Evolution of Polish hydrogeology

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A b s t r a c t. In Poland, hydrogeology as a separate scientific discipline came into being at the end of the 19th century. The first geologists were interested in springs, saline, mineralised waters of therapeutic use and dewatering of mines. Until World War I, in the early stages of hydrogeological developments, a different attitude towards groundwater problems was clearly notable in all three annexed Polish territories.

The next stage of the development of Polish hydrogeology is dated to the years 1918–1939. In those times, the major focus of hydrogeological investigations was on building structures to extract artesian groundwater; mineral groundwater in the Polish spas; building municipal water intakes; and on Quaternary aquifers, widespread in Poland. Early hydrogeological handbooks were published at those times. The contemporary stage of Polish hydrogeology started in 1945, after World War II.

In the early 1950s, the Department of Hydrogeology and Engineering Geology was established at the Central Board of Geology (CUG in Polish), which belonged to the Polish government as a separate ministry up to 1970. Hydrogeological companies with technology and development sections were founded in big cities. Nowadays, academic centres exist in Warsaw, Cracow, Wrocław, Gdańsk, Sosnowiec, Poznań, Kielce and Toruń. About 1400 persons with academic diplomas, 160 doctors and 22 professors of hydrogeology are active at present in the field of hydrogeology.

The principal fields of Polish hydrogeology comprise the following: mine dewatering, recognition of groundwater resources and their protection, construction and exploitation of water intakes, hydrogeological cartography, mineral and thermal water resources, regional hydrogeology for physical planning, groundwater modelling and groundwater pollution, migration of pollutants and forecasting of groundwater changes. Up to the late eighties, political censorship was the main difficulty for the development of Polish hydrogeology, especially in publications related to sensitive information of groundwater occurrence and resources.

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The selection of major achievements of Polish hydrogeology chosen for this publication includes primarily research hydrogeology, which, however, is exercised with a practical use also. The article is based on materials published previously by A.S. Kleczkowski & A. Sadurski (1999) and B. Paczyński & A. Sadurski (2007). Information from archival sources, private practitioners and the administration was included to a limited degree.

It is accepted that the origins of Polish hydrogeology are closely related to investigations on searching and defining brines and therapeutic waters, which had started in the 17th century, and dynamically developed after the first partition of Poland in 1772, when salt mines in Wieliczka and Bochnia fell within the Austrian territory.

In the 19th century, more precise analyses of mineral waters, especially from the Carpathian Mts. and the Sudetes, became more common. It can be assumed that one of the first such analyses was made by B. Hacquet at the end of the 18th century, for the main spring source of Krynica. Hydrogeology of mineral waters developed earlier than hydrogeology of freshwater. In contrast to springs, groundwater resources were not usually described in regional geological descriptions of the 19th century. In the years 1844–1845, articles by L. Zejszner and J.B. Pusz (J.G. Pusch) regarding the temperature of springs in regions of the Tatras and Warsaw were published in annual publications of the Warsaw Library.

Polish hydrogeology flourished eventually at the turn of the 19th and 20th centuries and this is closely linked to the construction of waterworks in big cities. Works on constructing groundwater supplies are documented in publications by J. Niedźwiedzki, E. Romer, R. Ingarden and S. Zaręczny. In 1906–1908 R. Rosłoński published his first works on a mathematical description of groundwater flow. Polish groundwater terminology that was introduced in that period, including very early terms of *hydrogeology* and *hydrogeological*, have been used consistently in subsequent periods. An early example of Polish hydrogeological publications is a book by N.I. Krisztafowicz, dated 1902, describing groundwater in the vicinity of Lublin city.

At the turn of the 19th and 20th centuries, there were numerous Polish drilling companies in Poland which cooperated closely with geological enterprises, e.g. the *Technical Office* of engineer Rychłowski, *Wehr & Co.* founded

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in 1894 in Warsaw or the *Office of Drilling and Mining M. Łempicki & Co.* based in Sosnowiec. Another Polish company constructing dug and bored wells, owned by J. Kopczyński, was established in Poznań in 1893.

Development of the industry at the end of the 19th century resulted in increased needs for groundwater supplies. At the same time, well drilling methods were developing very quickly allowing the extraction of waters from depths reaching 200–300 m. Deep groundwater supplies were located mainly in zones of regional drainage, i.e. in large river valleys, where artesian wells were providing a discharge of > 200 m^3/h. Hydrogeological studies of that time were very limited and provided descriptions of (mainly) geological profiles, pumping test data and chemical signatures, which can be found in works by J. Łempicki, R. Rosłoński and B. Rychłowski. The first manuals, regional syntheses and studies on mineral, therapeutic and mining waters started to appear only in the interwar period and were written by J. Lewiński, J. Samsonowicz, K. Pomianowski et al. (1934) and R. Rosłoński (1908, 1928).

In 1919, by the law of the Polish Parliament, the Polish Geological Institute was established, which acted as the Polish geological survey. In its structure, the Hydrogeology Division was established and this was organised and led by R. Rosłoński for over 10 years. The first hydrogeological cartography works started then and by World War II, the first sheets of the hydrogeological map of Poland in 1: 300 000 scale were completed (Paczyński & Sadurski, 2007).

Development of Polish hydrogeology

The 1939–1945 war period brought to Poland enormous damage, in both a material and a human sense. The geographical positioning of the State and its political organisation changed. Between 1945 and 1950, the major focus of the State was on reconstructing the country after the war. The Polish Geological Institute resumed its operations and opened two divisions: the Hydrogeology Department and the Geological Engineering Department. Universities reopened their doors. The State took control over geological and drilling companies.

The development of a national database of natural resources became a focal economic task for the country. In response to that, in 1951, a decree regarding the Polish geological survey was delivered, which subsequently led to the formation of the Central Board of Geology in 1952 (CUG in Polish). Within the CUG, the Department of Hydrogeology and Engineering Geology was created and in 1955, the Committee for Hydrogeological Documentation was established. In general, the geological administration played a very important role by its legislative and control activities as well as by financing the hydrogeological research and publications.

However, under the communistic regime and during „cold war" period, hydrogeologists in Poland faced a huge problem with censorship. A famous monograph of Kleczkowski (1979) titled *Hydrogeological conditions of the territories surrounding Poland* had been, for a long time, the main source of knowledge about Polish hydrogeology. The exclusion of Poland in this work resulted from the fact that the censorhip eliminated publishing of most regional hydrogeological studies of Poland during 40 years up to 1991.

Reactivation of the Polish geological survey is related also to the reorganisation of higher education in the field of geology, which happened in 1951, following a concept by A. Bolewski. In addition to already existing faculties of geology at the universities of Warsaw, Cracow and Wrocław and at the Mining and Metallurgy Academy (AGH in Polish) in Cracow, a new Department of Technical Geology with a specialisation in hydrogeology and engineering geology was created at the Gdańsk University of Technology, Faculty of Civil Engineering. The department was organised and managed by Z. Pazdro. Hydrogeological training was later transferred to the University of Warsaw, Faculty of Geology, to which Z. Pazdro moved. In 1945–1948, lectures at the faculty, including hydrogeology, were given by F.Z. Rutkowski. In 1954, a hydrogeology division was created within the department and this was run by J. Gołąb. Warsaw became an important academic centre for hydrogeological teaching and research.

The second hydrogeological centre existed in Cracow at AGH, where R. Krajewski taught hydrogeology at the Faculty of Mining Geology from 1945. The main focus of the AGH teaching and research programme was firmly associated with hydrogeology of deposits and dewatering of mines.

In the Polish Geological Institute, the Hydrogeology Department was led by F.Z. Rutkowski from 1948. The division was involved in numerous projects and expertise for constructing and managing natural resources. Above that, the PGI worked on archiving data such as drilling materials, geological profiling data and borehole information, mainly from wells, gathered after the war. In 1957, the PGI began publishing double-charted hydrogeological maps of Poland in 1: 300 000 scale, which were created and edited by C. Kolago (1955, 1956, 1970). He worked on hydrogeological cartography for over 30 years and greatly contributed to its development. Sheets covering the entire country were available in 1964.

As a result of the already mentioned decree regarding the Polish geological survey, the structure of geological and drilling companies was reorganised in Poland. Each ministry, according to their needs, could form their own enterprises, several of which were groundwater drilling companies. Among others, there were drilling companies established by the ministries of agriculture, civil engineering, municipal economy and the ministry of health, in which a company called *Balneoprojekt*, devoted to exploring therapeutic waters, was created. Enterprises governed by the Ministry of Mining and the Chemical Industry worked on hydrogeological problems associated with the construction and operation of mines.

In response to that, there was an increased demand for groundwater specialists. In the late 50s there were, approximately, 300 hydrogeological professionals, who had graduated mainly from the AGH in Cracow, Faculties of Geology at the University of Warsaw, the Gdańsk University of Technology and the University of Wrocław. These colleges ran either hydrogeological or engineering geology specialisations or allowed students to prepare their master theses in these fields.

The following legislative moves were very conducive to the development of Polish hydrogeology. In 1957, the

president of the Central Board of Geology (CUG) issued a decree which obliged all hydrogeological professionals to design projects of *geological works* prior to their execution. Since then, any construction of a well or any studies on groundwater properties have had to be firstly designed and then sent for evaluation and approval by the office. The Geology Act of 1960 strengthened the role of hydrogeology by binding the degree of probability of groundwater identification with financing of an investment.

An obvious improvement of Polish hydrogeology occurred between 1960 and 1980, and this is, to a certain degree, correlated to undertaking thousands of well and borehole drillings, which were systematically improving hydrogeological identification of groundwater resources as well as forcing professionals to develop new and modern technologies. To do so, the CUG created a Geological Technology and Technical Development Centre (named OBRTG in Polish), whose aim was to develop and implement new research and engineering technologies. New economic conditions and needs for researching the regional groundwater resources appeared. Studies on the chemical signature and the origin of groundwater became common. The development of deep and open pit mines required a wide range of hydrogeological field investigations including deep dewatering. In the light of increased extraction rates, sometimes too excessive, a new need for analysing groundwater availability and its protection became important. It was linked to a risk of groundwater pollution from the ground surface, which was also expected to increase. After 1980, aspects of groundwater protection became dominant in Polish hydrogeology (Kleczkowski & Witczak, 1985; Witczak & Adamczyk, 1994, 1995; Krogulec, 2004; Małecki et al., 2006). New hydrogeological studies on the aeration zone (Małecki, 1998) and the age of water (Dowgiałło & Nowicki, 1999) became available. While preparing these various and difficult tasks, teams of experienced hydrogeologists formed in large enterprise centres of Gdańsk, Cracow, Poznań and Warsaw. A special note needs to given to Poznań, where in the research division of the Hydrogeological Enterprise, assessments of groundwater admissive resources were executed in practice by pumping test analyses, in conditions of unknown filtration coefficient. Further, analogue and numerical modelling methods were being applied in analyses of renewable resources (Dąbrowski & Przybyłek, 2005; Szymanko, 1980). The leading hydrogeologist of this hydrogeological centre was Jan Przybyłek, who became a professor of the University of Poznań in the 90s.

A thematic differentiation started to appear within the hydrogeology division at the University of Warsaw. The leader of the division, J. Gołąb focused mainly on hydrogeology of the Podhale province. In the late 60s, he noted a need for identification of rules of groundwater circulation and the age of groundwater. Z. Pazdro, who in 1968 became the head of the division, in 1964 published the first hydrogeology handbook in Poland titled *General Hydrogeology*, with the latest edition of the book being published together with B. Kozerski in 1990. He researched groundwater saline intrusion in the region of the Polish Lowlands and the regional hydrogeology of Gdańsk province. From 1956 to 1974, Z. Pazdro was a chairman of the Commission of Hydrogeological Documentation. His teaching, research and management activities greatly influenced the development of Polish hydrogeology, for which he is considered to be the creator of modern Polish hydrogeology.

Alongside the professors mentioned, their students undertook research too. T. Macioszczyk researched regional issues and then moved towards the dynamics of groundwater, and then to analogue and numerical modelling (Macioszczyk, 1969, 1974). Krajewski (1970; Krajewski & Motyka, 1999) dealt with hydrogeology of the Lublin region, properties of fissured bedrocks and methods for assessment of groundwater resources. B. Kozerski (1971) examined dependencies between filtering parameters of Quaternary deposits. D. Małecka (1981) gave her attention to the waters of the Inner Carpathians. and specifically the Podhale region. The genesis of carbon dioxide in Carpathian brine was explained by P. Leśniak (1998). A. Macioszczyk dealt with the groundwater chemistry of water bearing layers of Paleogene and Neogene periods in the region of Polish Lowlands as well as hydrochemical background levels and hydrogeochemical anomalies. In 1987 she published a handbook on hydrogeochemistry and then, together with D. Dobrzyński (2002) and as a contributor and editor of the handbook *Fundamentals of applied hydrogeology* (2006).

In 1980 J. Szymanko presented a concept of the hydrogeological system and a package of the first Polish numerical programs called HYDRYLIB, used for numerical groundwater flow modelling for the evaluation of groundwater resources. Other packages of mass transport programmes ANPLA and ASPAR were developed by J. Michalak (1983, 1997). These programs are still used in Polish hydrogeological practice. Hydrogeological research and teaching at Warsaw University is currently ongoing by the third generation of Polish hydrogeologists.

In the Warsaw centre, J. Dowgiałło researched mineral and thermal waters from different regions of Poland. He had started his work when working for *Balneoprojekt* and continued in the hydrogeology division of the Polish Academy of Sciences. In 1971, he published a study on brines of the West Pomerania region and on the genesis of brines in the Mesozoic strata of the Polish Lowlands. It was the first publication in which isotopic analysis for defining the genesis of water was presented. A very important part of his scientific achievements regards research on thermal waters. He is a co-author of a book titled *Geology of balneological resources*, which was published by Geological Press in 1969. It should be noted that J. Dowgiałło was one of the first Polish hydrogeologists joining the International Association of Hydrogeologists and it is thanks to his efforts that the Polish National Chapter of the IAH was established in 1973. For many years in a row he acted as chairman of the IAH Commission on Mineral and Thermal Waters and, eventually, became its honorary member.

In the Polish Geological Institute, the Hydrogeology Department was run, in different times, by S. Turek, C. Kolago and Z. Płochniewski. Alongside numerous studies prepared to fulfil the needs of the State's economy, other works focused mainly on hydrogeological cartography and on regional studies. Between 1959 and 1972 works focused on establishing groundwater resources for the entire country. Twenty hydrogeological studies were completed whose boundaries usually referred to the bor-

ders of geological units. These works, coordinated by the PGI, were used for developing and then publishing by the PGI, the *Atlas of fresh groundwater resources and their exploitation in Poland* in the scale 1 : 500 000 (Malinowski, 1976). All together, between 1960 and 1980, the PGI published 9 maps in scales from 1: 1 000 000 to l : 2 000 000, including two maps of mineral waters of Poland by C. Kolago and others (1966) and J. Dowgiałło and others (1974). In 1977, the PGI published the *Hydrogeochemical Atlas of Poland* in the scale 1 : 2 000 000, which was initiated and edited by S. Turek. B. Paczyński worked on the hydrogeological regionalisation of Poland, hydrogeological cartography and methods for assessing groundwater resources, which was crowned with the *Hydrogeological Atlas of Poland* (Paczyński, 1993, 1995, 2002, 2003; Paczyński et al., 1999).

Another important achievement of those times was undertaking in 1979 a national groundwater monitoring programme, which included groundwater observations from over 500 measuring sites. Results of this campaign were fully analysed and published (Kazimierski, 2003–2010). Based on the observation network, a national groundwater quality monitoring programme was developed in the 1980s. In 2003, the PGI published the *Map of disposable and prospective groundwater resources in water regions* in a scale of 1 : 500 000 by P. Herbich, Cz. Nowakowski and S. Dąbrowski. In the same year, the PGI developed the *Map of initial valorisation of the major groundwater reservoirs, 1 : 500 000* (Paczyński, 2003). In 1997 a hydrogeological dictionary edited by A.S. Kleczkowski and A. Różkowski came out. The second, expanded edition of the dictionary was published in 2002 edited by J. Dowgiałło, A.S. Kleczkowski, T. Macioszczyk and A. Różkowski.

Teams engaged in the hydrogeological research were active also in regional offices of the Polish Geological Institute. Major hydrogeological achievements were made by hydrogeologists of the Upper Silesian Branch in Sosnowiec, who worked on groundwater resources of the Upper Silesian Coal Basin (USCB) located in their region. Works by A. Różkowski, who managed the team between 1958 and 1986, have special meaning for the operation of the USCB. Results of these works are gathered in numerous publications regarding hydrogeology of the Upper Carboniferous deposits of the USCB and chemistry of the Tertiary sediments in this region (Różkowski & Kowalczyk, 1997; Różkowski, 2000, 2008). In the region of the Lublin Coal Basin (LCB) A. Rożkowski researched groundwater and gas conditions. In 1975 he became a professor of the Silesian University, where he ran the Department of Hydrogeology and Engineering Geology.

An important hydrogeological centre was established in Cracow, at the AGH. Research in mining hydrogeology was developed by Z. Wilk, who worked on developing prognoses of groundwater inflows to mines, impacts of hydrogeological conditions on exploitation of natural deposits, impacts of mining on local hydrogeological conditions and developing hydrogeological methodologies. The achievements and experience of Z. Wilk in mining hydrogeology were acknowledged worldwide and were gathered in a monograph (Wilk, 2003; Wilk & Bocheńska, 2003; Wilk & Kulma, 2004). Hydrogeological research was focused mainly on developing mining operations and dewatering.

In 1961 A.S. Kleczkowski joined the Department of Applied Geology at AGH in Cracow where he focused on hydrogeology. In 1963, in a publication dedicated to the hydrogeology of the Hopei Plateau, he presented results of research he had done in China. In 1979 A.S. Kleczkowski published a well-known study *Hydrogeological conditions of the territories surrounding Poland*. The main focus of Kleczkowski's work concerned groundwater protection from anthropogenic sources. In 1985, together with S. Witczak he proposed a strategy for the protection of the major groundwater basins in Poland (GZWP), which was acknowledged in the national and regional legal planning regulations (Kleczkowski, 1990).

The team of hydrogeologists gathered around the AGH centre undertook numerous research problems. A. Szczepański researched groundwater dynamics and methods for assessing admissible groundwater resources for documenting hydrogeological conditions, estimating inflows and risk assessment of mines and surrounding areas (Pluta & Zuber, 1995; Szczepański, 1999). A. Szczepański (2004) noted that liquidating mines in basin areas poses new challenges and threats of increased inflow to other, still operating mines.

S. Witczak worked on hydrogeological conditions of the Carboniferous rocks and mineral waters in the region of Upper Silesia. He focused on hydrochemistry of groundwater and its protection (Kleczkowski & Witczak, 1985; Witczak & Adamczyk, 1994, 1995). J. Motyka (1988, 1998) worked on hydrogeology of deposition fields, karstic and fissured rock hydrogeology. He placed specific attention on zinc and lead mines and groundwater dynamics of the karst. Groundwater pollution and credibility of groundwater monitoring data were researched by J. Szczepańska (Szczepańska & Kmiecik, 1998, 2005). Her publications of groundwater quality monitoring and the assessment and analyses of monitoring data should be especially noted. An important role in the applicability of isotopes in hydrogeology was played by the Institute of Atomic Research at AGH. Most of the groundwater isotopic analyses were undertaken in their laboratory. A. Zuber played a key role in popularizing the isotopic research due to his methodological publications (1986) and a fruitful cooperation with numerous hydrogeologists.

When talking about the history of Polish hydrogeology, one cannot forget to mention the Wrocław centre, where large hydrogeological companies were established to work on designing coal and copper mines. Many well qualified hydrogeologists worked in those companies. The Department of Hydrogeology at the University of Wrocław was opened in 1970. Before that, hydrogeological research had been carried out there by M. Różycki and J. Bieniewski. Bieniewski's research was focused on groundwater dynamics. His work at the Wrocław University of Technology, Department of Mining concerned the mining of brown coal. At the end of his professional life he worked also as a professor at the University of Wrocław where he ran the Department of Hydrogeology for a short while. In 1980, the position was taken over by T. Bocheńska and later, in 1997 by S. Staśko, whose main research interests were in hydrogeology of the Sudetes (Bocheńska & Staśko, 1997; Staśko, 2002). The University has its own publication called *Acta Universitatis Wratislaviensis*, which includes a special series devoted to hydrogeology. Hydrogeology of

fissured rocks and the karst have been dominating issues published in the series. At the Wrocław University of Technology, the Department of Therapeutic Waters has been operating since 1990, created by W. Ciężkowski.

One cannot omit the activity of A. Wieczysty from the Cracow University of Technology, who worked on the protection of municipal groundwater intakes. In 1970 he published the *Engineering Hydrogeology* handbook.

When in 1972, the Department of Hydrogeology at the Gdańsk University of Technology was reactivated, the major focus of the centre aimed at groundwater resources within the southern Baltic coastal area and the Vistula Delta, researched between 1973–2000 by B. Kozerski and the Gdańsk artesian basin researched by K. Burzyński and A. Sadurski (1990). Hydrogeology of the Baltic coast was researched also by H. Piekarek-Jankowska (1994).

In Poznań, T. Błaszczyk researched groundwater of the Wielkopolska Lowland and together with J. Górski he looked at the changing groundwater quality in response to its exploitation (Górski, 1981). Of great importance are works by hydrogeologists from Poznań on groundwater resources, their protection and water intakes with induced infiltration.

The most impressive achievement of Polish hydrogeology is a digital hydrogeological map of Poland in 1 : 50 000 scale, which consists of 1069 sheets and was prepared in the GIS system with a numerical database structured in the Oracle system. Over 400 professionals worked on the map, which allowed the project to be completed within less than 10 years (Paczyński et al., 1999).

The GIS methods combined with computer graphics for over 20 years have been intensively implemented in hydrogeological research and practice. Digital databases have been created since the mid 70s. The biggest of them have over 130 000 records, for example bank HYDRO run by the PGI, which operates in a professional database system of Oracle. At present, works are focused on integrating numerous databases into one platform, which will include data from hydrogeological, geological and surveying databases.

Among achievements of the hydrogeological cartography, in particular with regard to specialised mapping studies, we should mention the publication by A. Różkowski et al. (1997) regarding useful groundwater aquifers of the USCB region and the *Groundwater Vulnerability Map* by S. Witczak (2005). Groundwater resources with respect to therapeutic and thermal waters have also been well defined (Górecki, 1990; Bojarski, 1996; Paczyński & Płochniewski, 1996).

Polish hydrogeological academic centres

Higher diplomas in geology with a specialisation in hydrogeology became available in Poland over 50 years ago. It can be estimated that there are over 3000 professionals in Poland with such a degree and some 1000 people actively work as hydrogeologists. A number of graduates of other disciplines including IT, physics, geodesy, geophysics or chemistry have collaborated with hydrogeology greatly, which greatly increases skills, experience and research interests. For that reason, the number of specialists employed in Polish hydrogeology may account for some 1200–1300 people.

At present there are eight academic centres where hydrogeology is still developing. The most important of these are Warsaw, Cracow, Poznań, Wrocław and Sosnowiec; however, in the latter two, there are at least two or three scientific institutions (Polish Academy of Sciences, universities, or the PGI's regional branch). There are also academic centres in Gdańsk, Kielce and Toruń. These centres have their own specialisations and specific research fields that they have been developing for many years now. The centre in Warsaw has specialised in hydrogeological cartography and the GIS, national groundwater assessments, isotopic research, groundwater flow modelling and in some aspects of groundwater protection. Cracow has some impressive achievements and became a leading centre with respect to mining hydrogeology, isotopic analyses and prognoses of the chemical changes in groundwater. The dominating role is played here by the AGH. A very dynamic development over the past 15 years has been noted at the University of Poznań, where many research projects on laboratory and field methods as well as groundwater modelling have been undertaken at the Department of Earth Science. Above that, the Department carries out expert assessments for water supply companies. The academic centre of Wrocław is represented mainly by the University of Wrocław, Wrocław University of Technology and companies of CUPRUM and POLTEGOR, where works focus on dewatering of mines. The centre specialises in therapeutic waters and hydrogeology of karst, for example of the Sudetes.

Specialisations in mining hydrogeology and hydrogeology of karst have been opened by the centre in Sosnowiec, in which a high position has been reached by the Department of Hydrogeology and Engineering Geology at the University of Silesia. In Gdańsk, both the University of Gdańsk and the Gdańsk University of Technology as well as the PGI regional branch specialise in aspects of salt and freshwater balance and Toruń specializes in environmental impact assessments, especially with regard to the groundwater environment.

Publications by Polish hydrogeologists

Extensive collections of articles by Polish hydrogeologists are published in volumes of the *Current Challenges in Hydrogeology* (*Współczesne problemy polskiej hydrogeologii*), which each time include over 100 articles and short communications. Hydrogeological works occur also in other cyclical publications such as *Scientific Papers of the AGH, Bulletin of the University of Warsaw, Geologos* – publication of the University of Adam Mickiewicz in Poznań, *Bulletin of the PGI – Hydrogeology series*, conference proceedings from a cyclical symposium called *Hydrogeology of urban and industrial areas* organised by the University of Silesia; *Acta Universitatis Wratislaviensis – Hydrogeology series*; proceedings of a technical symposium PZiTS in Częstochowa; volumes of the *Groundwater Flow Modelling*, which are proceeding papers from a recurring conference organised every two years, alternately with the *Current Challenges in Hydrogeology*, by different scientific centres. There are also publications by the Polish Hydrogeological Survey released in the *Quarterly Bulletin of Groundwaters* containing raw groundwater data and predictions and the *Hydrogeological Annual Report* an

annual publication which includes groundwater monitoring data as well as numerous monographs regarding water supplies (Nowicki, 2009).

Furthermore, many hydrogeological works by Polish authors have been published in conference proceedings from various seminars, mostly geological but also from other fields such as hydrology, geophysics, environmental protection and water management. International conferences and symposia have also been organised in Poland with proceedings published in English: e.g. *Hydrogeochemistry of Mineralized Waters* – proceedings of the IAH Conference in Cieplice Spa (Dowgiałło & Sławiński, 1978), 11th Salt Water Intrusion Meeting (SWIM) organized in Sopot (Kozerski & Sadurski, 1990) or 16th SWIM held in Międzyzdroje (Sadurski, 2000), proceedings of the international conference on *Karst-Fractured Aquifers – vulnerability and sustainability*, Katowice-Ustroń (Różkowski & Kowalczyk, 1996), proceedings of the international symposium *Hydrogeology of Coal Basins* organised in Katowice (Wilk & Libicki, 1987) and also in: the *Selected Papers on Hydrogeology (*Witkowski et al., 2007), in the IMWA publications and in many other international journals.

The past twenty years provides a great example of dynamic activity of Ministry of the Environment and especially the Chief National Geologist in the Ministry – dr. H.J. Jezierski. The long term research programme called *Policy of the department and directions for research in field of hydrogeology*, financed by the National Fund for Environmental Protection and Water Management has been established for the first time in the modern politics. In parallel to amending legal acts, including the *Mining Act* and the *Water Act*, and directing hydrogeological research on a national scale, the significant contribution of the Ministry in progressing Polish hydrogeology is initialisation a release of lecture books, handbooks, atlases and hydrogeological guidance documents. The Ministry took over this responsibility from academic and research centres which past achievements in that matter (Pazdro, 1964; Zuber, 1986; Leśniak et al., 1995; Macioszczyk, 2006; Małecki et al., 2006) were rather limited due to financial reasons. Taking over this duty by the Ministry resulted in a significant step up with publishing of these works. It is just enough to say that over 40 titles were published throughout the past 20 years including many fundamental hydrogeological books such as, comprising 2 volumes and 744 pages, *Regional Hydrogeology of Poland* (Paczyński & Sadurski, 2007) which was produced in cooperation of 52 authors from all academic centres in Poland.

Summary

The obvious achievement of Polish hydrogeology is the digital hydrogeological map of Poland (MhP), 1 : 50 000, which is the first, serial (1069 sheets), detailed hydrogeological map of Poland and one of few in Europe. It is closely connected with the development of the GIS techniques. Over 400 professionals gathered in 22 Polish hydrogeological centres participated in the project, mastering techniques offered by the GIS/Intergraph. The map is an interrelational database about groundwater resources, with a graphical interface. Digital hydrogeological data bases have been successfully introduced in Poland for over 40 years. Modern laboratory and field measuring techniques have been implemented. At present times, the assessment of admissive and disposable groundwater resources is practically not possible without numerical groundwater modelling, and without mass transport models, it would not be possible to predict hydrochemical changes in these waters.

In the past decade, Polish hydrogeology has come closer to general issues of water management and protection of the aquatic environment. The requirement of a conjunctive treatment of surface and groundwater resources, as wells as measures taken to improve their quality, which is required by EU legislations (2000/60/UE and 91/676/UE), have become the major challenge for Polish hydrogeology. There is a certain need therefore to continue works on valorisation of groundwater resources and assessment of their vulnerability to pollution from the ground surface, threats of saline intrusions, methods for controlling groundwater quality as well as assessing groundwater quantity.

Since 2003, the Polish hydrogeological survey has been operated in Poland, established by the *Water Act* for coordination and implementation of works required by EU directives, especially the *Water Framework Directive*.

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