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JOURNAL OF SUSTAINABLE MINING

# Identification of hazards for water environment in the Upper Silesian Coal Basin caused by the discharge of salt mine water containing particularly harmful substances and radionuclides

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ARTICLE INFO

*Article history:*
Received 10 December 2015
Received in revised form
22 January 2016
Accepted 25 January 2016
Available online 8 February 2016

*Keywords:*
Mine drainage
Pressure on water bodies
Radionuclides
Particularly harmful substances
Bioindication

ABSTRACT

The Upper Silesian urban-industrial agglomeration is one of the most industrialized areas in Europe. The intense industrialization should be attributed mostly to the presence of coal and other minerals deposits and its extraction. Mining areas of hard coal mines comprise approximately 25% of the total catchment area of watercourses in the area of Upper Silesian Coal Basin, including the river basin of the Upper Oder River and the Little Vistula River. The mining, its scope and depth, duration of mining works, extraction systems being used and the total volume of the drainage fundamentally affect the conditions of groundwater and surface water in the studied area. In this paper, an overall characteristics of the coal mining industry in the area of USCB was made, including the issues of its influence on water environment in the light of the requirements of the Water Framework Directive (WFD) and its guidelines transposed into Polish law. An analysis of the collected data, obtained from collieries, relating to the quantity and quality of water flowing into the workings and discharged to surface watercourses, was performed. An approach to the requirements for wastewater discharge into the environment by these enterprises was presented regarding the physicochemical parameters, possible harmful substances and radionuclides measured in mine waters. The main goal of the paper is to recognize the condition of surface water bodies in the area of Upper Silesian Coal Basin and to make the assessment of the biological condition using Ecological Risk Assessment and bioindication methods.


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Peer review under responsibility of Central Mining Institute in Katowice.
http://dx.doi.org/10.1016/j.jsm.2016.01.001

## 1. Introduction

Upper Silesian Coal Basin (USCB) with an area of 7500 $km^2$, including 5500 $km^2$ within Poland, is one of the largest mining areas in Europe in terms of mineral resources, especially hard coal (Różkowski, 2004). The development of mining in the Upper Silesian Coal Basin on an industrial scale was visible at the turn of 18th and 19th century. The oldest coal mines were "Murcki" (at present hard coal mine "Murcki-Staszic" and the "Boże Dary" mining zone), where the start of mining was estimated even at 1657, "Wawel" Colliery from 1752 (part of hard coal mine "Pokój"), "Reden" from 1785 (part of the former hard coal mine "Paryż") and the former hard coal mine "Siemianowice" from 1786. Mining areas of hard coal mines are grouped essentially in two main districts: the Upper Silesian and Rybnik District. Initially, the exploitation of coal seams was carried out exclusively at the outcrop areas with open-pit and underground system in the north-eastern part of the basin, above the water table of underground water. Then, after their exploitation and with the advances in mining technology, parts of deeper coal seams were started to be exploited in the area of watered rock mass (Różkowski, 2004). The most intensive exploitation of the USCB has been performed in the 70s–90s of 20th century, when coal production reached about 140 million tons per year (http://stat.gov.pl/statystyka-miedzynarodowa/porownania-miedzynarodowe/tablice-o-krajach-wedlug-tematow/przemysl-i-budownictwo/) access on 09/10/2014). In 1993, the restructuring of the mining industry in Poland and adaptation of this branch of industry to market economy conditions, was started. It was connected with the processes of the merging or liquidation of mines and ownership changes, which was caused by the economic results, i.e. the so-called unprofitability of mines or running out of mineral resources. Currently, the annual productivity in the Upper Silesian Coal Basin is at around 76.5 million tonnes per year (http://stat.gov.pl/statystyka-miedzynarodowa/porownania-miedzynarodowe/tablice-o-krajach-wedlug-tematow/przemysl-i-budownictwo/, access on 09/10/2014). The process of liquidation and reduction of coal mining is important in relation to the pressure on water environment since it turned out that drainage of the abandoned mine workings is still necessary for the security of neighbouring deposits in the mines still performing the exploitation of coal.

In recent years, there is a visible phenomenon of returning to coal extraction in some mining areas and formerly abandoned mines, moreover new licenses are issued for prospecting and exploration of coal deposits in the USCB. According to the Ministry of Environment (List of licences for searching, exploration and mining of hard coal deposits in Poland www.mos.gov.pl, access on 01.12.2014), the number of issued licenses for searching and exploration of coal deposits in the USCB as of 1st December 2014 is 34, while the number of currently existing licenses for coal extraction is 63. This information is not irrelevant in terms of the influence of mining on the water environment in the Upper Silesian Coal Basin, particularly with regard to time horizons specified in the Polish regulations and the Water Framework Directive (Directive 2000/60/EC), i.e. the planning periods of water management in 2015, 2021 and 2027. The continuation of coal mining, the resumption of exploitation in the abandoned mines, or a construction of new collieries are connected with inevitable drainage of underground aquifers and the discharge of mine water to surface watercourses. The pressure on the water environment will not stop even in the case of liquidation of mines due to the necessity of their drainage to protect neighbouring workings of active collieries against the water hazard. The authors of this paper, however, are far from creating scenarios for the development or reduction of coal mining in the region, because from the point of view of the pressure on the water environment, these two processes are of equal importance.

Fig. 1 shows the mining areas of active and liquidated coal mines (according to the data obtained from the last license) in the Upper Silesian Coal Basin.

In the Upper Silesian Coal Basin, in line with the proposed division, 16 mines (or mining zones) do not carry out the dewatering, and 49 (active and abandoned but still being drained) discharges mine water to the environment, i.e. bodies of surface water which are therefore subject to the pressures on the ecological and physiochemical condition and change of hydrological regime. The purpose of the study presented in this paper is to prepare basement monitoring data about mine water (chemistry parameters and concentrations of radionuclides) in relation to preliminary assessment of the biological condition of water bodies using Ecological Risk Assessment and bioindication methods.

## 2. Research methods

Changes in physicochemical parameters and chemical characteristics of mine water because of its origin (Kleczkowski & Wilk, 1964; Pluta, 2002), the first classification of mine water for its suitability for development (Bromek & Żmij, 1992) and the total content of chloride and sulphate ions due to the possibility of their utilization (Budaszewski, 1964; Magdziorz, 1993; Marchacz, Malinowski, Orczyk, & Sieradzki, 1966; Pluta, 2004; Rogoż, 1997), have already been started in the 60s of the last century and reported in the scientific literature of Polish researchers. The dependence of physiochemical parameters on the depth from which water is pumped (Cowart, 1981; Dickson, 1985; Moise, Starinsky, Katz, & Kolodny, 2000; Wiegand & Feige, 2002; Różkowski, 2006), changes in water chemistry due to flooding of inactive workings (Gzyl, Banks, 2007; Pluta, 2004), the age of mine waters from different geological formations (Pluta, 2007) were examined by numerous authors. The results of their investigations have been published in the period from the post-war years, showing the development of hydrogeological and hydro-geochemical (Różkowski, 2004; Różkowski, Pacholewski, & Witkowski, 2005) studies in the Upper Silesia. Increase in the intensity of hard coal mining and its impact on the environment was reflected also in the scientific research related to the regional issues as determination of resources and water quality (Adamczyk, 1999), the interpretation of threat and protection of utility water (Adamczyk & Haładus, 1994) and the impact of salty water on these

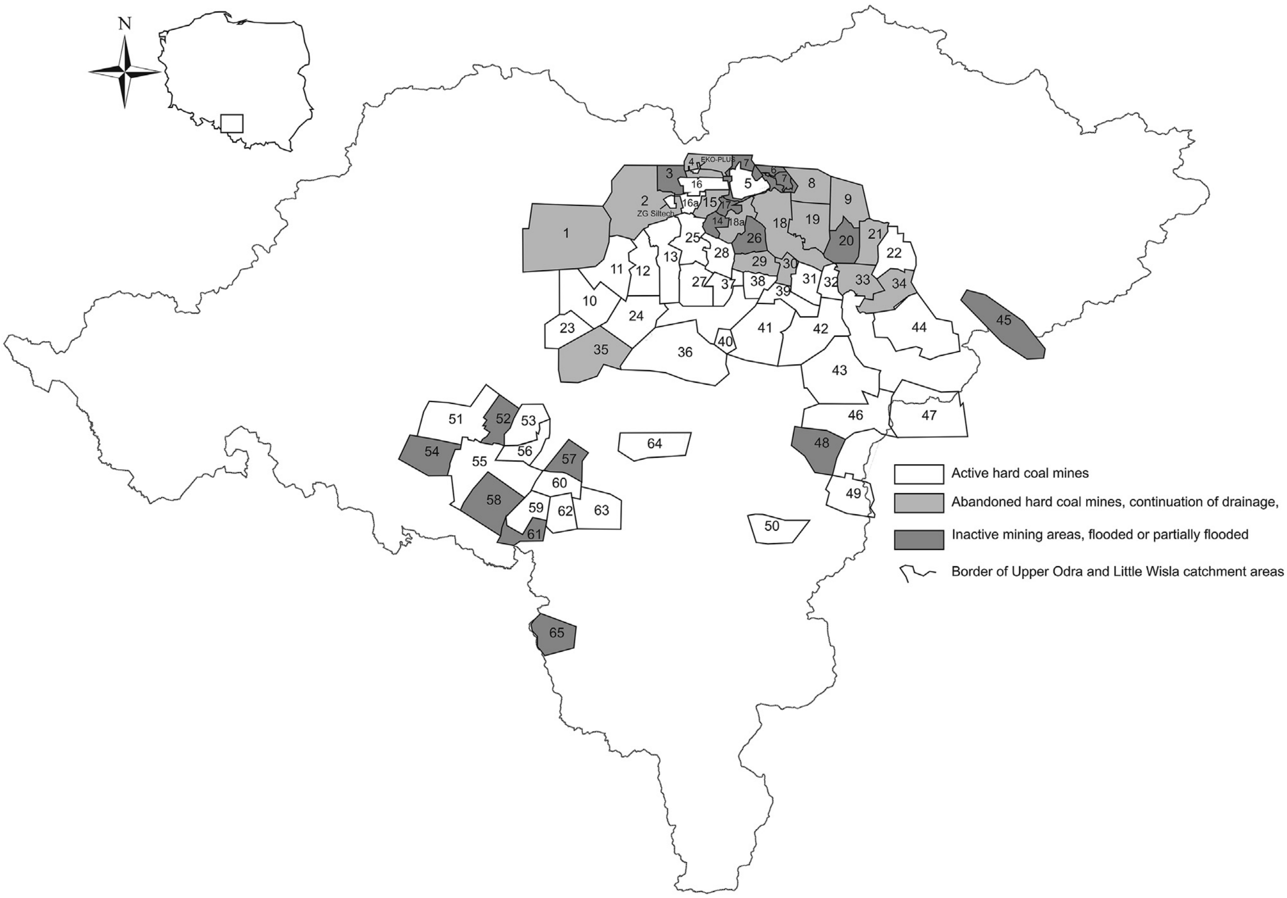


**Fig. 1 – Mining areas of hard coal mines in the Upper Silesian Coal Basin showing active mines, abandoned collieries with a continuation of drainage and totally abandoned, being flooded or partially flooded (Register of mining areas, http://geoportal.pgi.gov.pl/portal/page/portal/MIDASGIS/start, access on 1.12.2014). 1 – Region of Gliwice SRK S.A., 2 – Region of Pstrowski SRK S.A., 3 – Region of Miechowice SRK S.A., 4 – Region of Powstańców Śl. – Bytom I SRK S.A., 5 – hard coal mine Piekary KW S.A., 6 – Region of Jowisz SRK S.A., 7 – Liquidated hard coal mine Andaluzja, 8 – Region of Grodziec SRK S.A., 9 – Region of Paryż SRK S.A., 10 – hard coal mine Knurów Szczygłowice Movement Knurów JSW S.A., 11- hard coal mine Sośnica – Makoszowy Movement Sośnica KW S.A., 12- hard coal mine Sośnica-Makoszowy Movement Makoszowy KW S.A., 13 – hard coal mine Bielszowice KW S.A., 14 – liquidated hard coal mine Wawel, 15 – Region of Szombierki SRK S.A., 16 – hard coal mine Bobrek-Centrum movement Bobrek KW S.A., 17 – liquidated hard coal mine Rozbark SRK S.A., 18 – Region of Siemianowice pumping station Siemianowice SRK S.A.,18a – Region of Siemianowice pumping station Barbara Chorzów SRK S.A., 19 – Region of Saturn SRK S.A., 20 – Region of Sosnowiec SRK S.A., 21 – Region of Porąbka Klimontów SRK S.A., 22 – hard coal mine Kazimierz Juliusz SRK S.A., 23 – hard coal mine Knurów Szczygłowice movement Szczygłowice JSW S.A., 24 – hard coal mine Budryk JSW S.A., 25 – hard coal mine Pokój KW S.A., 26 – liquidated hard coal mine Polska, 27 – hard coal mine Halemba Wirek Movement Halemba KW S.A., 28 – hard coal mine Halemba Wirek movement Wirek KW S.A., 29 – Region of Kleofas SRK S.A., 30 – Region of Katowice SRK S.A., 31 – hard coal mine Wieczorek KHW S.A., 32 – hard coal mine Mysłowice-Wesoła movement Mysłowice KHW S.A., 33 – Region of Niwka Modrzejów SRK S.A., 34 – Region of Jan Kanty SRK S.A., 35 – Region of Dębieńsko SRK S.A., 36 – hard coal mine Bolesław Śmiały KW S.A., 37 – hard coal mine Wujek movement Śląsk KHW S.A., 38 – hard coal mine Wujek movement Wujek KHW S.A., 39 – hard coal mine Murcki-Staszic movement Staszic KHW S.A., 40 – experimental mine Barbara GIG, 41 – hard coal mine Murcki-Staszic movement Boże Dary KHW S.A., 42 – hard coal mine Mysłowice-Wesoła movement Wesoła KHW S.A., 43 – hard coal mine Ziemowit KW S.A., 44 – ZG Sobieski Tauron Wydobycie S.A., 45 – liquidated hard coal mine Siersza SRK S.A., 46 – hard coal mine Piast KW S.A., 47 – ZG Janina Tauron Wydobycie S.A., 48 – liquidated hard coal mine Czeczott KW S.A., 49 – hard coal mine Brzeszcze KW S.A., 50 – hard coal mine Silesia PG Silesia, 51 – hard coal mine Rydułtowy Anna Movement Rydułtowy KW S.A., 52 – liquidated hard coal mine Rymer KW S.A., 53 – hard coal mine Chwałowice KW S.A., 54 – hard coal mine Rydułtowy Anna Movement Anna KW S.A., 55 – hard coal mine Marcel KW S.A., 56 – hard coal mine Jankowice KW S.A., 57 – liquidated hard coal mine Żory SRK S.A., 58 – liquidated hard coal mine 1 Maja SRK S.A., 59 – hard coal mine Borynia-Zofiówka-Jastrzębie Movement JAS-MOS JSW S.A., 60 – hard coal mine Borynia-Zofiówka-Jastrzębie Movement Borynia JSW S.A., 61 – hard coal mine JAS-MOS liquidated movement Moszczenica SRK S.A., 62 – hard coal mine Borynia-Zofiówka-Jastrzębie movement Zofiówka JSW S.A., 63 – hard coal mine Pniówek JSW S.A., 64 – hard coal mine Krupiński JSW S.A., 65- liquidated hard coal mine Morcinek SRK S.A.).**

resources (Chmura & Różkowski, 1998). Other investigated issues were as follows:

- The effect of mining on the hydromorphology of watercourses in the area of Upper Silesian Coal Basin (Czaja, 2005);
- The water table level of underground water (Cempiel, 1997);
- Methodology of analytical determinations of water parameters, including mine waters (Witczak & Adamczyk, 1995);
- The development of methods for hydro-geochemical processes modelling in the Upper Silesian Coal Basin (Gzyl & Banks, 2007);
- The issue of the impact of salty mine water on underground water reservoirs (Adamczyk & Haładus, 1994, de Jesus, 1984);
- Salty water treatment technologies in mine workings (Adamczyk, Haładus, Szczepański, & Zdechlik, 2000; Budaszewski, 1964; Buła, Chmura, Jureczka, Różkowski, & Wagner, 1994; Kleczkowski & Wilk, 1962; Rogoż, 1997);
- The formation of acid mine waters in liquidated gobs and flooded mines (Razowska-Jaworek & Pluta 2005, Fernandes & Franklin, 2002);
- The dewatering method of liquidated mines (Centeno, Lee, & Faure, 2001, Adamczyk et al., 2000);
- Water capacity of rock mass with the aspects of the water hazard (Bukowski, 2000);
- Reconstruction of hydrographic conditions in isolated and flooded mines (Czop, Motyka, & Szuwarzyński, 2005).

So what aspects of the environmental impact of water drainage of hard coal mines can still be the subject of the research? Is an innovative approach still viable in the area where surface waters are affected due to the pressures of drainage waters? The answer to these questions is primarily dictated by the upcoming period of planning update in water management, forced by the EU legislation in the field of water protection policy, implemented into Polish legislation.

The environmental objectives are set out in Art. 4 of Water Framework Directive (Directive 2000/60/EC), which is an essential article of this Directive. They give guidelines for a long-term, sustainable water management based on a high level of water environment protection. In the Art. 4 par. 1, the overall objective of WFD is set out, which is to be achieved by 2015 with respect to all parts of the surface water and groundwater, and also the principle of preventing any further deterioration of its condition was introduced. Then, a number of exemptions from the general objectives was established that allow less stringent objectives, to be prolonged in time beyond 2015, or until the implementation of new solutions, allowing to achieve a certain set of conditions.

The Water Framework Directive requires that good condition or ecological potential within a specified time limit should be achievable for water. Criteria of reference conditions (and ecological potential) are provided directly by the WFD, for the three groups of quality elements: biological (phytoplancton, macrophytes, phytobenthos and benthic invertebrate fauna) as a primary element, the second group of hydromorphological conditions (hydrological regime, the continuity of river, morphological conditions) and finally physicochemical and chemical (general conditions, specific synthetic pollutants, certain non-synthetic pollutants including salinity, priority substances) as the supporting elements.

So far, the assessment of the impact of the mine water on surface water was based on the indicators characterizing salinity, namely: chlorides and sulphates. These indicators are characteristic for mine waters, while it is a standard that they are always determined as part of the monitoring of surface water bodies. The salinity of surface waters which act as receivers of salty mine water is not the decisive factor influencing the state of their ecosystems. Polish Environmental Monitoring Agency since 2010 only (Reports on the state of the environment in the Silesian province, 2004 http://wios.katowice.gov.pl) has changed its scope and included biological indicator of watercourses state (body of surface water) in the selected points of catchment area of the Upper Oder River and the Vistula Little River.

## 3. The monitoring results of mine water quality

The monitoring of the water environment is required not only in the vicinity of active mines carrying out the exploitation of minerals and a result draining the rock mass, but also in the vicinity of mines carrying out the drainage of inactive mine workings in order to protect against water hazard of adjacent mineral deposits and even in cases when drainage is not carried out from abandoned mining plants in the region of which the extraction was completed. In the case of mines that use surface water for a specific purposes, the aim and scope of the monitoring is established by the authority competent to issue a water use permit. As part of this study, an analysis of data from the monitoring of the quality and quantity of mine water discharged into the environment was done for mines extracting hard coal and carrying out drainage and for abandoned mines where drainage is done to protect neighbouring mineral deposits against water hazard. The data from the monitoring of mine water quality and quantity was provided by six mines operating in the Upper Silesian Coal Basin. The decade of 2004–2014 was taken into consideration and the range of the determined parameters was analysed primarily with particular attention to the determination of particularly hazardous substances and radioactive nuclides.

Mines monitoring systems of the quantity and quality of water from drainage and discharged to the environment, is limited to the content of substances characteristic for the wastewater, i.e. the concentrations of chloride and sulphate ions and the content of total suspended solids. The remaining parameters listed in Table 1 of the maximum permissible concentration values for wastewater discharged into water or ground (Regulation of the Minister of the Environment of 18 November 2014 on the conditions that must be met during disposal of waste into water or ground) are not monitored or the access to these data is difficult or impossible. Table 1 presents a list indicating the number of mines monitoring different parameters in waters discharged to the environment with different frequency. Information was based on the frequency of performed determinations and was compiled on

**Table 1 – The frequency of physical and chemical analyses of mine water discharged to the environment with the division of the range of measured indicators.**

| Frequency of carrying out determinations | The range of determinations in mining waters discharged to the environment | | | |
|---|---|---|---|---|
| | $Cl^-$,$SO_4^{2-}$, total suspended solids | $Cl^-$,$SO_4^{2-}$, total suspended solids, total Fe | Ions, main nitrogen forms, heavy metals Pb, Zn, Cd, Cu, Cr, Ni, Fe, Mn, pH, total mineralization | Isotopes $^{226}Ra$ and $^{228}Ra$ |
| 1 per month | 4 | – | – | – |
| 1 per two months | 45 | 4 | – | 5 |
| 1 per six months | – | – | 15 | 5 |
| 1 per year | – | – | 30 | 39 |

the basis of the available collected data from particular coal mines.

The Table shows, that in accordance with the provisions defining the conditions of discharging waste into the water or ground (Regulation of the Minister of the Environment of 18th November 2014 on the conditions that must be met during placing waste in water or ground), mines usually carry out monitoring in the minimum obligatory range. In the predominant number of mining plants, physicochemical analyses of mine water discharged to the environment are performed with a frequency once per year. Considering the group of particularly dangerous substances, apart from cadmium content in mine waters, the content of mercury is occasionally determined. With a frequency of once per every two months, the basic monitoring of the quality of water discharged into the environment has been extended to determine the content of general iron and it refers to the four abandoned mines carrying out drainage along with systematic raising of the water table in the mine gobs (monitoring of acid mine water with high iron and sulphates content). The content of radium nuclides in the water discharged into water sheds are generally determined once a year.

Groundwater monitoring in hard coal mines is done by mining hydrogeologists and involves measuring the amount of water flowing into the mine workings and its quality at selected points. The methods and scope of monitoring of groundwater are determined in the hydrogeological documentation, prepared in connection with the proposed drainage following the mineral extraction from the deposit. The documentation must be approved by written notification, and in the recent period get the legal status by the approval decision of the Minister of the Environment. Types of hydrogeological documentation and its content (including the methods of carrying out monitoring) are set out in the relevant provisions regarding these documents and their content. The monitoring should be done in sampling points chosen by the mine hydrogeologist, in which the flow of water into the workings is constant and it is possible to measure its intensity. They are measured with a frequency twice a year, and water chemistry is determined once a year in each point, basically the key parameters of water quality are monitored (most important ions, total dissolved solids concentration, pH, total suspended solids, heavy metals, nitrogen forms). The availability of data and the need for its transmission for instance to environmental authorities is usually not indicated in the respective decisions (e.g. the notification or the decision to approve the hydrogeological documentation). This is important in the case of information on the state of underground water in the area of closed down plants, where mining was ceased, and the drainage is not carried out.

In the case of a mines carrying drainage of abandoned workings to protect adjacent mineral deposits against water hazard (SRK S.A. CZOK), the monitoring is carried out as one of the main tasks of the entity responsible for its implementation. The purpose of this monitoring is to determine the status of groundwater in the area of abandoned mine, in order to ensure the safety of the mining plant, safety of the neighbouring mines and environmental protection.

On the basis of the relevant regulations (Regulation of the Minister of Economy of 28.06.2002 on occupational health and safety, traffic management and specialized fire protection in underground mines), mines are obliged to monitor the status of the groundwater. The geological survey service performs sampling of the mine water and evaluate its balance on the basis of measurements, performed at least 2 times a year. The analyses of the chemical variability of waters flowing into the mine workings are performed annually, also the requirement to conduct measurements of the radium isotopes concentrations in the water and sediment is needed, if the concentration of radium in the water is higher than 1 $kBq/m^3$. Identification of threats to the water environment for surface water bodies in the USCB is impeded due to lack of the systematic monitoring of the quality of discharged waters, besides chlorides, sulphates and mechanical suspension. The concentrations of substances that are particularly harmful in the majority of cases are below the detection limits of applied methods, or their concentrations are not exceeding the permissible level (Regulation of the Minister of Environment of 18th November 2014 on the conditions that must be met during placing waste in water or ground).

## 4. Discussion on the proposed approach of bioindicative method application to assess the impact of mine water on the state of surface water bodies in the area of USCB

For the identification of the hazard for water environment in the Upper Silesian Coal Basin, a following approach is proposed, based on the individual assessment with regard to the possibility of achieving a good state or the potential by the part of surface water body in consideration. This approach can be useful to assessment of the status of surface water bodies in the study area and the impact of the discharged mine water. The guidelines of Water Framework Directive (Directive 2000/60/EC) indicate the need that the receiver i.e. watercourse should be kept in a good conditions (biological and chemical – supportively). Permissible levels of harmful elements, indicating the maximum values of impurities in wastewaters, discharged into the environment, should be considered as supportive ones, with the assessment of clear individual influence. The impact of discharged mine water on the water quality of the receiver to date was treated rather marginally. The decisions on special use of water by mines indicated the limit values of impurities (chlorides and sulphates) as important for the quality of discharged waste at the representative sampling point – i.e. generally at the outflow of the mine waters into the environment. This paper proposes an approach consisting in the individual assessment of the impact of discharged mine water on the water quality in the receiver. Preferably the state of surface water body should be evaluated primarily on the basis of biological indicators, contents of particularly harmful substances in the discharged wastewater, additionally in specific cases analysis of the content of radionuclides in water and river deposit should be done (Gott & Hill, 1953; Gans, 1981; Tomza & Lebecka, 1981; Kolb & Wojcik, 1984; Paridaens & Vanmarcke 2002; Chałupnik, 1996; Chałupnik, Michalik, Wysocka, Skubacz, & Mielnikow, 2000; Jerez Vegueria, Godoy, & Miekeley, 2002; Chałupnik, 2007; Chałupnik & Wysocka, 2003).

Discharge of mine waters into surface waters, despite meeting criteria for permissible emissions of pollutants, can pose a serious threat to the entire ecosystem. Estimation and assessment of the potential effects caused by release of mine water in the receiver, may be performed only by means of the so-called indicator methods which are based on relevant toxicological values (eco-toxicological indicators), obtained from available databases, simulation models or based on results of bioindicative research, carried out either in the *ex-situ* or *in-situ* conditions. Such an approach should enable us to determine the limit values of the concentrations of pollutants, to ensure the environmental safety.

The key activities within the water policy, which the Member States are required to apply due to the Water Framework Directive (Directive 2000/60/EC), is a risk characterization and prediction of potential ecological impacts, which improper management of water resources may cause. These activities are, for example, application of the standard approach of the *Ecological Risk Assessment* (ERA). Such an approach can be used to assess the impact of the mine water on water ecosystems. The individual phases of the Environmental Risk Assessment process will help to estimate the scale of exposure (the value of emissions), quantifiable assessment of the potential effects (environmental consequences), and as a result will allow a full risk characterization, based on which it will be possible to take steps towards its reduction, through the use of appropriate technologies of treatment of mine water.

Bioindication is a method of obtaining biological information about the state of the natural environment with the use of living organisms. A broader definition describes bioindication as a process in which information about the other object or the whole enviromental state is obtained on the basis of qualitative and quantitative changes in one object (bioindicator). The estimation is done, including the biotic and abiotic parameters and taking into account the anthropogenic influence (Szmajda, 1994; Traczewska, 2011; Zimny, 2006). Bioindication methods can be used in impact assessments or forecasting the effects of potential impact on the environment, for almost every sector of the economy.

Biomonitoring is defined as the act of observing and assessing the state and ongoing changes in ecosystems, components of biodiversity and landscape, including the types of natural habitats, populations and species. Bioindication is one of the basic methods of biological monitoring, allowing the determination of the state of the natural environment much more accurately than it is possible to obtain using the physical parameters and chemical analyzes only. The effectiveness of forecasting the state of the ecosystem is the result of natural processes in the living cells, which as a result of exposure to stress factors.

Frequently, the cells are exposed to a complex interaction effects of many chemical and physical factors. Based on the physicochemical parameters of the environment it is difficult to fully predict the reaction of the living structures (organism, population or biocoenosis). Moreover, determining the full spectrum of pollutants, including their metabolites and cometabolism products due to the analitical limitations and economic considerations, it is simply impossible. Therefore it is necessary to complement chemical analyzes with data obtained from biomonitoring. The organisms may accumulate large amounts of toxic compounds, even if their concentration in the environment is low and than it shows a reaction to a toxicant (Walker, Hopkins, Sibly, & Peakal, 2002) in a relatively short time. It is particularly important that the assessment of the toxicity for either a single compound or a mixture of compounds can be carried out taking into account the effect of the synergistic or antagonistic interactions of components. Moreover, it is also taken into consideration that the reaction of the organism can be measured at multiple levels from molecular and cellular through indirect levels, i.e. organism and populations to the whole biocenoses. Bioindication methods are therefore the most effective assessment tool of the adverse effects or prevention of environmental degradation (Załęska-Radziwiłł, 2007).

## 5. Summary and conclusions

Monitoring of the quality of the mine water discharged into the environment is very important from the point of view of ensuring good ecological status of surface waters in all member states of the European Union. Especially important issue is focus on the reduction of volumes of discharged water and wastewater, to mitigate the concentrations of substances classified as priority substances, particularly dangerous for the environment. This problem relates significantly to mine waters, which in addition to its high salinity, are characterized by the presence of heavy metals and radioactive isotopes. The reference method of assessment of the impact of mine water discharged to the water reservoirs to date were based on acceptable limit values for selected groups of pollutants. It should, however, be taken into account that the physicochemical analysis, even the most precise, provides information only on certain levels of contamination and possible exceeding of certain standards. Moreover, even knowing the content of pollutants in the mine water, it is extremely difficult to forecast the impact caused by their migration to the environment. Mine water is a kind of mixture, containing different impurities, and interaction mechanisms of the components present in it, even if they are present in trace amounts, are not fully understood, making it difficult to be predicted. Therefore, the process of environmental risk assessment, carried out for mine waters in respect of surface water is desirable. Only taking into account the reactions of living organisms inhabiting the endangered ecosystem, are we able to assess the potential risks and consequences caused by discharge of mine water into the surface reservoirs. The environmental risk assessment will allow the visualization and the assessment of the hazard, caused by mine waters for waster ecosystems, exposed to their influence and will constitute the basis for further action, for the maintenance or improvement of the current state of surface waters. Aiming to minimize the environmental risk can be achieved through the implementation of appropriate technologies of mine water treatment. The environmental risk assessment conducted as secondary tool, will allow the estimation of the effectiveness of the adopted technology in terms of the environmental safety.

The mines use a number of methods to reduce the impacts of salty water on the aquatic environment. In practice, to mitigate the impact of salty mine water on surface water the following solutions can be applied: geological and mining methods (Adamczyk, Haładus, Szczepański, & Wątor, 1992; Kleczkowski & Wilk 1962), the hydrotechnical method of introducing saline mine water to surface water, desalination of mine water (Rogoż, 1997) including the removal of barium and radium (Chałupnik, 2007), and the utilization of mine water for the plant's own needs. for the production of drinking or technological water (Buła et al. 1994). It should be noted that the methods used are of different importance in relation to the scale of the occurring problem of salty mine water discharged from the active and abandoned coal mines.

The effectiveness of these technologies has not yet been evaluated with respect to the biological elements of water environment, it means with reference to benthic invertebrates, macrophytes and phytobenthos organisms. The current and projected permissible levels of salinity of surface water should be assessed, from the environmental point of view, rather as the sum of chlorides and sulphates concentrations, and not as the concentration of sodium chloride. For water organisms and their groups, more important is the content of individual ions (such as sodium or magnesium cations, and chloride or sulphate anions) having osmotic properties in the environment. In connection with the necessity of discharge saline mine water to surface water from active and abandoned mining plants, in the time horizon beyond 2027, for surface water bodies subjected to pressure of mining, a change of the principle of achieving good condition the establishment of less stringent environmental objectives is needed. The increased content of chlorides and sulphates in the water under the influence of mines does not preclude the achievement of limit values for other indicators of water quality in receivers. Nevertheless, monitoring of these parameters is very valuable and helpful in respect of the estimation of its impact on the aquatic environment, while very desirable will be use a particularly innovative and useful tool for this objective an eco-toxicological analysis using the method of bioindication.

## Acknowledgements

The study was carried out in the Department of Water Protection and the Silesian Centre for Environmental Radiometry of the Central Mining Institute in Katowice, within the framework of the statutory work (no. 11310344-340) in the period 4.01.2014–31.12.2014 and it is an introduction to further research in the use of bioindicative methods of determining the impact of mine waters with high content of salts and radionuclides and hazardous substances on the status of surface water bodies.

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