water sample	Buckwheat Values	Cabbage Values
Length of root (cm)	Lesa I	6,82 ±0,95 a	4,62 ±0,81 a	Length of shoot (cm)	Lesa I	5,77 ±0,70 a	6,05 ±0,06 a
	Lesa II	6,10 ±1,26 a	4,20 ±0,51 a		Lesa II	5,95 ±1,15 a	5,65 ±0,49 a
	Control	5,87 ±0,96 a	3,80 ±0,53 a		Control	4,87 ±0,17 ab	4,97 ±0,33 b
	F value	0.87 ns	1.71 ns		F value	2.176 ns	9.96 *
Fresh weight of root (g)	Lesa I	0,32 ±0,07 a	0,08 ±0,04 a	Fresh weight of shoot (g)	Lesa I	2,50 ±0,20 a	0,99 ±0,10 a
	Lesa II	0,33 ±0,11 a	0,07 ±0,04 a		Lesa II	2,55 ±0,34 a	0,95 ±0,27 a
	Control	0,22 ±0,08 a	0,06 ±0,03 a		Control	2,14 ±0,11 ab	0,77 ±0,10 a
	F value	1.98 ns	0.34 ns		F value	3.47 ns	1.84 ns
Dry weight of root (g)	Lesa I	0,03 ±0,005 a	0,011 ±0,001 a	Dry weight of shoot (g)	Lesa I	0,23 ±0,029 a	0,054 ±0,007 a
	Lesa II	0,02 ±0,008 a	0,010 ±0,003 a		Lesa II	0,24 ±0,026 a	0,051 ±0,016 a
	Control	0,03 ±0,005 a	0,009 ±0,001 a		Control	0,24 ±0,024 a	0,048 ±0,004 a
	F value	1.24 ns	2.29 ns		F value	0.30 ns	0.39 ns

Conclusion

Based on the conducted tests and the results achieved on the impact of water quality (Lesa I, Lesa II) on the test plants (buckwheat, cabbage) the following can be concluded:

• In water sample from Lesa river site I, detected pollutants, in the quantities exceeding MAC according to the Regulations, are: nitrites, ammonia, cadmium, magnesium, fonofos, MCPA and none of the tested pharmaceuticals. Based on the biological test of water quality on phyto-indicators, cabbage reacted in a significant stimulation of the length of shoot, which can be attributed to the presence of ammonia, nitrites and MCPA;

• In a sample of water from the site Lesa II in quantities exceeding MAC, nitrates, ammonia and iron were detected. The pharmaceuticals such as: paracetamol, naproxen, ibuprofen, hydrochlorothiazide, azithromycin, diclofenac, furosemide and ciprofloxacin, were alsoregistered. Water significantly stimulated shoot length of cabbage. These effects can be attributed to the presence of ammonia, nitrates and iron in a greater amount in this sample;

Bioassay test results indicate the different susceptibility of tested plant species and parameters as well as their validity in assessing water contamination. Different plant species and parameters responded in dissimilar manner to the quality of the sampled water.An expressed variability of parameters indicates their potential as possible bioindicators.

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References

[1] Bauder, T.A., Waskom, R.M., Sutherland, P.L and Davis, J.G. (2014): Irrigation Water Quality Criteria. Colorado State University, 1-5.

[2] Hochmuth, G. (2011): Iron Nutrition of Plants. University of Florida, IFAS Exst.,1-7.

[3] Konstantinović, B. (2008): Weeds and their control. Faculty of Agriculture, Novi Sad, 220-226.

[4] Rascio N. & Navari-Izzo F. (2011): Heavy metal hyperaccumulating plants: How and why do they do it? Plant Science 180, 169–181.

[5] Wagner, S.L. (1983): Clinical Toxicology of Agricultural Chemicals. Noyes Data Corp. 1983., 205-246.