Waters of the "Szczakowa" sand pit (Poland) – high quality in danger

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Abstract: Mining waters of the „Szczakowa" sand pit supply potable water intake in Maczki. These waters are subjected to hazards connected with atmospheric deposition of pollutants, infiltration of contaminated waters from the Sztoła river, and influence of effluents from a mining-waste and fly ash dump. This causes a necessity of continuous monitoring of surface and groundwaters occuring within the sand pit mining area.

1 INTRODUCTION

„Szczakowa" is the biggest sand pit in Poland; it is situated in the Upper Silesian Industrial Region. (Figure 1).

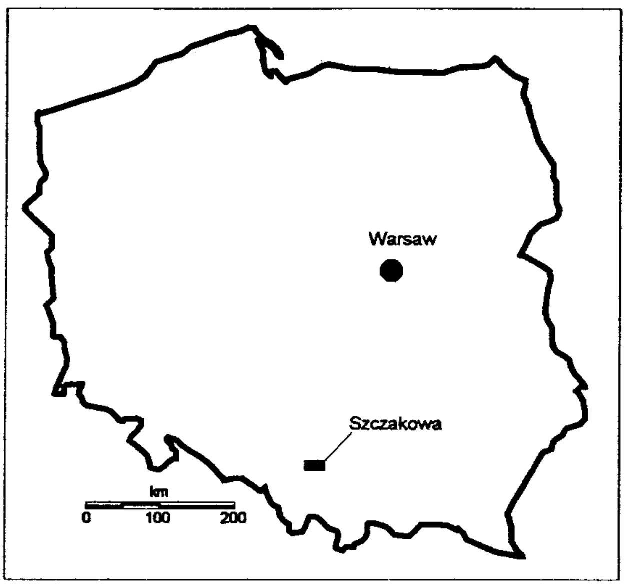

Figure 1 Localisation of the study area

Gravitational dewatering of the exploitation pits (fields I, II and the Siersza field) is carried out by a system of ditches, streams and channels. The greater part of mining waters is carried to potable water intake in Maczki. The remaining part together with effluents from mining-waste and fly ash dump (localised in the southwestern fragment of the pit) flows into the Jaworznik stream. (Figure 2). It is then important to maintain the waters carried away from the pit in high quality in order to utilise them as a source of potable water, and to support their role in a relatively undisturbed environmental system.

Surroundings of the “Szczakowa” are fairly urbanized, however some important industrial works (the “Bolesław” zinc and lead mining and refinery works in Bukowno, the “Siersza” coal mine and power plant, the “Trzebionka” zinc industry works and the “Szczakowa” glass works in Jaworzno) are localised within this territory.

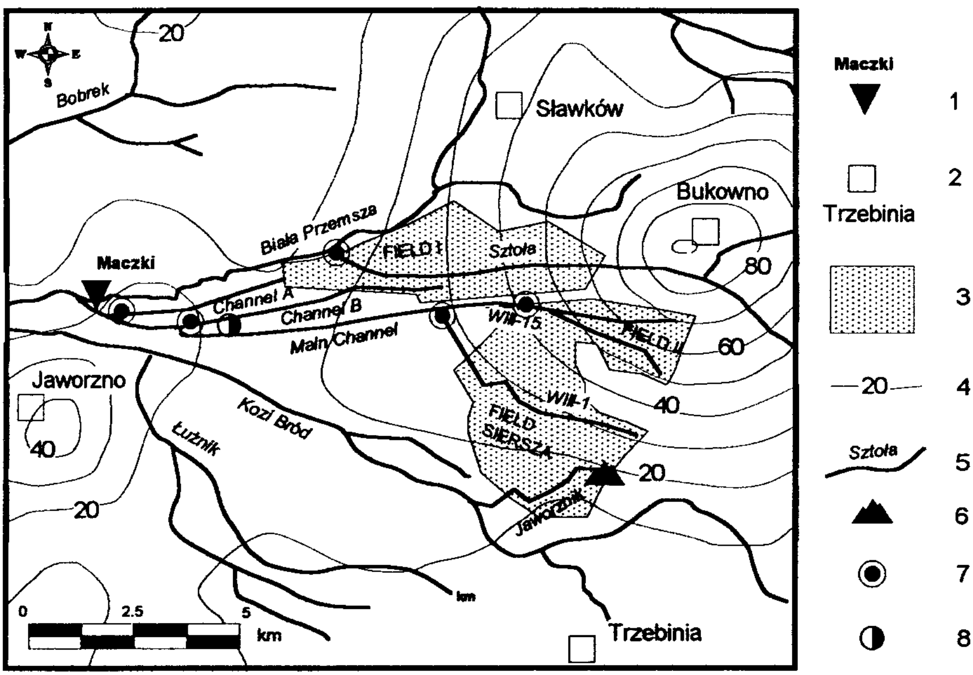

Figure 2 Scheme of the “Siersza” sand pit
1 – water intake, 2 – towns, 3 – sand exploitation field, 4 – cadmium deposition isolines for 1992-1995 period, 5 – surface waters, 6 – waste dump, sampling points of: 7 – surface waters, 8 - groundwaters

2 HYDROGEOLOGIC SETTING

The study area is situated within the Triassic Silesia-Cracov Region. A thick Quaternary glacial series of sands (Mindel) cover Triassic carbonates (limestone and dolomites) (Figure 3).

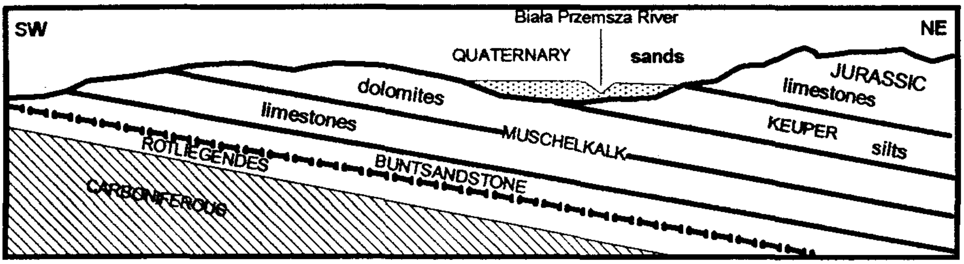

Figure 3 Synthetic cross-section of the study area

Palaeozoic series of aquifers, Triassic, Jurassic and Quaternary aquifers were ascertained within the area.

Fluvio-glacial sediments that are filling river valleys and corrosional furrows build the Quaternary aquifer. These sediments consist of fine and medium grained sands with intercolated beds of pebbles, rock waste, silts, clays and dusts. Thickness of water-bearing horizons ranges from several to tens of meters. Precipitation or infiltration from flotation tailing ponds, which are situated close to the zinc and lead works in Bukowno, recharge the aquifer. Drainage is due to dewatering of sand pits and the leakage to the underlying carbonate beds. Average hydraulic conductivity of quaternary sands equals to $2.7 * 10^{-4}$ m/s („Szczakowa", 1999). The Major Groundwater Basin (MGB) number 457 was ascertained within this formation; modulus of its resources equals to 13.4 dm^3/s/km (Różkowski et al, eds., 1997).

Triassic multiaquifer formation is built by carbonates (to 150 meters thick) with secondary seams of marls and silts. Two aquifers of Muschelkalk and of Roethian dolomites could be ascertained within this formation. It is considered that the mentioned aquifers, as they are connected, form a joint aquifer (Motyka & Wilk, 1980). The aquifer is recharged within the outcrops, by Jurassic aquifer in its eastern part and also through water-bearing Quaternary sediments of river valleys (such a process dominates within the "Szczakowa" mining area. Drainage areas are represented by workings of Zn-Pb ore mines and regions of extensive water intake by wells (Różkowski, 1990). Average permeability coefficient of Triassic carbonates in the described area equals to $6.5 * 10^{-5}$ m/s (Motyka & Wilk, 1976).

Palaeozoic and Jurassic aquifers are of less importance in context of the "Szczakowa" sand pit hydrogeological regime.

3 WATER QUALITY

Mining waters examined in 1995 – 1999 in Maczki (sampling point on the Main Channel at the mentioned potable water intake) were characterised by high quality parameters (Table 1). The total discharge at this point ranged between 1.56 and 2.54 m^3/s.

Table 1 Physic-chemical parameters of surface waters of the “Szczakowa” sand pit

Sampling point		Reaction pH	El. cond. μΣ/χμ	Alkalinity mval/ dm^3	Tot. hardness mg $CaCO3$/ dm^3	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	$SO4^{2-}$	Tot. Fe	$N_{NH4}{}^+$	N_{NO2}-	N_{NO3}-	BOD	SS
						mg^2/dm^3										mg^2/dm^3	mg/dm^3
	mean	7.76	476	3.2	241.5	65.1	19.1	10.7		17.3	91.7	0.18	0.04	0.006	2.90	1.8	14.4
	min.	7.59	436	2.6	225..1	45.7	17.4	1.1	1.0	14.0	81.9	0.05	0.02	0.001	1.00	0.8	6.0
	max.	8.44	476	3.4	268.0	72.8	36.2	10.7	2.0	19.0	97.9	0.50	0.06	0.008	3.00	3.6	31.0
	st. dev.	0.18	39	0.6	20.9	9.0	3.4	4.1	1.1	1.6	12.2	0.10	0.03	0.012	1.60	0.7	6.2
WIII15 (1)	mean	7.99	493	3.1	259.2	67.0	22.3	6.8	0.9	15.9	89.4	0.05	0.04	0.004	2.33	2.0	17.0
	min.	7.84	399	2.9	237.6	54.3	17.5	5.8	0.8	14.0	76.5	0.05	0.01	0.001	1.00	0.8	10.0
	max.	8.45	741	3.4	287.7	77.8	27.4	7.5	1.1	18.0	106.6	0.05	0.40	0.009	4.00	4.8	36.0
	st. dev.	0.15	60	0.1	12.8	5.3	2.4	0.5	0.1	1.2	7.8	0.00	0.08	0.002	0.64	1.0	5.7
	mean	7.86	376	1.9	194.4	53.9	14.5	5.8	2.7	11.8	96.6	0.08	0.03	0.001	0.82	2.2	22.9
	min.	7.47	280	1.5	167.9	47.8	10.9	4.2	1.1	9.0	76.5	0.05	0.01	0.001	0.30	0.8	9.0
	max.	8.16	436	2.4	223.3	59.3	21.2	7.4	10.8	15.0	120.1	0.15	0.08	0.003	4.00	5.6	53.0
	st. dev.	0.16	31	0.3	13.8	3.4	2.6	1.1	2.9	1.4	10.1	0.03	0.02	0.001	0.77	1.1	9.6
Sztoła (2)	mean	8.16	511	n. e.	319.5	n. e.	n. e.	n. e.	n. e.	15.6	90.8	0.54	0.09	0.004	3.32	2.0	13.1
	min.	8.10	480	n. e.	277.0	n. e.	n. e.	n. e.	n. e.	11.0	74.0	0.33	0.05	0.001	2.90	2.0	10.0
	max.	8.30	580	n. e.	335.2	n. e.	n. e.	n. e.	n. e.	22.0	102.0	0.89	0.10	0.010	3.79	2.0	102.0
Slope 18	mean	7.83	477	1.9	227.0	63.3	18.0	16.2	2.9	13.0	149.9	0.24	0.05	0.001	1.82	1.8	47.4
	min.	7.30	309	1.4	121.6	43.5	9.8	2.5	1.1	9.0	70.0	0.05	0.01	0.001	0.50	0.2	4.0
	max.	8.37	491	2.3	266.2	72.8	20.5	7.6	5.7	19.0	168.7	1.00	0.50	0.005	7.00	4.2	217.0
	st. dev.	0.13	29	0.2	31.6	4.5	2.6	1.0	1.0	1.8	19.2	0.37	0.07	0.001	1.40	1.2	49.5
	mean	7.33	487	2.9	256.0	69.7	19.1	7.5	1.5	16.9	108.7	0.48	0.10	0.001	0.34	1.4	14.4

Channel B (1)	mean	7.78	500	3.5	269.1	73.6	20.8	5.8	1.2	16.2	80.3	0.08	0.03	0.004	2.33	1.6	13.2
	min.	7.60	444	3.0	236.0	46.0	16.1	5.0	0.9	14.0	65.8	0.05	0.01	0.001	0.20	0.3	9.0
	max.	8.10	528	4.0	290.0	85.0	39.8	6.5	1.5	19.0	91.7	0.15	0.06	0.009	4.00	3.6	16..0
	st. dev.	0.12	18	0.3	12.0	8.5	5.0	0.5	0.2	1.3	7.4	0.03	0.01	0.003	0.78	0..8	1.9
Poland (3)		6.5-8.5	-	-		-	-		-	300	200	0.5	0.5	-	10	-	-
WHO (4)			-	-		200					250	0.3	0.2	0.91	11.3	-	-
I class (5)			800	-	350	-	-	100	10	250	150	1	1	0.02	5	4	20

n.e. –not examined; 1) calculated basing on the data after „Szczakowa" and Strzyszcz 1996; 2) after OBiKŚ Katowice, 1999; 3) Polish limits for potable water; 4) WHO limits for potable water; 5) Polish limits for I class quality surface waters.

Table 2 Physic-chemical parameters of waters of the sump, the Jaworznik stream, the "Siersza" mining waters and groundwaters of the 457 MGB.

Sam-pling Point		Rea-ction pH	El. cond. μΣ/χμ	Alka-linity mval/dm^3	Tot. har-dness mg $CaCO_3$/dm^3	Ca2+	Mg2+	Na+	K+	Cl-	SO42-	Tot. Fe	NH4+	NO2-	NO3-	BOD mg/dm^3	SS mg/dm^3
						mg/dm^3											
Jaworznik (1)	mean	8.23	985	4.6	542.4	122.7	56.0	13.8	7.0	16.1	336.3	0.20	0.03	0.001	1.50	1.7	23.1
	min.	8.1	937	4.3	472.0	104.2	38.7	11.7	6.4	13.0	291.7	0.10	0.02	0.003	1.00	0.4	12.0
	max.	8.3	1044	4.8	591.0	142.8	63.1	14.6	7.6	18.0	381.4	0.30	0.04	0.020	2.00	5.3	35.0
	st. dev.	0.08	36	0.2	31.6	11.2	7.7	1.0	0.51	1.3	31.2	0.09	0.01	0.004	0.39	1.3	8.2
The sump (1)	mean	7.81	1019	4.5	505.0	149.6	31.2	27.6	10.5	24.1	427.7	2.47	0.11	0.011	1.32	2.0	23.5
	min.	7.37	655	0.2	232.7	51.5	1.2	6.6	1.6	14.0	173.2	0.05	0.02	0.001	0.10	0.2	3.0
	max.	8.25	1240	3.5	691.5	227.1	40.8	58.2	16.7	37.0	711.7	35.70	1.20	0.120	3.00	5.0	53.0
	st. dev.	0.23	158	0.6	133.8	48.3	7.1	11.6	3.2	5.7	117.6	8.89	0.20	0.018	0.86	1.0	9.3
The "Siersza" mining water	mean (2)	7.89	956	4.6	477.9	128.6	38.1	18.2	19.5	12.2	301.5	0.37	n. e.	n. e.	5.00	n. e.	n. e.
MGB 457	(3)	6.86	438	2.5	n. e.	70.4	26.0	7.7	1.9	13.1	155.1	2.92	<0.2	<0.02	<0.2	n. e.	n. e.

These waters were carried to the Main Channel by the following elements of the drainage system, which share in the total discharge ranged respectively between: Channel A - 3 and 11%, Channel B -9 and 27%, Channel WIII-15 together with Channel WIII-1 - 68 and 88%.

The key role of waters carried by Channels WIII-15 and WIII-1 from the Field II and the Siersza field should be underlined regarding the quality of waters at the Maczki intake. Physic-chemical parameters of waters examined at monitoring points localised on the channels are displayed in the table 1.

Some part of waters carried out from the southern part of the pit, reaching the Jaworznik stream, contain effluents from the mining-waste and fly ash dump and also mining waters from the "Siersza" coal mine. Physical characteristics and chemical constituents of the Jaworznik waters, waters from the colliery as well as waters of the sump that collects the effluents are presented in table 2. It must be stressed that mineralisation of waters of the sump decreases as the sump ages.

The Major Groundwater Basin (number 457) is controlled in one point (belonging to regional system of groundwater monitoring) just within the "Szczakowa" mining area. Parameters of its waters are displayed in table 2.

4 FACTORS AFFECTING QUALITY OF WATERS

Despite the high quality of waters, the system is presently subjected to the following threats:

- atmospheric deposition of pollutants,
- infiltration of contaminated waters from the Sztoła river,
- influence of effluents from the mining-waste and fly ash dump.

Atmospheric deposition of heavy metals, presented on the example of cadmium deposition in period 1992-1995 (Figure 2) and acid reaction of precipitation – average pH equals to 4.46, threaten the waters with potential contamination. Heavy metals emissions derived from Zn-Pb mining industry, which center is situated in Bukowno are able to degrade quality of groundwater in case the sorption potential of the cover formation is exceeded (Labus, 1999).

The Sztoła river, polluted mainly by Zn-Pb industry waste-waters with high contents of heavy metals (Table 3), flowing through the Field I of the pit, in case of intensified bed infiltration, could degrade waters of the WIII-15 and B channels.

Chemicals released from the mentioned above mining-waste and fly ash dump potentially endanger quality of waters from the southern part of the pit. These substances can be mobilised in case of repeated exploitation of the dumped material, improper reclamation of the dumping ground or even by excessive acidification caused by precipitation. Advantageously results of sulfates decomposition within the dump's body, are diminished owing to buffering capacity of Ca and Mg minerals that are contained in dumped material (Bednarczyk & Labus 1996).

Table 3 Mean heavy metals concentrations in waters of the Sztoła river and precipitation in 1995-1999.

Sample		Zn	Cd	Pb
		mg/dm3		
Sztoła [1]		0.699	0.006	0.125
Precipitation [1]		0.18	0.005	0.840
	Poland [2]	5	0.005	0.050
	WHO [3]		0.003	0.010
	I class [4]	0.2	0.005	0.050

[1)]*calculated basing on the data after „Szczakowa" 1999 and Strzyszcz 1996;*
[2)] *Polish limits for potable water;* [3)] *WHO limits for potable water;*
[4)]*Polish limits for I class quality surface waters*

5 CONCLUSION

Waters from the "Szczakowa" sand pit are of high quality, however they are subjected to numerous hazards. To avoid them, a continuous monitoring of waters should be performed not only at the measuring point in Maczki but also at the remaining important points listed in this paper. Mainly the surface waters are presently sampled in order to determine the water quality within the "Szczakowa" mining area. The only one existing monitoring point is insufficient for effective groundwater quality control. Numerous observation wells situated within the area are still not adopted for hydrochemical sampling.

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Wody kopalni piasku – „Szczakowa” (Polska) – zagrożenie ich jakości

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Streszczenie: Wody kopalniane z piaskowni „Szczakowa” zaopatrują ujęcie wody pitnej w Maczkach. Wody te narażone są na degradację swej jakości związaną z wielkopowierzchniowymi ogniskami zanieczyszczeń, jak również ze względu na infiltrację zanieczyszczonych wód z rzeki Sztoły, oraz wypływy ścieków ze składowiska odpadów kopalnianych. Stwarza to ciągłą konieczność monitorowania wód podziemnych i powierzchniowych w obrębie piaskowni.