

WOJCIECH ROSZAK*

EFFECT OF AGRICULTURE ON CHEMICAL COMPOSITION OF SHALLOW UNDERGROUND WATER

The concentrations of TDS, nitrates, sulfates, chlorides, potassium, sodium, and zinc in the underground waters within the studied agricultural areas of the Odra Valley in the vicinity of Wrocław are greater than those of the hydrochemical background for the Odra Valley. Underground waters during infiltration through soil layers are enriched with large amounts of various species. A model of geochemical processes of chemical composition formation of waters in soil was elaborated. The concentrations of chemical elements and ions in water infiltrated from soil were calculated basing on the balance of the mass of water and substances in water in soil.

It was proved that ploughlands are the source of pollution of underground waters in the prevailing part of the area studied. Almost all amounts of the dissolved substances (TDS), nitrogen compounds, potassium and zinc as well as chlorides and sulfates are of fertilizer origin. Calcium fertilizers can introduce toxic metals to soil.

NOTATIONS

- 1 — soil,
- 2 — unsaturated zone,
- A — atmosphere,
- A_i — extraction coefficient of i th species from the soil,
- c_i — concentration of i th species,
- \bar{c}_i — arithmetical mean of concentration of i th species,
- c_{\max} — maximal concentration,
- c_{\min} — minimal concentration,
- c_{esi} — concentration of i th species in water infiltrating from soil,
- c_l — concentration of i th species in lyzimetric water,
- $c_{q,li}$ — concentration of i th species in overland flow.

* University of Wrocław, Institute of Geological Sciences, ul. Cybulskiego 30, 50-205 Wrocław, Poland.

E	— evaporation and evapotranspiration,
H_s	— throughflow,
I_{es}	— infiltration from soil,
M_{ai}	— mass of i th species in gases adsorbed in soil,
M_{asi}	— mass of i th species in dust sediments,
M_{ci}	— mass of i th species in crops,
M_{crsli}	— mass of i th species forming in chemical reaction in soil,
M_{crslli}	— mass of i th species decaying in chemical reaction in soil,
M_{di}	— mass of i th species in gases evolved from soil,
M_{dpsi}	— mass of i th species extracted from soil,
M_{dssi}	— mass of i th species absorbable in soil water as a result of sorption and ion exchange,
M_{esi}	— mass of i th species in water infiltrating from soil,
M_{fi}	— mass of i th species in inorganic fertilizers and other agricultural chemicals,
$M_{hsl i}$	— mass of i th species in inflow of throughflow,
$M_{hsll i}$	— mass of i th species in outflow of throughflow,
M_{li}	— mass of i th species in lysimetic water,
M_{msli}	— mass of i th species forming in the process of mineralization of organic matter in the soil,
M_{mslli}	— mass of i th species decaying in the process of mineralization of organic matter in the soil,
M_{psi}	— mass of i th species precipitating from water to soil,
$M_{qsl i}$	— mass of i th species in overland flow,
M_{ri}	— mass of i th species in rain water,
M_{ssi}	— mass of i th species absorbable in soil as a result of sorption and ion exchange,
M_i^{aflux}	— mass of i th species in i th aflux,
M_j^{reflux}	— mass of i th species in j th reflux without the water infiltrating from soil,
P	— precipitation,
Q_{sl}	— overland flow,
TDS	— total dissolved solids,
c	— g/m^3 ,
M	— $g/m^2 \cdot y$,
E, H, I, P, Q	— $m^3/m^2 \cdot y$.

1. INTRODUCTION

Underground waters in quaternary formations are the main source of drinking water in Poland. They are mostly shallow underground waters of river valleys and Pleistocene sediments on upland areas. In several cities in Poland the underground waters are enriched with artificial infiltration. The Odra Valley in the vicinity of Wrocław and drainage area of the Ciemna River were chosen as the study areas. These areas are typical of the formation of chemical composition of lowland shallow underground waters. The study area of the Odra Valley (fig. 1A) covers: agricultural area (60%), Wrocław city area (25%), forest area (10%), and small industrial area (A) in the vicinity of infiltration intake (I). Drainage area of the Ciemna River (fig. 1B) is situated in the area of the intensive agricultural activity where neither industrial plants nor canalization system can be found.

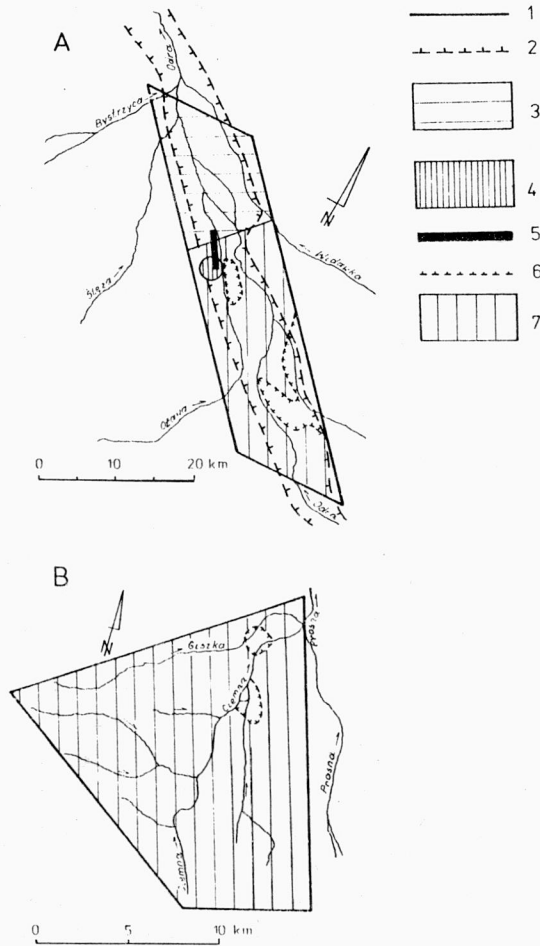


Fig. 1. Areas investigated

A – Odra Valley (600 km²), B – drainage area of the Ciemna river (150 km²), 1 – boundary of the area, 2 – boundary of the paravalley, 3 – Wrocław area, 4 – industrial region A, 5 – infiltration water intake I, 6 – forest area, 7 – agricultural area

2. METHODS

Water samples were taken according to the Polish Standards in five series in the period from December 1982 to November 1983 from 63 wells in the Odra Valley and 31 wells in the drainage area of the Ciemna River. In addition, the results of 282 chemical analyses of well water from the area of Wrocław city, carried out by Sanitary Service of Wrocław, were used. The depth of most of the wells did not exceed 6 m; only a few of them, including all the ones of infiltration intake, were

deeper (6–12 m). Water level in the study area was up to 3 m bgl*, except for wells on the infiltration intake up to 5 m bgl and several wells on estuary area of the Ciemna River (10–15 m bgl).

Chemical analyses were carried out according to the Polish Standards. Metals were determined by means of atomic absorption spectroscopy.

3. RESULTS AND DISCUSSION

The chemical composition of the Quaternary underground water in the area investigated is characterized by a great diversity. The water is of multi-ions type, the dominant ions being calcium (occasionally sodium, potassium, and manganese) and bicarbonate, often sulfate, seldom chloride, and only sometimes nitrate.

The arithmetical mean concentration from five series was compared with the hydrochemical background calculated for the Odra river in 1983 [1]. The comparison proved that the concentrations of dissolved substances (TDS), sulfates, nitrates, chlorides, potassium, sodium, calcium, and zinc are greater than those of the hydrochemical background within over half of the area investigated, whereas the concentrations of those substances, except zinc, in the infiltration intake (area I) are smaller than those of the background [2], [3]. In the intake area more than 90% of water intake is infiltrated from infiltration ponds on the Oława river, which indicates that agricultural activity considerably contributes both to underground water pollution in the remaining part of the areas studied and to the formation process of their chemical composition [3]. In order to support that idea, the chemical composition of the underground water studied (tab. 1) was compared with the chemical composition of fresh underground water of dune area of the Łeba spit located between the Baltic Sea and the Łebsko Lake. Chemical composition of shallow underground water of the Łeba spit is characterized by low concentrations of TDS (up to 215 g/m³), HCO₃⁻ (up to 92.2 g/m³), Cl⁻ (up to 54.9 g/m³), SO₄²⁻ (up to 41.2 g/m³), Ca²⁺ (up to 30.0 g/m³), Mg²⁺ (up to 12.1 g/m³), Na⁺, and K⁺ (up to 49.2 g/m³) [4]. This indicates that the processes occurring in the soil determine the chemical composition of shallow underground water in the river valley.

Mass balance of water and substances in soil was used to illustrate the influence of agriculture on underground water composition. It was assumed that substances introduced to the soil are soluble in soil water. Chemical compounds contained in mineral fertilizers are easily soluble in water except calcium sulfate and calcium phosphate. Loads and the concentration of substances in soil infiltration water

* bgl — below ground level.

Table 1

Chemical composition of shallow Quaternary underground water in the agricultural area in 1983

Species	Concentration in ground water (g/m ³)		
	Odra Valley (fig. 1A)		Drainage area of Ciemna river (fig.1B)
	Total area	Agricultural area	
Na ⁺	12.6–244.9	12.6–142.6	5.8–153.2
K ⁺	4.1–348.6	4.1–365.2	0.8–232.4
Ca ²⁺	40.1–285.6	40.1–249.5	80.2–440.0
Mg ²⁺	3.6–81.4	3.6–76.6	2.4–120.1
N _{NH₄⁺}	≤0.009–10.0	≤0.009–5.0	≤0.009–0.5
N _{NO₃⁻}	≤0.009–100.0	0.4–100.0	0.2–100.0
Cl ⁻	12.5–621	12.5–621	8.2–500
SO ₄ ²⁻	7.7–482	34.1–453	28.8–527
HCO ₃ ⁻	61.0–629	61.0–622	70.0–988
Fe	≤0.09–25.0	≤0.09–5.76	≤0.09–7.85
Mn	≤0.009–3.61	≤0.009–3.21	≤0.009–0.28
Cd	≤0.0009–0.015	≤0.0009–0.010	≤0.0009–0.012
Cr	0.0006–1.08	0.0006–0.014	0.0006–0.012
Cu	≤0.009–1.46	≤0.009–0.05	≤0.009–0.05
Hg	0.00012–0.00184	0.00032–0.00128	0.00022–0.00122
Ni	≤0.009–0.39	≤0.009–0.39	≤0.009–0.04
Pb	≤0.0009–1.43	≤0.009–0.15	≤0.009–0.19
Zn	0.05–8.46	0.08–3.05	0.02–4.0
TDS	226–2581	230–2400	340–1990
phenols	≤9·10 ⁻⁴ –0.015	≤9·10 ⁻⁴ –0.010	–
HCH+DDT	≤9·10 ⁻⁶ –0.098	≤3·10 ⁻⁵ –0.0098	–
pH	5.9–7.75	5.9–7.85	6.4–7.7

(tab. 2) were calculated from mass balance of substances introduced into the soil and removed from it according to the geochemical model.

The concentration of *i*-species (c_{esi}) in water infiltrating from the soil can be expressed according to the balance as follows:

$$c_{esi} = \frac{M_{esi}}{I_{es}} = \frac{\sum_{i=1}^n M_{ii}^{\text{flux}} - \sum_{j=1}^m M_{ji}^{\text{reflux}}}{P - E} \quad (1)$$

where $(P - E)$ was calculated from the Turc formulae.

In the formula (1) the following terms have been neglected: 1) M_{asi} , 2) Q_{sII} and M_{qsIIi} , 3) M_{ai} and M_{di} , 4) M_{msIIi} . In the agricultural area without an industrial source of dust emission, the quantity of M_{asi} is low. An overland flow (Q_{sII}) in the plane area

Table 2

Chemical composition of soil infiltration ground water (values calculated on the basis of water and mass balances)

Species	Concentration (g/m ³)	Load (g/m ² ·y)	Hydrochemical background BH (1) (g/m ³)
Na ⁺ ⁱⁱ	4.0–22.1	0.53–0.95	35.5
K ⁺	0.25–58.3	0.035–2.45	26.3
Ca ²⁺ ⁱⁱ	11.9 ⁱⁱⁱ –1418	1.60 ⁱⁱⁱ –75.2	134.0
Mg ²⁺ ⁱⁱ	4.9 ⁱⁱⁱ –530	0.64 ⁱⁱⁱ –28.1	52.1
N _{NH₄⁺}	2.4 ⁱ –134 ⁱ	0.31 ⁱ –5.64 ⁱ	—
N _{NO₃⁻}	—	—	1.0
Cl ⁻ ⁱⁱ	43.5–141	5.74	81.0
SO ₄ ²⁻ ⁱⁱ	116–559	15.3–23.5	160.0
HCO ₃ ⁻	—	—	419.0
Mn ⁱⁱ	≤ 1.3	≤ 0.055	—
Cd ⁱⁱ	0.003–0.009	0.0021–0.0037	0.0089
Cu	≤ 5.2	≤ 0.215	—
Cr ⁱⁱ	0.074–0.60	0.010–0.025	0.013
Hg ⁱⁱ	0.03–0.36	0.004–0.015	0.00084
Ni ⁱⁱ	0.026–0.16	0.0035–0.0089	—
Pb	0.14–5.1	0.019–0.209	0.12
Zn	0.46–18.1	0.06–0.745	0.39
TDS	260 ⁱⁱⁱ –5360 ⁱⁱ	21.0 ⁱⁱⁱ –225 ⁱⁱ	800

ⁱ — total nitrogen.

ⁱⁱ — without the amount assimilable by plant.

ⁱⁱⁱ — without soil lime.

studied is small. The concentration of *i*-species in the overland flow (c_{qsl_i}) is not great either and considerably smaller than that in the water infiltrating from the soil (c_{esi}). Therefore the mass of *i*-species in the overland flow (M_{qsl_i}) is small. The mass of gases absorbed in the soil (M_{ai}) or evolved from it (M_{di}) in the case of all considered species, excluding nitrogen, phosphorus, sulfur, and mercury, can be omitted. Volatility of mercury, which may occur as a chemical element and in the form of alkylmercury compounds, can cause mosaic variation of mercury concentration in water and soil. However, from the regional point of view the mercury concentration can be neglected.

The reduction of sulfate to hydrogen sulfide is not possible in the cultivated soil since it is usually oxidizing and neutral or alkaline medium. Therefore the hydrogen sulfide is not evolved from the soil. Absorption of sulfur oxides from the atmosphere can be neglected in the agricultural areas situated beyond reach of industrial sources of sulfur oxides emissions. In the cultivated soil hydrogen sulfide is not evolved

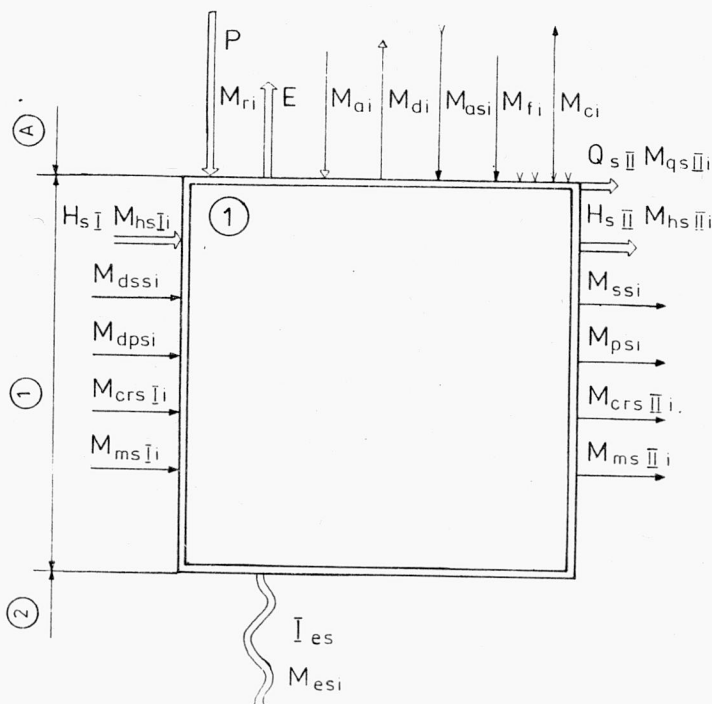


Fig. 2. Model processes in soil

during decay of organic matter and insoluble sulfides cannot be formed. Therefore the mass of species in water remains unchanged.

Besides, the following assumptions were made:

1. $M_{hsIi} = M_{hsIIi}$. In the plane area of valleys the inlet of throughflow did not differ much from outlet throughflow, and concentration difference was negligible.

2. $M_{dpsi} = M_{psi}$. Mineral fertilizers introduced into soil are readily soluble excluding calcium sulfate, phosphate, oxide, hydroxide of calcium, and manganese. That is why dissolution and precipitation of those species in the soil can be omitted.

3. $M_{crsIi} = M_{crsIIi} = 0$. Chemical reactions of carbon dioxide with carbonate and oxide minerals in the soil are crucial for the formation of soluble hydrogen bicarbonates of calcium, magnesium, iron, and manganese. The amounts of calcium and magnesium in the soil before fertilization are much smaller than those introduced with calcium fertilizers and can be neglected.

4. $M_{ssi} = M_{dssi}$. Sorption and desorption (including ion exchange) of clay minerals and humic matter affect considerably cations and only slightly anions, except phosphate concentration in the water. Since fertilizers deliver a great loads of

calcium and manganese to the soil in comparison with its sorption capacity and due to the lack of data on trace metal sorption, it was assumed that masses of absorbed and desorbed species were equal. On the basis of the above discussion, the equation (1) can be transferred to:

$$c_{esi_{\min}} = M_{esi_{\min}} \cdot I_{es_{\max}}^{-1} = (M_{ri} + M_{fi_{\min}} + M_{mi})(P - E)_{\max}^{-1}. \quad (2a)$$

$$c_{esi_{\max}} = M_{esi_{\max}} \cdot I_{es_{\min}}^{-1} = (M_{ri} + M_{fi_{\max}} + M_{mi})(P - E)_{\min}^{-1}. \quad (2b)$$

The $(P - E)$ value was calculated from the Turc formula for maximal and minimal values of mean year precipitation and temperature for Wrocław and Kalisz in the period from 1970 to 1983. Nitrogen load absorbed from the atmosphere or evolved to it is great ($n \cdot 10 \text{ g N/m}^2 \cdot \text{y}$ for $n < 10$) and depends on the kind of cultivation. Due to the great variety of cultivation, potassium and nitrogen concentrations in water infiltrating from the soil were calculated from the ratio of loads in lysimetric water M_{li} (equal to loads in water infiltrating from the soil — M_{esi}) to sum of loads introduced into soil:

$$M_{esi} = A_i(M_{ri} + M_{fi} + M_{mi}), \quad (3)$$

$$A_i = M_{li}(M_{ri} + M_{fi} + M_{mi})^{-1}. \quad (4)$$

Concentrations of nitrogen and potassium in water infiltrating from the soil were calculated from the following equation:

$$c_{esi_{\min}} = M_{esi_{\min}} \cdot I_{es_{\max}}^{-1} = A_{i_{\min}}(M_{ri} + M_{fi_{\min}} + M_{mi})(P - E)_{\max}^{-1}, \quad (5a)$$

$$c_{esi_{\max}} = M_{esi_{\max}} \cdot I_{es_{\min}}^{-1} = A_{i_{\max}}(M_{ri} + M_{fi_{\max}} + M_{mi})(P - E)_{\min}^{-1}. \quad (5b)$$

Maximal and minimal values of A_i were calculated on the basis of lysimetric tests of various kinds of soil fertilizers used in this area [5]–[8]. The calculated values are listed in tables 3 and 4.

The increased concentrations of nitrogen compounds, TDS, potassium, calcium, manganese, chloride, sulfate, and zinc in soil layer are comparable with those occurring in the greater part of agricultural area of the Odra valley and the drainage area of the Ciemna river and higher than hydrochemical background of the Odra Valley. Concentrations of nitrogen, potassium, and sodium in lysimetric waters (tab. 5) are comparable with the concentrations calculated from the equation (5b). Thus, high concentrations of these substances are due to agricultural activity.

Calcium fertilizers used in Poland may contain quite large concentrations of

Table 3

Loads of inorganic fertilizers in the area studied (results of an inquiry)

Inorganic fertilizer	Mean load of fertilizer			Mass of fertilizer (g/m ² ·y)	Mean concentration (%)		
	kg N	kg P ₂ O ₅	kg K ₂ O		N	P ₂ O ₅	K ₂ O
	ha·y	ha·y	ha·y				
NITROGEN (total)	94.7	—	—	33.53	—	—	—
Urea	19.4	—	—	6.96	31	—	—
Ammonium saltpetre	57.3	—	—	17.90	32	—	—
Nitro-chalk	8.5	—	—	4.16	20.5	—	—
Ammonium sulfate	9.5	—	—	4.51	21	—	—
PHOSPHORUS (total)	4.8	63.2	6	29.41	—	—	—
Superphosphate 1	—	39.9	—	22.19	—	18	—
Superphosphate 40	—	4.6	—	1.15	—	40	—
Pulverized phosphates	—	5.1	—	1.74	—	29	—
Ammonium phosphate	2.5	6.7	—	1.46	18	46	—
Ammonium phosphate and potassium chloride	2.3	6.9	6.9	2.87	8	24	24
POTASSIUM (total)	—	—	100.9	58.82	—	—	—
Kainit	—	—	44.6	44.60	—	—	10
Potassium chloride	—	—	55.0	13.35	—	—	40
Potassium sulfate	—	—	1.2	0.44	—	—	25
Kameks	—	—	0.1	0.03	—	—	33

Soil lime 134.0 kg(CaO + MgO) ha/y

chromium, cadmium, lead, arsenic [11] zinc, and other elements [12] and they are one of the sources of these substances in shallow underground waters.

The concentrations of chromium, zinc, lead, mercury, copper, and nickel in underground water in the infiltration intake (I) are high and greater than those of hydrochemical background. This is a consequence of underground water pollution due to eolian transport [3]. According to the mechanism presented in the previous paper [3], the dust from smelter and electrical power plants migrates to the infiltration area where it forms bottom sediments in infiltration ponds. Metals permeate through acid and reductive environment of bottom sediment to infiltration water and migrate there in ionic form and complex compounds.

Table 4

Mass balance in soil

1	$M_{esN}/(M_{fN} + M_{mN} + M_{rN})$		0.026–0.46 [5]; 0.32 [13]
	$M_{esK}/(M_{fK} + M_{mK} + M_{rK})$		0.0023–0.61 [5]
	$M_{esP}/(M_{fP} + M_{mP} + M_{rP})$		0.000004–0.0036 [5]
2	M_{rN}	g N/m ² ·y	1 [5], [13]; 1.5 [14]; 2.2–5.5 [15]; 0.6–2.3 [16]
	M_{rK}	g K/m ² ·y	0.22–0.55 [15]; 0.1–1.2 [16]
	M_{rMg}	g Mg/m ² ·y	0.06–0.26 [15]; 0.07–2.3 [16]
	M_{rNa}	g Na/n ² ·y	0.15–0.45 [15]; 0.11–271 [16]
	M_{rHg}	g Hg/m ² ·y	0.004–0.015 [15]
	M_{rCd}	g Cd/m ² ·y	0.0006–0.0017 [15]
	M_{rCu}	g Cu/m ² ·y	0.048–0.252 [15]
	M_{rNi}	g Ni/m ² ·y	0.0018–0.0052 [15]
	M_{rPb}	g Pb/m ² ·y	0.019–0.209 [15]
	M_{rZn}	g Zn/m ² ·y	0.05–0.568 [15]
	M_{rSO_4}	g SO ₄ /m ² ·y	6.6–14.8 [15]; 2.4–28.4 [16]
3	M_{mN}	g N/m ² ·y	3.0 [13]; 3.0–6.0 [14]
4	M_{mK}	g K/m ² ·y	4.0 [5]
5	M_{mP}	g P/m ² ·y	1.5 [5]
	Values assumed for calculation		
6	M_{rN}	g N/m ² ·y	1.0
	M_{rK}	g K/m ² ·y	0.5
7	M_{mN}	g N/m ² ·y	3.0
8	M_{mK}	g K/m ² ·y	4.0
9	M_{mP}	g P/m ² ·y	1.5
10	(P–E)	m ³ /m ² ·y	0.053–0.135

Table 5

Chemical composition of lysimetric water (from cultivated soil)

Species	Concentration (g/m ³)
Na ⁺	7.5–23.5 [7]; 7.1–22.9 [8]; 4.9–60.9 [10]
K ⁺	0.4–10.0 [6]; 0.0–5.7 [7]; 1.1–11.8 [8]; 13.0–28.7 [9]
Ca ²⁺	70–219 [7]; 43.8–107.6 [8]; 18.3–32.7 [9]; 19–263 [10]
Mg ²⁺	8–36 [7]; 6.7–24.2 [8]; 9.3–19.9 [9]; 0.7–43.2 [10]
N _{NH₄⁺}	0.0–2.4 [6]
N _{NO₃⁻}	0.8–98.8 [6]; 0.9–78.5 [7]; 6.2–37.4 [6]; 0.5–42.4 [9]; 0.7–26.2 [10]
SO ₄ ²⁻	1.1–87 [7]; 23.2–45.3 [8]
HPO ₄ ²⁻	0.0–0.3 [6]; 0.0–0.2 [7]; 0.02–0.99 [10]
Cl ⁻	0.8–314 [0]
pH	5.8–7.5 [8]

4. CONCLUSIONS

On the basis of the above considerations the following conclusions can be formulated:

1. Intensive agricultural activity is one of the main sources of underground water pollution in the area studied.

2. Some of calcium fertilizers are the main source of underground water pollution with toxic metals.

3. The agricultural activity should be diminished or excluded in the area of underground water supply.

4. In the protection area, the application of fertilizers and pesticides should be limited. Calcium fertilizers and others which contain a great amount of heavy metals should not be used at all.

REFERENCES

- [1] ROSZAK W., Acta Univ. Wratisl. (in press).
- [2] ROSZAK W., Materiały III Ogólnopolskiego Sympozjum *Aktualne Problemy Hydrogeologii*, Kraków, 28–30 May, 1985, AGH Kraków, p. 465.
- [3] ROSZAK W., Scientific Papers of Inst. of Geotechnics, Techn. Univ. of Wrocław, 49 (1986), 229.
- [4] ZIĘTKOWIAK, Z., Thesis, Poznań 1980.
- [5] PONDELH., unpublished data (1984).
- [6] RUSZKOWSKA M., Materiały Sympozjum *Skład Chemiczny Wód Gruntowych i Powierzchniowych w Warunkach Intensywnej Produkcji Rolnej*, Falenty, 11–12 June, 1979, IUNG, Puławy 1984, part I, p. 17.
- [7] SYKUT S., *ibid.*, part I, p. 35.
- [8] VÖMEL A., *Forschrichte in Acker- u. Pflanzenbau*, 3 (1974), p. 1.
- [9] SILOVA E. T., KOROVKINA, L. N., *Pocvovedenie*, 18 (1982), p. 1.
- [10] OHLENDORF W., Thesis, Gießen 1976.
- [11] UMIŃSKA R. *Medycyna wiejska*, 20 (1985), 66.
- [12] CZUBA R., SADOWSKI, S., *Nowe rolnictwo*, 20 (1971), p. 1.
- [13] STRIBAL J., VRBA, J., *Stud. in Environ. Sci.*, 17 (1981), p. 181.
- [14] CAREY M. A., LLOYD, J. W., *J. Hydrol.*, 78 (1985), p. 83.
- [15] TWOROWSKI R., Materiały II Polsko-Czechosłowackiego Sympozjum, IG, Warszawa 1985, p. 124.
- [16] CHOJNACKI A., *Pam. Puł.*, 29 (1968), p. 171.

WPLYW ROLNICTWA NA SKŁAD CHEMICZNY PŁYTKICH WÓD PODZIEMNYCH

Stężenia substancji rozpuszczonych, azotanów, siarczanów, chlorków, sodu, potasu i cynku w wodach podziemnych na badanym rolniczym obszarze doliny Odry w okolicy Wrocławia są większe od tła hydrochemicznego. Woda podczas infiltracji przez warstwę gleby wzbogaca się w przeważającą część substancji w niej zawartych. Opracowano model procesów geochemicznych formowania się składu

chemicznego wód w glebie. Na podstawie bilansu masy wody i substancji w wodzie w glebie obliczono stężenia pierwiastków i jonów w wodzie infiltrującej z gleby.

Stwierdzono, że użytki rolne są ogniskiem zanieczyszczeń na przeważającej części badanego obszaru. Prawie cała ilość substancji rozpuszczonych, tj. związków azotu, potasu, chlorków i siarczanów oraz cynku, pochodzi z nawozów sztucznych. Z nawozami wapniowymi mogą być wprowadzone do gleby metale toksyczne.

ВЛИЯНИЕ СЕЛЬСКОГО ХОЗЯЙСТВА НА ХИМИЧЕСКИЙ СОСТАВ МЕЛКИХ ПОДЗЕМНЫХ ВОД

Концентрации растворенных веществ, нитратов, сульфатов, хлоридов, натрия, калия и цинка в подземных водах на исследуемой сельскохозяйственной территории долины Одера в окрестностях Вроцлава больше гидрохимического фона. Вода во время инфильтрации через слой почвы обогащается большинством веществ, содержащихся в ней. Разработана модель геохимических процессов формирования химического состава вод в почве. На основе баланса массы воды и веществ в воде в почве рассчитаны концентрации химических элементов и ионов в инфильтрующей из почвы воде.

Было установлено, что сельскохозяйственные угодья являются источником загрязнений на большей части исследуемой территории. Почти все количество растворенных веществ, т.е. соединений азота, калия, хлоридов и сульфатов, а также цинка, происходит из искусственных удобрений. Вместе с известковыми удобрениями могут быть введены в почву токсические металлы.