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SODIUM AND POTASSIUM IN THE GROUNDWATER IN AREAS NEAR THE MAŚLICE MUNICIPAL REFUSE DUMP IN WROCŁAW*

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Abstract

Sodium and potassium are alkaline metals commonly occurring in natural environment. In clean groundwater their content usually does not exceed the value of 100 $mg \cdot dm^{-3}$ (Na) and 90 $mg \cdot dm^{-3}$ (K). Leakage waters of unsealed or improperly sealed refuse dumps constitute a potential grave source of water environment contamination. In the initial years of refuse dumping the leakage may contain up to 2,500 $mg \cdot dm^{-3}$ of sodium and up to 3,100 $mg \cdot dm^{-3}$ of potassium. The leakage from "old" dumps contains up to 3,700 $mg \cdot dm^{-3}$ sodium and up to 1,580 $mg \cdot dm^{-3}$ potassium.

The purpose of this paper was to demonstrate the character and the dynamics of the changes in sodium and potassium concentrations in the leakage waters of the Maślice Refuse Dump in Wrocław and in the groundwater in the adjacent areas. Since sand-gravel deposits lie in the base of the dump and the groundwater level is fairly high, contact occurs between the groundwater and the dumped waste as well as contamination transfer. Only part of the dump has a sealing and a drainage carrying the leakage to a tank. In the late 1990s the exploitation of the dump was terminated and rehabilitation started with a view to limiting the access of the water to the refuse dump.

The paper presented the results of the research covering the period from 1995 to 2007 on sodium and potassium contents in the groundwater coming to the dump, in the dump leakage and in the groundwater coming out of the dump.

The research has shown that both the concentrations and the proportions between sodium and potassium contents in the groundwater coming to the dump stayed within the natural ranges, exceeding them only in 2000-2001. The leakage, despite closing and rehabilitating the dump, was still characterized by fairly high and balanced concentrations of the

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analyzed elements. Also sodium and potassium contents in the groundwater coming out of the dump were high and balanced, which proves a continuous inflow of pollution through the unsealed base of the facility.

Key words: municipal refuse dump, groundwater, leakage waters, sodium, potassium.

SÓD I POTAS W WODACH PODZIEMNYCH NA TERENACH OTACZAJĄCYCH SKŁADOWISKO ODPADÓW KOMUNALNYCH „MAŚLICE" WE WROCŁAWIU

Abstrakt

Sód i potas są pospolicie występującymi w środowisku metalami alkalicznymi. W czystych wodach podziemnych ich zawartości najczęściej nie przekraczają 100 $mg \cdot dm^{-3}$ (Na) i 90 $mg \cdot dm^{-3}$ (K). Poważnym źródłem zanieczyszczenia środowiska wodnego mogą być odcieki z nieuszczelnionych lub nieprawidłowo uszczelnionych składowisk odpadów komunalnych. W początkowych latach składowania odpadów odcieki mogą zawierać do 2500 $mg \cdot dm^{-3}$ sodu i do 3100 $mg \cdot dm^{-3}$ potasu. Odcieki ze „starych" składowisk zawierają do 3700 $mg \cdot dm^{-3}$ sodu i do 1580 $mg \cdot dm^{-3}$ potasu.

Celem pracy było wykazanie charakteru i dynamiki zmian stężeń sodu i potasu w odciekach ze składowiska odpadów komunalnych „Maślice" we Wrocławiu oraz w wodach podziemnych na przyległych terenach. Ponieważ w podłożu składowiska zalegają utwory piaszczysto-żwirowe, a poziom lustra wód podziemnych jest dość wysoki, następuje kontakt wód podziemnych ze składowanymi odpadami oraz transport zanieczyszczeń. Tylko część składowiska ma uszczelnienie i drenaż odprowadzający odcieki do zbiornika. Na przełomie lat 1999-2000 zakończono eksploatację składowiska i rozpoczęto rekultywację, której głównym zadaniem było ograniczenie dostępu wody do złoża odpadów.

W pracy przedstawiono wyniki badań prowadzonych w latach 1995-2007 dotyczących zawartości sodu i potasu w wodach podziemnych dopływających do składowiska, odciekach składowiskowych oraz w wodach podziemnych wypływających za składowiskiem.

Wykazano, że zarówno stężenia, jak i proporcje między zawartościami sodu i potasu w wodach podziemnych dopływających do składowiska mieściły się w naturalnych zakresach, przekroczonych jedynie w latach 2000-2001. W odciekach, pomimo zamknięcia i rekultywacji składowiska, nadal stwierdzano dość wysokie i wyrównane stężenia analizowanych składników. Również zawartości sodu i potasu w wodach podziemnych odpływających za składowiskiem były wysokie i wyrównane, co świadczy o utrzymującym się dopływie zanieczyszczeń przez nieuszczelnione podłoże obiektu.

Słowa kluczowe: składowisko odpadów komunalnych, wody podziemne, odcieki składowiskowe, sód, potas.

INTRODUCTION

Sodium and potassium are alkaline metals commonly occurring in natural environment. In clean groundwater their content rarely exceeds the value of 100 $mg \cdot dm^{-3}$ (Na) and 90 $mg \cdot dm^{-3}$ (K). Na/K ratio in weakly mineralized water usually ranges from 0,2 to 0,9; the ratio increases along rising mineralization (usually up to 30-200) (Macioszczyk, Dobrzyński 2002).

Apart from natural sources, considerable amounts of sodium and potassium can reach water environment as a result of leakage from unsealed or improperly sealed refuse dumps. According to literature in the initial years of refuse dumping the leakage may contain up to 2,500 $mg \cdot dm^{-3}$ of sodium and up to 3,100 $mg \cdot dm^{-3}$ of potassium. The leakage from "old" dumps contains up to 3,700 $mg \cdot dm^{-3}$ of sodium and up to 1,580 $mg \cdot dm^{-3}$ of potassium (WILLIAMS 2002, ŻYGADŁO 2001, PAPADOPOULOU et al. 2007). During the examination of leakages occurring in the model deposits sodium concentrations ranged from 1,000 to 5,000 $mg \cdot dm^{-3}$, while potassium concentrations were slightly lower (from 580 to 3,800 $mg \cdot dm^{-3}$). Another factor which significantly affects the amount of sodium and potassium in dump leakages is the amount of water infiltrating the refuse dumps. With larger rainfall volume the concentrations diminish and the leakage volume grows, which gives rise to insignificant changeability of the charges of the removed impurities (KARTHIKEYAN et al. 2007, THORNTON et al. 2005).

The purpose of this paper was to demonstrate the character and the dynamics of the changes in sodium and potassium concentrations in the leakage waters of the Maślice Refuse Dump in Wrocław and in the groundwater in the adjacent areas.

MATERIAL AND METHODS

The research of the groundwater and the leakages was conducted in the area surrounding a closed municipal waste dump called Maślice in Wrocław. In the late 1960s neutralization process of the waste was begun, with an aid of excavation (covering a surface area of about 7ha) remaining after the exploitation of sand deposits. Sand-gravel deposits lie in the base of the dump and the groundwater level is fairly high (usually *ca.* 1-2 m above the foot of the dump). Under these conditions, both contact between the groundwater and the dumped waste as well as transfer of impurities are commonplace. The groundwater flows from south-west to north-east towards the Odra River (SZYMAŃSKA-PULIKOWSKA 2001). Only part of the dump (*ca*. 2 ha, built in 1994) has a sealing and a drainage carrying leakage to a tank, from which the research samples were taken. At the end of 1990s the exploitation of the dump was terminated and rehabilitation started. It involved reinforcing the slopes of the waste dump, sealing the dome with synthetic mineral material as well as, on the side of the groundwater inflow (in 2002), fixing a screen down to the impermeable layer to prevent the inflow. In 2004 the leakage tanks were filled in (SZYMAŃSKA-PULIKOWSKA 2005).

The paper presents the results of the research on sodium and potassium contents in the groundwater coming to the dump, in the dump leakage and in the groundwater coming out of the dump. The research into ground-

water content was conducted from 1995 to 2007, whereas the examination of dump leakages was terminated the moment the tank had been filled in. Research material was taken 3 times a year. The analyzed dump leakages were from the derived from the tank and the groundwater originated from four piezometers located on the inflow (2) and the outflow (2) side of the dump. The water stagnant in the piezometer well was pumped out twice prior to taking samples of the groundwater. The contents of sodium and potassium in the taken samples were marked according to the methodology described in the literature (NAMIEŚNIK, JAMRÓGIEWICZ 1998, HERMANOWICZ et al. 1999). The statistical analysis of the research results was conducted by means of Statistica 7.1 programme.

RESULTS AND DISCUSSION

Table 1 depicts the characteristic values (mean, standard deviation, variance coefficient) and mean sodium-potassium concentration ratio in the consecutive years of the research into the groundwater flowing to the dump. Mean annual sodium contents ranged from 11.43 to 303.7 $mg \cdot dm^{-3}$ and these of potassium from 1.735 to 30.57 $mg \cdot dm^{-3}$ (ten times less). The highest concentrations were observed at the onset of the research period (1995--1996) and in the years 2000-2001. Only in this last period the contents of sodium and potassium exceeded the natural concentrations range (MACIOSZCZYK, DOBRZYŃSKI 2002). However, the results obtained for potassium content displayed a greater variability. The proportions between sodium and potassium concentrations fluctuated within the range between 2.524 and 14.04; reaching the highest values in 2001 (high sodium concentrations) and 2003 (distinctive decrease in potassium content).

Table 2 depicts the characteristic values (mean, standard deviation, variance coefficient) and mean sodium-potassium concentration ratio in the consecutive years of the research into dump leakages (1995-2003, excluding 1998). Mean annual sodium contents in the leakages ranged from 1,013 to 3,711 $mg \cdot dm^{-3}$, reaching higher values after the dump was closed (since 2000). Mean annual sodium concentrations ranged from 905.8 to 2,350 $mg \cdot dm^{-3}$. Na/K coefficient values fluctuated between 0.749 and 2.372. The results were characterized by a very significant variability, which diminished in the last years of the research (2002-2003). That is also when sodium and potassium concentrations became balanced; however, they still remained at a high level.

Research conducted by other authors also show high and balanced contents of the examined elements in leakages from refuse dumps, or their parts, exploited for a long time. The dumps in Pomorze Środkowe emitted leakages containing 273.7-1,708 mg $Na \cdot dm^{-3}$ and 268.3-1,143 mg $K \cdot dm^{-3}$

Table 1

Characteristic values and mean sodium to potassium ratios in groundwaters coming to the dump

Years		μ (mg·dm^{-3})	Na/K	σ	ν (%)
1995	Na	63.33	5.099	39.60	52.86
	K	12.42		6.563	62.53
1996	Na	43.85	2.702	22.99	47.14
	K	16.23		7.653	52.43
1997	Na	19.18	2.524	10.25	46.14
	K	7.600		3.507	53.41
1998	Na	29.04	3.596	7.877	19.35
	K	8.075		1.563	27.13
1999	Na	53.15	7.935	45.09	58.16
	K	6.698		3.895	84.84
2000	Na	303.7	9.935	297.2	44.18
	K	30.57		13.51	97.86
2001	Na	179.6	13.23	184.1	37.50
	K	13.58		5.093	102.5
2002	Na	46.68	7.802	34.46	45.87
	K	5.983		2.745	73.82
2003	Na	47.51	14.04	37.53	41.37
	K	3.383		1.400	79.01
2004	Na	17.22	4.314	11.14	68.72
	K	3.992		2.743	64.68
2005	Na	11.43	6.588	6.586	49.13
	K	1.735		0.852	57.64
2006	Na	23.83	3.733	5.856	38.31
	K	6.383		2.446	24.57
2007	Na	44.25	7.416	43.45	56.35
	K	5.967		3.362	98.20

Explanations: μ – mean, σ – standard deviation, ν – variance coefficient

(Sianów) as well as 619.3-2,460 mg Na·dm^{-3} and 710.8-2,048 mg K·dm^{-3} (Karlino) (Janowska, Szymański 1999). Leakages from older sections of the refuse dump in Sierakowo (near Szczecin) contained 570-1,590 mg Na·dm^{-3} and 542-1,494 mg K·dm^{-3}, whereas the newest section emitted leakages containing 103-638 mg Na·dm^{-3} and 85-516 mg K·dm^{-3} (Meller et al. 2001).

Table 2

Characteristic values and mean sodium to potassium ratios in dump run-offs

Years		μ (mg·dm^{-3})	Na/K	σ	ν (%)
1995	Na	1013	1.118	273.4	146.7
	K	905.8		423.5	169.2
1996	Na	1615	0.749	156.7	121.2
	K	2157		216.5	118.6
1997	Na	1243	1.103	784.7	264.5
	K	1127		1008	408.9
1999	Na	1604	1.201	2518	2.593
	K	1335		986.3	29.64
2000	Na	3711	1.579	1484	65.52
	K	2350		672.7	152.2
2001	Na	2700	2.372	2174	315.2
	K	1138		636.9	81.21
2002	Na	1780	1.037	321.1	82.74
	K	1717		350.3	66.07
2003	Na	2461	1.162	439.5	73.75
	K	2118		172.0	85.44

Explanations, see Table 1

Thus the concentrations were approximate to the values demonstrated by the authors quoted previously (Mor et al. 2006, Thornton et al. 2005, Williams 2002).

Table 3 depicts the characteristic values (mean, standard deviation, variance coefficient) and mean sodium-potassium concentration ratio in the consecutive years of the research into groundwater flowing out behind the dump. The examined waters contained on average from 481.0 to 4,084 mg Na·dm^{-3} and from 209.2 to 2,520 mg K·dm^{-3} per year. As in the case of the leakages, the highest sodium and potassium concentrations occurred after closing the dump (2000-2003). The proportions between mean annual sodium and potassium contents ranged between 1.163 and 2.567.

Such large amounts of the examined elements and the values of Na/K coefficient prove a considerable influence of the leakages on the composition of groundwater flowing out behind the dump. Since mean annual concentrations of sodium and potassium tended to be even higher in the discussed leakages, it is possible to suppose that the impurities getting into the ground from the old unsealed part of the dump contained even more of the examined elements. The research results of the waters flowing to the dump and the waters flowing out behind it were characterized by a similar variability.

Table 3

Characteristic values and mean sodium to potassium ratios in waters flowing from the dump

Years		μ (mg·dm^{-3})	Na/K	σ	ν (%)
1995	Na	1049	1.163	729.1	69.52
	K	901.9		815.8	90.45
1996	Na	1786	1.634	532.5	29.82
	K	1093		686.8	62.84
1997	Na	1486	1.550	945.2	63.61
	K	958.9		894.0	93.23
1998	Na	2443	1.851	227.4	9.310
	K	1320		1008	76.38
1999	Na	2436	2.085	1198	49.17
	K	1168		905.3	77.48
2000	Na	3853	1.529	2262	58.71
	K	2520		2917	115.8
2001	Na	3983	2.567	1184	29.72
	K	1552		1218	78.46
2002	Na	3203	1.553	900.5	28.11
	K	2063		346.0	16.77
2003	Na	4084	2.015	1404	34.39
	K	2027		733.8	36.21
2004	Na	1400	2.188	1175	83.92
	K	639.8		550.9	86.10
2005	Na	481.0	2.299	355.7	73.95
	K	209.2		193.0	92.25
2006	Na	1790	1.687	1155	64.51
	K	1061		825.4	77.78
2007	Na	793.6	2.212	576.3	72.61
	K	358.7		296.3	82.61

Explanations, see Table 1

During research conducted on the dump in Radiowo (Pachuta, Koda 2001) the groundwater polluted by leakages from the unsealed facility contained similarly high sodium concentrations (up to 4,730 mg·dm^{-3}) but much lower potassium concentrations (up to 35 mg·dm^{-3}). The groundwaters in the vi-

cinity of other dumps (MOR et al. 2006, SRIVASTAVA, RAMANATHAN 2008) were also distinguished by an increased sodium content (up to 800 mg $Na \cdot dm^{-3}$) and a relatively low content of potassium (to 60 mg $K \cdot dm^{-3}$).

CONCLUSIONS

1. The concentrations of sodium and potassium in the groundwater coming to the Maślice Refuse Dump stayed within the natural ranges (except the years 2000-2001).

2. Despite closing and rehabilitating the dump, the leakage still contained fairly high and balanced amounts of sodium and potassium, implying that the dump will continue to contaminate the environment for a long time in the future.

3. High and balanced sodium and potassium contents in the groundwater leaving the dump prove a continuous inflow of impurities to the base of the dump.

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