Pergamon

Wat. Sci. Tech. Vol. 37, No. 8, pp. 235–241, 1998.
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Printed in Great Britain.
0273–1223/98 $19·00 + 0·00

PII: S0273-1223(98)00262-5

INFLUENCE OF A URANIUM MINE ON THE MACROZOOBENTHIC COMMUNITIES OF THE STREAMS IN THE NEAREST ENVIRONS, SLOVENIA

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ABSTRACT

The aim of this non-radiological research was to determine the influence of uranium mine Žirovski vrh (Slovenia) with two dumps of tailings on the macrozoobenthic communities of four streams in the environs. The mine has not been closed yet, but there has been no mining and processing since 1990, and the research was carried out four years later. The quantity of some non-metal oxides and heavy metals in water exceeded the acceptable maxima levels for the second quality class, and concentrations of metals were approaching toxic concentrations in the stream under the mine. The density of macrozoobenthic organisms decreased, the number of taxa was reduced, some orders vanished completely. Some kilometres downstream the quality of the stream improved. Our research shows very clearly that the uranium mine has been still influencing the biocenoses of streams, but only in the nearest environs. © 1998 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Macrozoobenthos; quality class; uranium mine.

INTRODUCTION

Unpolluted freshwater ecosystems support a diverse and balanced flora and fauna, with all trophic levels proportionally represented. In polluted ecosystems, some taxa may be uniformly depressed or unbalanced with some species eliminated and other ones dominant. This is the case in the environs of the only uranium mine in Slovenia. The uranium mine with two dumps of tailings is located in the mountains on the side of the hill Žirovski vrh (440 m above sea-level), about 30 km west of the capital Ljubljana. The mine has not been closed yet, but there has been no mining and processing since July 1990, and the research was carried out four years later. In the environs there are four streams, three of them receiving waste waters from the dumps and/or from the mine's effluent directly. Both dumps of tailings are lying on slopes and there is a possibility that 'immobilised' material is washed into the streams during rains and presents a potential hazard to water quality.

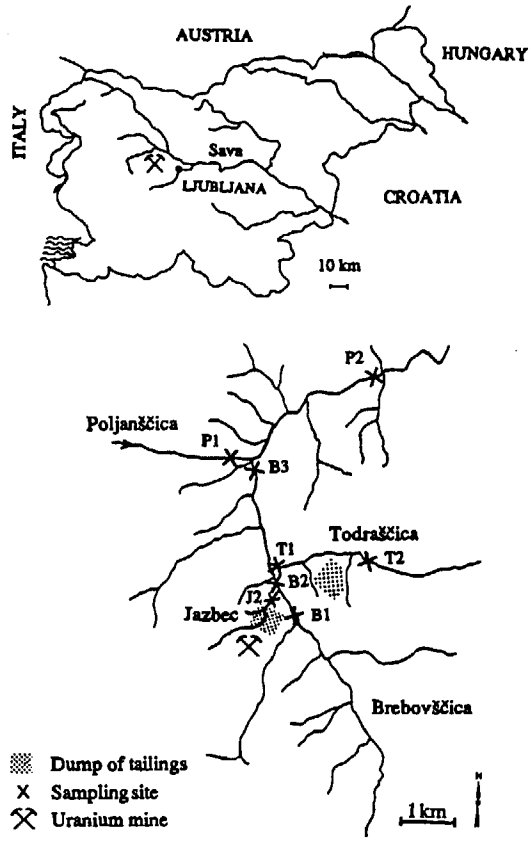
METHODS

Non-radiological physical and chemical analyses of water (Standard Methods, 1992) and analyses of macrozoobenthos were performed. The sampling sites (Map 1) were chosen in the streams above and under the polluted effluents, except in the brook Jazbec. The brook Jazbec and the river Todraščica were receiving

waste waters from the dumps. Both streams are tributaries of the river Brebovščica. The latter, which flows into the river Poljanščica, was receiving waste waters also directly from the dump Jazbec and from the mine's effluent.

Quantitative sampling of macrozoobenthos on stony substrata was used (ISO 8265:1988; ISO 5667/3-1994). Taxa determination (Schoenemund, 1930; Illies, 1955; Aubert, 1959; Bole, 1969; Ježek *et al.*, 1980; Quigley, 1980; Tachet *et al.*, 1984; Kerovec, 1986), density of organisms, abundance, saprobic and Wilhm-Dorris diversity indices and Kothé index for taxa-deficit were performed (Zelinka and Marvan, 1961; Sladecek, 1973; Wegl, 1983; Besch, 1984; Margreiter-Kownacka *et al.*, 1984). Because of the determination of higher taxa as species, the diversity indices could have lower values. The streams were classified into corresponding quality classes according to the Slovenian legislation (Official gazette, 1978a, b), considering Sladecek's system supplemented with cited biological indices (Sladecek, 1973; Besch, 1984).

In the class Oligochaeta each chain represented one organism. For taxa of the family Chironomidae, and for the subfamilies Chironominae, Diamesinae, and Orthocladiinae the saprobic values and the indicative weights were counted as the averages of the values for their subfamilies or tribes (Margreiter-Kownacka *et al.*, 1984).



Map 1. The location of the uranium mine Žirovski vrh in Slovenia and the streams with the sampling sites in the environs of the mine.

All streams in the environs of the uranium mine are swift, well-aerated, with stony beds, except the brook Jazbec on the dump and under it, where the brook is in a man-made channel. Temperatures were between 11°C and 15°C. There were higher concentrations of chlorides, nitrates, sulphates, and heavy metals, like

cadmium, strontium, and/or lead in the water under both dumps and mine on the sampling sites T2 and B2 (Table 1).

Table 1. Physical and chemical analyses of water from the streams Jazbec (J2), Todrašcica (T1, T2), Brebovščica (B1, B2, B3), and Poljanščica (P1, P2), in the environs of the uranium mine Žirovski vrh (Slovenia), August 1994

Stream:	Jazbec	Todraščica		Brebovščica			Poljanščica	
Sampling site:	J2	T1	T2	B1	B2	B3	P1	P2
T, °C	13.9	11.6	14.2	13.6	12.3	12.5	14.8	14.5
O_2, % of theoretical saturation	103	92.8	98.4	98.3	96.3	93.8	99.6	100
pH	8.1	8.2	8.4	8.2	8.2	8.2	8.5	8.5
Conductivity, µS/cm	1093	387	365	231	240	257	305	305
COD_d, mg/l	8	2	2	3	4	3	10	8
BOD_5, mg/l	1	1	1	1	2	2	3	5
Suspended solids, mg/l	3	7	3	5	3	3	5	3
Dissolved subs., mg/l	835	188	192	113	149	119	154	141
K, mg/l	8.7	0.4	0.7	0.5	0.7	0.8	0.8	0.8
Na, mg/l	25.0	0.7	3.1	1.3	2.5	2.5	1.7	1.7
NH_4^+-N, mg/l	0.20	0.05	0.06	0.08	0.06	0.06	0.08	0.06
Ca, mg/l	131	44.4	43.1	26.0	28.6	31.0	39.3	39.5
Mg, mg/l	49.2	24.7	20.5	10.8	11.0	12.3	15.8	15.4
Cl^-, mg/l	31.1	1.0	5.6	1.1	2.3	2.8	1.8	1.7
NO_2^--N, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO_3^--N, mg/l	15.2	0.4	1.0	0.6	1.2	1.3	0.8	1.0
HCO_3^-, mg/l	121	257	210	133	124	139	186	186
SO_4^{2-}, mg/l	406	4.0	18.5	6.2	16.6	16.8	14.5	14.1
As, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al, mg/l	<0.1	0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cu, mg/l	0.002	0.003	0.001	0.002	0.003	0.016	0.004	0.004
Ba, mg/l	0.05	0.04	0.03	0.07	0.07	0.06	0.003	0.003
Zn, mg/l	0.01	0.02	0.01	0.01	0.03	0.17	0.02	0.03
Cd, mg/l	0.0003	<0.0001	0.0003	0.0005	<0.0001	<0.0001	<0.0001	<0.0001
Co, mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cr, mg/l	0.005	0.004	<0.001	0.004	0.012	0.014	0.016	0.007
Mn, mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mo, mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Ni, mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Si, mg/l	3.3	1.3	1.6	2.1	1.9	2.0	1.6	1.6
Sr, mg/l	0.76	0.03	0.07	0.04	0.10	0.09	0.13	0.13
Pb, mg/l	0.07	0.04	0.06	<0.001	<0.001	0.04	0.04	0.03
V, mg/l	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fe, mg/l	0.08	0.04	0.03	0.05	0.04	0.05	0.08	0.04
Hardness, mg $CaCO_3$/l								
carbonate	8.9	205.3	160.7	98.2	91.0	103.5	142.8	141.0
noncarbonate	521.2	7.1	30.3	10.7	25.0	25.0	19.6	19.6
Quality class - water	IV.	I.	III.	I.	I.	II.	II.	III.

* Values that exceed maximum allowable concentrations of dangerous substances in surface waters for second quality class (Official gazette, 1978 b) are underlined.

The brook Jazbec

Water was hard in the brook Jazbec (Table 1) (Höll, 1986). The carbonate hardness was low, the noncarbonate hardness was high due to concentrations of chlorides, sulphates, and nitrates. The concentration of the latter classified the brook in the fourth quality class. The concentration of lead exceeded the value permitted for the second quality class.

In the brook, there were twenty different taxa (Table 2), due to sampling of animals in different habitats, lotic and lentic. Also the density of organisms was not low. The family Chironomidae (53.1%) were

prevailing and the mayflies (Ephemeroptera) with genus *Baetis* (32.8%) were abundant in the brook Jazbec (Table 2). Obviously adapted species of the macrozoobenthos were present which supported the high concentrations of some substances. The dominant genus of the subfamily Tanypodinae *Macropelopia* was present only on this sampling site. The saprobic and diversity indices showed better quality class than chemical analyses of water (Table 3).

The river Todrašcica

In the river Todrašcica the sampling sites were differently exposed to the sun: the upper sampling site was in forested location, the lower one was sunny. There were also higher concentrations of chlorides, nitrates, sulphates, and heavy metals (Cd, Sr, Pb) in the water under the dump (Table 1). Only the concentration of lead exceeded the value permitted for the second quality class.

In the upper sampling site the Amphipoda with the species *Gammarus fossarum* prevailed (51.9%), beetles (Coleoptera) and may flies (Ephemeroptera) with genus *Baetis* were abundant. The insects constitute only 45% of the total fauna.

In the lower sampling site the species *Gammarus fossarum* vanished. Its disappearance could be due to the exposition to the sun and/or to higher concentration of lead in water. The crustaceans are the most sensitive among freshwater invertebrates, especially for lead, and synergistic effects with temperature may occur (Moore and Ramamoorthy, 1983; Mance, 1987). The insect larvae were present. Among freshwater invertebrates they are least affected by heavy metals. The stoneflies (Plecoptera) with genus *Leuctra* (51.1%) prevailed, the Ephemeroptera with genus *Paraleptophlebia* and the family Chironomidae were abundant.

Both the density of organisms and the number of taxa increased in comparison with the upper sampling site. The Insecta percentage was higher twice with regard to the total fauna. Contradictory to chemical analyses (Table 1) the saprobic and diversity indices showed better quality class (Table 3).

The river Brebovščica

There was soft water in the river Brebovščica (Table 1) (Höll, 1986). In soft, poorly buffered water rapid change in pH may occur, which can, in turn, do harm to many organisms. In the water under the mine there were higher concentrations of chlorides, nitrates, sulphates and heavy metals. Some kilometres downstream of the mine the concentrations of zinc, lead, and copper increased due to the effluents from populated region. The river was still classified in the second quality class.

In the sampling site above the mine the Plecoptera with genus *Leuctra*, the Ephemeroptera with genus *Baetis*, the Coleoptera, and the Chironomidae were abundant. The insect faunas constituted 92% of macrozoobenthos.

Under the mine number of taxa was reduced from 33 to 7, the density of organisms decreased 16 times. Some complete main taxa, like the orders Plecoptera and Ephemeroptera and the family Chironomidae, which were all abundant above the effluents, vanished. Between first two sampling sites, taxa-deficit according to the Kothé index was high, almost 79%. It is a question, which quality class does it mean. The Wilhm-Dorris diversity index revealed worse biological quality also, but the saprobic index did not reflect the bad situation. With only chemical analyses of water and saprobiological analyses of macrozoobenthos, which are prescribed by Slovenian legislation, we would not detect the damaged zoocenoses and really worse quality class of the river Brebovščica.

Table 2. Abundance of taxa of macrozoobenthos in the streams in the environs of the uranium mine Žirovski vrh (Slovenia), August 1994

Stream:	Jazbec	Todraščica		Brebovščica			Poljanščica	
Sampling site:	J2	T1	T2	B1	B2	B3	P1	P2
Taxa	Abundance/%							
Hydra							0.2	0.2
Turbellaria		0.8						
Lumbricidae							0.2	
Oligochaeta, 2 taxa	3.7	2.5	1.5	2.8	21.9		7.0	2.1
Ancylus fluviatilis		0.1		0.6				
Physa acuta				0.1				
Gastropoda, n.det.			0.1					
Gammarus fossarum	2.7	51.9	0.1	2.7				
Hydracarina			0.3	1.5	6.7	1.1	0.6	0.9
Leuctra	0.2	2.5	51.1	24.5		31.9	48.7	44.7
Amphinemura			0.4	1.4		0.2		0.2
Protonemura	0.2	0.1		0.1				
Nemoura			2.2					
Dinocras			0.1					
Perla		0.7						
Perlodidae			0.3					
Plecoptera, 1.sp., n.det.	0.2			0.6		1.3	2.7	1.1
Ephemera								0.2
Ephemerella, 2 taxa.			3.3	1.3		3.5	8.3	7.3
Baetis	32.8	10.6	3.4	6.5		26.6	7.3	30.1
Habrophlebia						0.2		
Paraleptophlebia		0.4	11.4	8.2		2.2	0.6	
Ecdyonurus				0.1		0.4	0.2	
Epeorus				0.1		0.2		
Heptagenia		0.1	0.5	0.4		1.1	0.2	0.5
Rhithrogena		0.1		0.1				
Heptageniidae, n.det.		0.6						
Ephemera			2.3					
Ephemeroptera, n.det.		0.3						
Corixidae							1.1	
Hydropsychae	1.1			0.9		3.1		
Hydropsychidae, n.det.							0.8	0.2
Limnephilidae				0.4				0.2
Philopotamidae		0.1						
Polycentropodidae		0.4					0.2	
Rhyacophilidae	0.7					2.9		
Sericostomatidae				0.4				0.9
Trichoptera, 3.taxa	0.4		0.4	0.1		0.4	0.4	0.5
Elmidae, 3.taxa	1.4	14.3	7.3	18.0	50.5	1.5	7.3	2.1
Coleoptera, ad., 2 taxa	0.7	3.7	1.9	6.3	2.9	2.2	0.2	0.9
Tipulidae	2.0	5.4						
Simuliidae	0.2	0.4	0.1	0.4	2.9	1.6		
Atherix marginata		1.0	0.5	1.3	12.4	0.7	0.2	
Ceratopogonidae			0.3	0.1				
Empididae								0.2
Limoniidae, 2 taxa	0.2	0.1	0.4	0.2		0.7	0.2	0.7
Stratiomyidae								0.2
Tanypodinae, 2 taxa	26.7	0.4	4.2	3.6		4.1	4.6	1.6
Chironomini	5.2	2.1	4.2	4.0		0.4	1.3	0.5
Tanytarsini	13.8	0.1	1.4	7.5		2.2	1.9	0.7
Orthocladiinae+Diamesinae, 3.taxa	5.2	1.2	1.0	5.6		8.6	2.7	2.1
Chironomidae, n.det.	2.2		1.3	2.1		2.2	2.1	2.1
Diptera, 1.sp., n.det.	0.2			0.1	2.9	0.2	0.5	

Table 3. Biological analises of macrozoobenthic communities and quality classes of the streams in the environs of the uranium mine Žirovski vrh (Slovenia), August 1994

Stream:	Jazbec	Todraščica		Brebovščica			Poljanščica	
Sampling site:	J2	T1	T2	B1	B2	B3	P1	P2
Number of organisms/m^2	897	1789	3885	1690	105	896	1221	1060
Number of taxa	20	24	30	33	7	25	24	21
Kothé index	-	-	-	0	78.8	-	-	-
Saprobic index	2.0	1.7	1.5	1.6	1.9	1.5	1.5	1.5
Saprobic level	β	o-β	o-β	o-β	β	o-β	o-β	o-β
Wilhm-Dorris diversity index	3.1	2.6	2.9	3.8	2.3	3.2	3.0	2.5
Saprobic level	o	β-α	β-(α)	o	β-α	o	o	β-(α)
Quality class - macrozoobenthos	II.	II.	I.-II.	I.-II.	III.	I.-I.	I.-II.	II.
Quality class - water	IV.	I.	III.	I.	I.	II.	II.	III.
Quality class (macrozoobenthos + water)	IV.	II.	III.	I.-II.	III.	II.	II.	III.

* Values that represent the critical situation of macrozoobenthic communities are underlined.

From the biological point of view, some kilometres downstream the river quality improved, but it did not reach the quality of the first sampling site. Taxa of the Plecoptera, Ephemeroptera, and Chironomidae appeared again. The improvement was due not only to self-purification but also to small flows of polluted effluents and relatively great flows of other tributaries, including the river Todrašcica.

The river Poljanšcica

The river Brebovšcica did not have any effect on the river Poljanšcica under their confluence in the time of our research. On sampling sites *Leuctra* (Plecoptera) prevailed. The number of taxa, density of organisms, saprobic and diversity indices indicated the second quality class for the river Poljanšcica. But it was classified into the third quality class due to organic pollution (BOD_5) with domestic and agricultural waste waters from the populated region.

CONCLUSIONS

Non-radiological research showed very clearly that the uranium mine Žirovski vrh and its two dumps of tailings four years after the cessation of mining and processing have been still influencing the streams. Suspended matter, non-metal oxides, and heavy metals constitute a potential hazard to water quality. The nearest environs of the uranium mine are almost completely devoid of macrozoobenthos. The permanent monitoring should be continued.

With analyses prescribed by Slovenian legislation, we can not determine the real state of quality in the freshwater ecosystem. It would be necessary to change or to complement our legislation with other chemical and biological analyses.

ACKNOWLEDGEMENT

The authors are pleased to acknowledge to The Mine Žirovski vrh, Todraž, Slovenia for the financial support of the research.

REFERENCES

Aubert, J. (1959). *Plecoptera*. Imprimerie la Concorde, Lausanne.

Besch, W. K. (1984). Biologische Qualitätsklassifizierung von Fließgewässern. In: *Limnologie für die Praxis - Grundlagen des Gewasserschutzes*; Besch, W. K., Hamm, A., Lenhart, B., Melzer, A., Scharf, B. and Steinberg C. (eds). Ecomed, Landsberg, München, pp. 1-95.

Bole, J. (1969). *Keys to identification of animals, Mollusca-**Molusca***. Institute of biology, University in Ljubljana, Association of Slovenian biologists, Ljubljana. (In Slovene).

Höll, K. (1986). *Wasser, Untersuchung - Beurteilung - Aufbereitung - Chemie - Bacteriologie - Virologie- Biologie*, **7**, völlig bearbeitete Auflage, Walter de Gruyter, Berlin.

Illies, J. (1955). Steinfliegen oder Plecoptera. In: *Die Tierwelt Deutschlands und der angrenzenden Meeresteile*, Dahl, F., Dahl, M., Bischof, H. (eds), **43**. Teil, Jena Veb Gustav Fischer Verlag, pp. 1-148.

ISO, (1988). Water quality - Design and use of quantitative samplers for benthic macroinvertebrates on stony substrata in shallow freshwaters, *ISO 8265: 1988*, International Organization for Standardization, Genève.

ISO, (1994). Water quality - Sampling - Part 3: Guidance on the preservation and handling of samples, *ISO 5667/3: 1994*, International Organization for Standardization, Genève.

Ježek, J., Knoz, J., Kramár, J., Kram, F., Kubicek, F., Lelliák, J., Minár, J., Pokorny P., Raušer, J., Rozkošny, R., Sedlak, E., Špacková, V., Štusak, M. J., Zeleny, J. and Zelinka, M. (1980). *A Key to the water larvae of insects*. The Czech Academy of Sciences, Prague. (In Czech).

Kerovec, M. (1986). *Manual on identification of invertebrates in our streams and rivers*. University edition Liber, Zagreb. (In Croatian).

Mance, G. (1987). *Pollution threat of heavy metals in aquatic environments*. Elsevier Applied Science, London.

Margreiter-Kownacka, M., Pechlaner, R., Ritter, H. and Saxl, R. (1984). *Die Boden-fauna als Indikator für den Saprobitätsgrad von Fliessgewässern in Tirol*, Ber.nat.-med. Verein., Insbruck, bd., **71**, 119-135.

Moore, J. W. and Ramamoorthy, S. (1984). *Heavy Metals in Natural Waters*. Springer-Verlag, New York.

Official gazette (1978a). Order about classification of the interrepublic streams, interstate waters and coastal sea of Yugoslavia. *Official gazette of SFRY*, **XXXIV**(6), 145-147. (In Slovene).

Official gazette (1978b). Decree of maximum allowable concentrations of radionuclei and dangerous substances in interrepublic streams, interstate waters and in coastal sea of Yugoslavia. *Official gazette of SFRY*, **XXXIV**(8), 185-187. (In Slovene).

Quigley, M. (1980). *Invertebrates of Streams and Rivers*. Eduard Arnold Ltd., London.

Schoenemund, E. (1930). Eintagsfliegen oder Ephemeroptera. In: *Die Tierwelt Deutschlands und der angrenzenden Meeresteile*, Dahl, F., Dahl, M. and Bischof, H. (eds), **19.** Teil, Verlag von Gustav Fischer, Jena, pp. 1-106.

Sladecek, V. (1973). System of water quality from the biological point of view. *Arch. Hydrobiol. Beih.*, **7**, 1-218.

Standard Methods for the Examination of Water and Wastewater (1992). 18th edn, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC, USA.

Tachet, H., Bournaud, M. and Richoux, P. (1984). *Introduction à l'étude des macroinvertébrés des eaux douces*. (Systématique élémentaire et aperçu écologique). 2e édition. Association Française de limnologie, Lyon.

Wegl, R. (1983). Index für die Limnosaprobität. *Wasser und Abwasser*, **Band 26**, 1-175.

Zelinka, M. and Marvan, P. (1961). Zur Präzisierung der biologischen Klassifikation der Reinheit fliessender Gewässer. *Arch. Hydrobiol.*, **57**(3), 839-407.