



Variabilities of Surface Water Quality of Degraded Post-mining Areas in Bytom

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Abstract: In the paper there is presented an evaluation of variability of surface water quality (reservoirs and watercourses), on the area of degraded post-mining area in Bytom. The physicochemical analysis of water and compared with archival data obtained in 2009 and 2014. There were done analysis of following parameters: reaction, total content of substances dissolved in water, water hardness and the content of: Cl^- , SO_4^{2-} , HCO_3^- , Ca^{2+} , Mg^{2+} , K^+ , Na^+ , NH_4^+ , NO_3^- , NO_2^- , PO_4^- ions as well as Fe and Mn. The examined surface waters were characterised by high content of solutes. Anions were dominated by chlorides, the sodium proved to be the dominating cation, the examined water samples were characterised by high concentration of sulphates. In all analyzed reservoirs, permissible concentrations of chlorides and sulphates were exceeded. In all sample points there was observed a decrease of pH value in long term period, the concentration of chlorides lowered, however concentrations of sulphates increased in the majority of sampling points.

Keywords: degraded post-mining areas, quality of surface water, reclamation

1. Introduction

Degraded post-mining areas represent complicated, complex genesis as well as different environmental problems. One of the important problem is the issue of surface water protection. A good example of post-mining area is former Rozbark mine site in Bytom, where a surface water monitoring have been conducted for 10 years.

Investigated are is an example of an interesting and natural valuable greenery terrain of Bytom, showing significant influence of anthropogenic pressure. The storage of communal and mining wastes of the land's surface and



surface water contamination belong to the most important environmental problems in the described area. Coal, as well as Zn and Pb ores exploitation resulted in subsidence, collapses and construction of dumps, which led to the disturbance of natural water circulation. A particular characteristic of the area is the diversity of different anthropogenic landforms and types of wastes. The main impact of underground mining in study area is presence of subsidences, which caused origin of anthropogenic water reservoirs. Another important factor of post-mining character of the terrain is the vicinity of mining waste dump, which influence of the concentrations of chemical compounds, particularly chlorides and sulphures.

In the area connected with the mining activity, surface and groundwater chemistry was formed as a result of mine drainage, which begins from the intensive weathering of waste dumps. Finally, this process may lead to heavy acidification and increase the concentration of sulphates and metals in the water. Mine drainage is observed especially in ore, coal mine and waste dumps, where waste rocks are exposed to atmospheric factors. In Poland, this problem occurs eg. in coal mines, which are located in the southwestern part of the Upper Silesian Coal Basin (Pluta 2004), in the eastern part of the Arch of Muskau (Labus & Skoczyńska 2013), in the Częstochowa region (Razowska 2001) and in the vicinity of the mine waste dumps (Twardowska et al. 1988, Szczepańska 1990, Gawor & Lutyńska 2015). In the area of former mine Rozbark in Bytom, the influence of acide drainage is also observed.

2. Characterization of study area

2.1. Localization

The post-mining degraded area of the former coal mine Rozbark is situated in the southern part of Bytom, in the neighbourhood of Chorzów and Siemianowice Śląskie (Fig. 1), between the streets Cicha, Łagiewnicka and Krzyżowa, as well as municipal parc (Park Miejski im. A. Mickiewicza) and small stream Rów Graniczny.

As far as physio-geographical classification of J. Kondracki (2000) is concerned, investigated area is situated in the northern part of the Silesian Upland (Wyżyna Śląska), in the meso-region of the Katowice Upland (Wyżyna Katowicka) and in the Bytom-Katowice Plateau (Płaskowyż Bytomsko-Katowicki). These areas represent a terrain with relative elevations of 260-270 m a.s.l. A significant influence on the morphology of the land was derived from the mining exploitation (mining subsidences, coal mining waste dumps), as well as the exploitation of Zn and Pb ores.

The researched area has been used as a place of illegal waste storage for several years. As a result, water table and surface waters were exposed to contact with hazardous effluents from disposed waste. The wastes and effluents were also hazardous for the soil cover. The natural relief was transformed by of the rise of new hills and slopes built of waste. The degradation of the landscape influenced the aesthetics of the naturally rich and attractive area (Fig. 2).

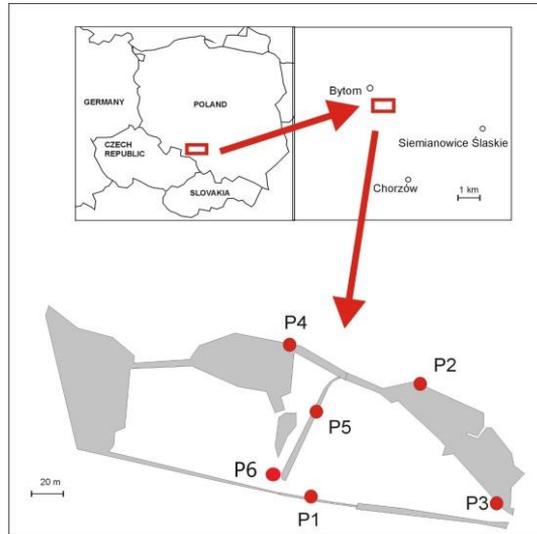


Fig. 1. Location of the study area and sampling points: P1-P6 – sampling points



Fig. 2. Study area in 2009 – illegal waste storage in the neighbourhood of water reservoirs (phot. Ł. Gawor)

2.2. Geological composition

The lithological-stratigraphic description of the study area includes the Carboniferous, Triassic, Jurassic, Paleogene, Neogene and Quaternary layers. The layers older than the Carboniferous were not taken into consideration, because of their low significance for reclamation processes. The oldest stratigraphic cell significant for the conducted work represent Carboniferous coal deposits, as well as accompanying rocks, associated with mining activity, which started more than 100 years ago in the region (Gabzdyl 1999).

The Carboniferous orogeny was recognized in the study area from the coal seam 401 rudzkie beds, until the seam 621 of the porębskie beds. Geological data on these seams are important, because they form the only basis on which the composition of the mining wastes disposed in the area may be concluded. In this site, the following beds are distinguished: rudzkie, siodłowe and porębskie. The rudzkie beds occur in a form of alternating layers of sandstones, mudstones and siltstones with coal seams. The siodłowe beds are the most rich in coal Carboniferous layers and represent a complex of sandstones (sometimes also conglomerates) with an admixture of siltstones. The thickness of the coal seams in this area reaches 9-12 m – coal seam 510). The porębskie beds are characterized by the dominance of siltstones and mudstones over sandstones. The coal seams show large variability in thickness (Mgłosiek 1998).

The Triassic deposits on the whole area reach significant thickness. Particularly sedimentary rocks from Muschelkalk are well developed. They are represented by different types of dolomites with Zn-Pb ores, comprised of ore minerals like sphalerite and galena. The thickness of carbonate rocks reaches 100 m (Gabzdyl 1999). Under the carbonate layers, deposits of the Lower Triassic – Bundsandstein, of which the main part (ret) is represented by limestone, marls and dolomites with an admixture of silts, can be found. Lower and medium Bundsandstein is built of silts, sands, gravels and sandstones.

In the neighbourhood of study area occur small patches of Jurassic deposits, which belong to Liass. Lithologically they represent multi-colour silts and clays with limonite as well as sands.

There is a thick layer of Miocene deposits, represented by marl silts, sands, sandstones, gypsum and tuffite. The Pleistocene layers are represented by ground moraine sediments, shaped as sands, clays and sandy clays with admixture of humus. The Holocene layers are represented by fluvial deposits – sands, clays and sandy clays with an admixture of humus. The thickness of these deposits reach 2.0-6.0 meters.

2.3. Hydrological and hydrogeological conditions

The hydrogeological conditions of the Upper Silesian Coal Basin are shaped by two factors: a natural factor, which is the influence of the geological composition of the region, as well as the mining factor. Groundwater flow occurs in the Neogene, Triassic and Carboniferous deposits.

Water-bearing strata and the quality of groundwater depend on mining exploitation and mine drainage. The study area is situated in the zone of degraded groundwater covering a surface of ca. 177 km². The mines located in the neighborhood of the Bytom-Rozbark are characterized by different inflows. Their intensity is connected with the hydraulic contact of the mining works with the water table in Triassic rocks. As a consequence of long-term mine drainage of the Bundsandstein, the water table has been dropping systematically (Kropka et al. 1998). The long-term mining exploitation of Zn-Pb ores and hard coal, in the neighborhood of the study area, has caused changes in the morphology of the ground surface. The mining subsidence and waste dumps leads to disturbances in natural water circulation. Changes in water conditions were caused, for example, by local inundation of the ground surface (Girczys, Sobik-Szołtysek 2002). The study area designated for reclamation belongs to the catchment of the Bytomka River and is situated on the Bytomka's tributary – "Rów Graniczny". In the terrain depressions, three ponds linked together are to be found. There is no natural outflow from water reservoirs. Water which recharges the ponds comes from precipitation and infiltration from the "Rów Graniczny" (Fig. 3-4).



Fig. 3. The stream "Rów Graniczny" (phot. Ł. Gawor)



Fig. 4. The pond in the central part of study area (sampling point P4) – low level aerial photograph (phot. Ł. Gawor)

3. Materials and methods

Surface water samples were collected in May 2018 at 6 measurement points: P1 – control profile of “Rów Graniczny”; P2 – shallow pond overgrown with water plants; P3 – shallow pond overgrown with water plants; P4 – shallow pond; P5 – tributary to the pond; P6 – tributary to the pond. Situation of sampling places referred to the samples taken in 2014 (measurement points P1-P5). Because of variable spatial conditions it was not possible to copy sampling place in P4 point. In the point 6 there was taken a sample only in 2018.

The places of collecting of the samples have been chosen regarding different kinds of surface water occurrence – ponds as stagnant water and streams and tributaries as flowing water. Between sampling points there was observed water flow.

What was measured as part of chemical analysis were: reaction, total content of substances dissolved in water, water hardness and the content of: Cl^- , SO_4^{2-} , HCO_3^- , Ca_2^+ , Mg_2^+ , K^+ , Na^+ , NH_4^+ , NO_3^- , NO_2^- , PO_4^- ions as well as Fe and Mn. The analyses were carried out in the chemical laboratory of the Department of Applied Geology of the Silesian University of Technology in Gliwice.

PH-value was marked with the use of ELMETRON – CX-742 multi-function meter, dry residue was analysed according to the gravimetric method, water hardness by means of versenate test, while the content of chloride ions by using titration method. HCO_3^- and Na^+ ions concentration was established by concentration method. Remaining ions were tested by means of SLANDI LF – 205 microprocessor photometer.

In 2009 there was done a complex technical and biological reclamation. There was done an inventarization and classification of wastes, which have been removed, what have had a key influence on the improvement of surface water of investigated area. The analysis and evaluation of complex reclamation including

surface water quality has been done after 10 years. The study area has been restored, the impact of communal wastes and mining wastes has been diminished, what was one of the reasons that Authors decided to compare quality of surface water in mentioned above periods.

4. Results

Results of the analysis are shown in Table 1.

Table 1. Results of the chemical analysis of surface water

Parameter/Analysis	Units	P1	P2	P3	P4	P5	P6
Dry residue	mg/dm ³	3072	2956	1650	4706	4723	4409
pH		7.15	6.87	7.48	7.03	7.08	7.07
Total hardness	°n	54.68	47.67	32.25	72.9	72.9	65.89
Carbonate hardness	°n	23.83	22.71	13.18	31.4	31.97	27.48
Non-carbonate hardness	°n	30.85	24.96	19.07	41.5	40.93	38.41
Chlorides	mg Cl/dm ³	763.25	869.75	550.25	1331.25	674.5	1278
Sulphates	mg SO ₄ /dm ³	1030	875	345	1850	1940	1670
Bicarbonates	mg HCO ₃ /dm ³	517.111	492.807	286.006	681.38	693.749	596.32
Calcium	mg Ca/dm ³	210.42	150.3	110.22	290.58	250.5	250.5
Magnesium	mg Mg/dm ³	109.44	115.52	72.96	139.84	164.16	133.76
Potassium	mg K/dm ³	35	32	11	23	40	36
Sodium	mg Na/dm ³	395.46	416.38	270.48	388.63	958.15	442.38
Ammonium nitrogen	mg NH ₄ /dm ³	0.3	0.3	0.2	< 0.1	0.2	0.2
Nitrates	mg NO ₃ /dm ³	10.7	3.5	3.4	0.9	1.5	1
Nitrites	mg NO ₂ /dm ³	< 0.02	0.02	0.08	0.04	< 0.02	0.03
Phosphates	mg PO ₄ /dm ³	< 0.2	< 0.2	0.4	< 0.2	< 0.2	0.4
Manganese	mg Mn/dm ³	0.12	0.32	< 0.05	0.38	0.24	0.31
Iron	mg Fe/dm ³	0.2	0.1	< 0.05	< 0.05	< 0.05	0.1

The examined surface waters were characterised by high content of solutes, ranging from 1650 mg/dm³ in P3 sampling site to 4 723 mg/dm³ in P4 and by slightly alkaline reaction. The only exception was the sample collected in P2 site, whose reaction was slightly acid.

According to Pazdro (1990) classification, as regards hardness, the tested waters can be considered very hard and with the predominance of non-carbonate type.

Anions were dominated by chlorides, whose concentration ranged from 550.25 mg Cl/dm³ in water collected in P3 site to 1331.25 mg Cl/dm³ in P4. Sodium proved to be the dominating cation and its concentration ranged from 270.48 mg Na/dm³ in P3 site to 958.15 mg Na/dm³ in P5.

The examined water samples were characterised by high concentration of sulphates; with the highest concentration observed in samples collected in P5 and P4 sites and amounting to 1940 mg SO₄/dm³ and 1850 mg SO₄/dm³ respectively. Calcium content ranged from 110.22 mg Ca/dm³ (P3) to 290.58 mg Ca/dm³ (P4), while that of magnesium from 72.96 mg Mg/dm³ (P3) to 164.16 mg Mg/dm³ (P5).

Water with the lowest level of mineralisation, collected in P3 site, had the highest concentration of nitrites (0.08 mg NO₂/dm³) and phosphates (0.4 mg PO₄/dm³). At the same time, it was characterised by the lowest concentration of manganese and iron – below 0.05 mg/dm³. The highest concentration of these metals could be observed in sites: P4 (0.38 mg Fe/dm³), P2 (0.32 mg Fe/dm³) and P1 (0.2 mg Mn/dm³). Concentration of potassium ranged from 11 mg K/dm³ in P3 site to 40 mg K/dm³ in P5 and that of nitrates also varied, amounting to 0.9 mg NO₃/dm³ in P4 site and 10.7 mg NO₃/dm³ in P1.

In order to determine how the quality of water changed in the course of time, results of this research were compared to those from 2014 and 2009. The exceptions were water samples taken at the measurement point P6, which were not included in the analysis from previous years. When compared to the analysis from 2014, all the sampling sites proved to have a decreased reaction value of water. Concentration of chlorides in samples collected in sites P1, P4 and P5 was lower in comparison to the samples collected in 2009 and 2014. The most significant decrease was observed in P1 site, where concentration of chlorides decreased by approximately 41% in comparison to 2009 and by 61% when compared to 2014 (Fig. 5).

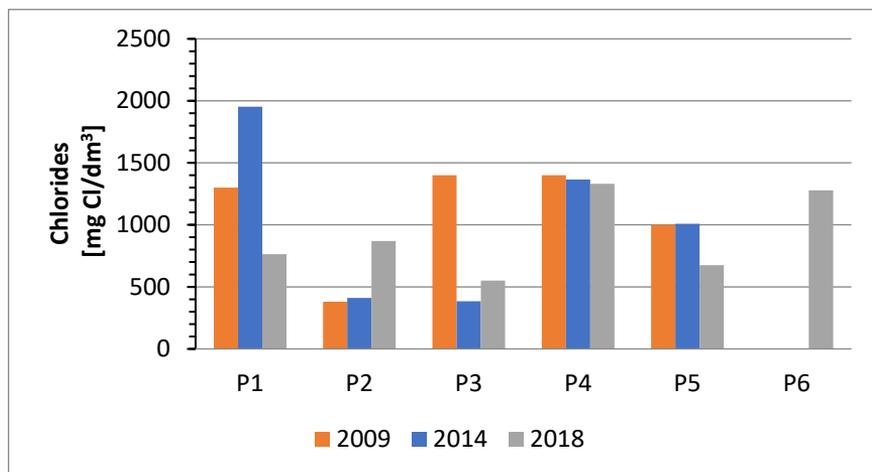


Fig. 5. Concentration of chlorides in the sampling sites

In P2 and P3 sampling sites, concentration of chlorides increased by 111% and 43% respectively in comparison to 2014.

In comparison to 2014, concentration of sulphates increased in water samples collected in all the sampling sites except for P1 (Fig. 6).

The most notable difference as regards concentration was observed in P2 sampling site, where the content of sulphates increased from 428 mg SO₄/dm³ to 875 mg SO₄/dm³. In P1 site a decrease was observed in the content of sulphate ions by 33% when compared to 2009 and 38% in comparison to 2014.

A similar tendency can be observed as regards Ca²⁺ and Mg²⁺ ions. In the surface water samples collected in 2018 in P2, P3, P4 and P5 sampling sites, both calcium and magnesium concentration is higher than in the samples which were analysed in 2014 (Fig. 7 and 8).

The most considerable difference was noticed in P3 sampling site, where concentration of calcium increased by 83% in comparison to the results from 2014, as well as in P2 site in which the concentration of magnesium increased by 179% when compared to the samples collected in 2014.

In comparison to the results from 2009 a considerable decrease was noticed in the content of ammonium ion in the examined water samples (Fig. 9). Concentration of that particular ion observed in water in 2018 was lower, by 44% in P2 site and by 91% in P4, when compared to the results from 2009.

In reference to 2014, decreased concentration was observed only in two sampling sites, which are P2 and P3. In P1 site one could observe an increased concentration of ammonium ion in comparison to the two previous measuring series (Fig. 9).

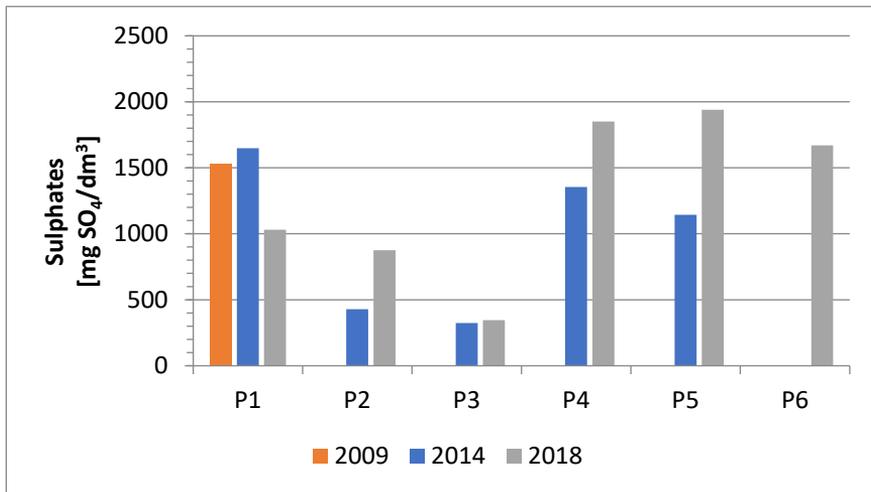


Fig. 6. Concentration of sulphates in the sampling sites

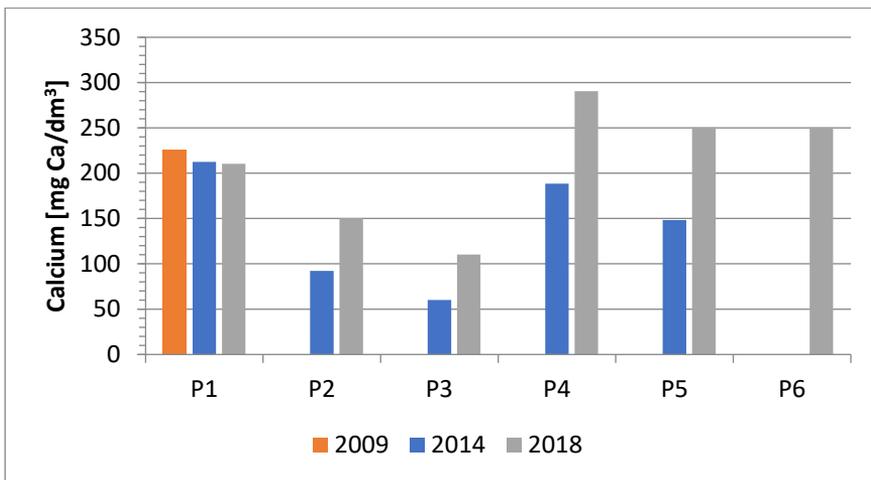


Fig. 7. Concentration of calcium in the sampling sites

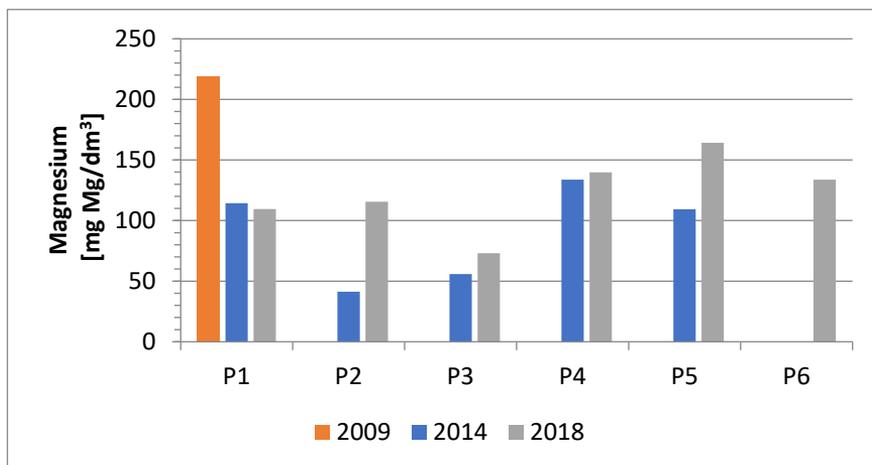


Fig. 8. Concentration of magnesium in the sampling sites

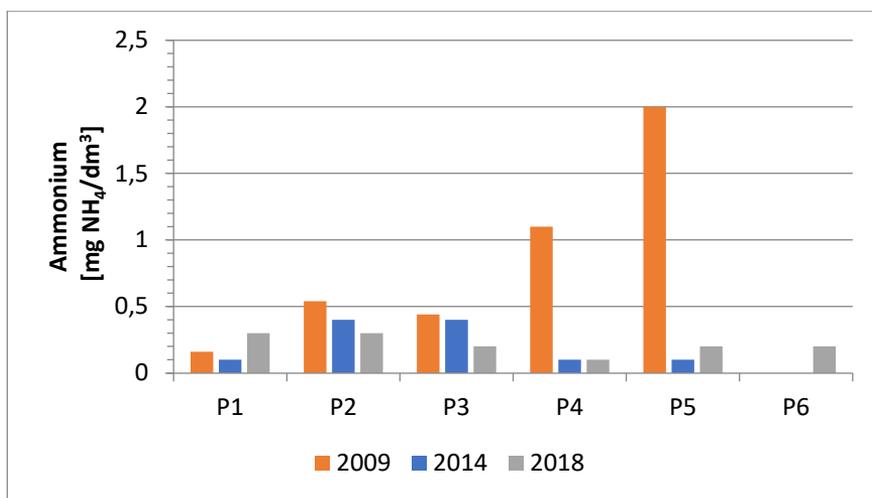


Fig. 9. Concentration of ammonium ion in the sampling sites

Concentration of nitrates was the highest in 2018 in all the sampling sites, except for P4 (Fig. 10). In comparison to the results from 2014, concentration increase was noticed in sites P5 (by 88%) and P1 (by 1683%).

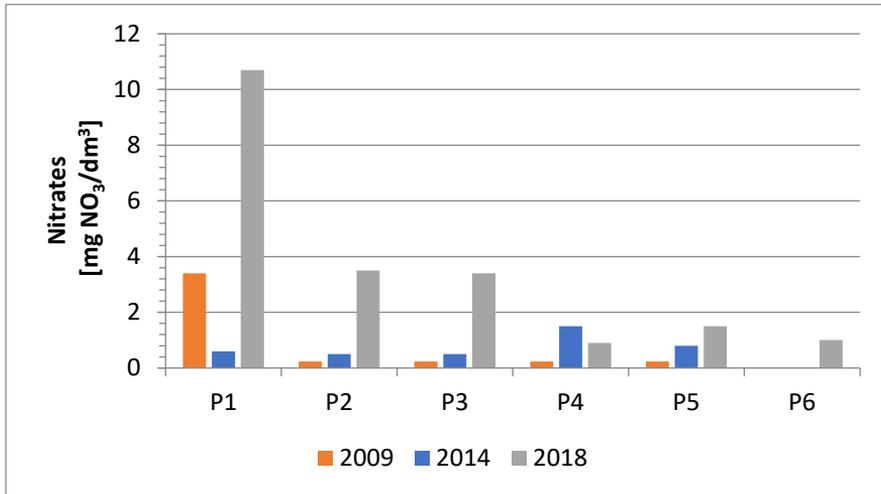


Fig. 10. Concentration of nitrates in the sampling sites

Area of disposed wastes and degraded water reservoirs in Bytom presents interesting, but not typical area, where surface water has been tested. In the literature (Pluta 2004, Labus & Skoczyńska 2013, Twardowska et al. 1988, Szczepańska 1990, Wiggering & Kerth 1991) the problem of contamination of surface water in post mining areas is limited to waste dumps or considers regions of open-pit exploitation (Cała, Bismarck & Illig 2014). Only one position of literature describes similar study area, but in different period of time (Gawor & Lutyńska 2015). A part of results which can be compared is presence of chlorides and sulphates in surface water, what is typical for coal mining wastes and geochemical processes occurring in these wastes. The values of mentioned chemical compounds are higher in similar mining areas like e.g. Ruhr Basin (Wiggering & Kerth 1991, Melchers, Westermann & Reker 2020).

5. Summary and conclusions

Area of disposed wastes and degraded water reservoirs in Bytom represent interesting and valuable terrain having though high degree of anthropogenic pressure and implicating environmental problems. To the most important problems belong negative impact of disposed on the land's surface wastes and the issue of surface water protection.

In 2009 there was done a complex technical and biological reclamation. There was done an inventarization and classification of wastes (stored on the land's surface and in the water reservoirs), which have been removed, what have had a key influence on the improvement of surface water of investigated area. The analysis and evaluation of complex reclamation including surface water quality has been done after 10 years. The results are positive and it should be outlined the complexity of environmental issues, which required interdisciplinary knowledge on project and reclamation stages.

In the first five years no significant improvement of water quality has been observed (Gawor & Lutyńska 2015). In the majority of collected samples the permissible concentrations of chlorides and sulphates were high and exceeded. On this basis, it seems that the waste dumps located in the analysed area have not been completely leached yet, which causes additional pollution and the migration of pollutants to the surface water. It can be assumed that the self-purification processes occurring in the aquatic environment are so slow, that they do not lead to perceptibly natural elimination of the pollutants.

After 10 years since finishing the reclamation the anions were dominated by chlorides, the sodium proved to be the dominating cation, the examined water samples were characterised by high concentration of sulphates. In all analysed reservoirs, permissible concentrations of chlorides and sulphates were exceeded. This may be caused by presence of coal mining wastes in the northern part of study area. Although a part of this wastes has been removed (lying in the direct vicinity of the pond), the other part of the dump still exists and precipitation water infiltrates through waste material.

In all sample points there was observed a decrease of pH value in long term period, the concentration of chlorides lowered, however concentrations of sulphates increased in the majority of sampling points.

Comparing analysed project with numerous similar projects in the area of the Upper Silesian Coal Basin it should be outlined that it represents one of the most interesting realizations concerning both the complexity and effective management of the terrain.

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