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WATER RESOURCES AND CLIMATE CHANGE – GROUNDWATER AS AN ALTERNATIVE SOURCE OF WATER SUPPLY

Abstract: In recent years, the world, including Europe, has seen a much higher incidence of extreme weather phenomena. The ongoing climatic changes have a direct impact on the condition of surface waters. Groundwater is less affected by anthropogenic pollution than surface water, since groundwater can be used in distribution systems for municipal purposes, for food purposes, sold in unit packages, and for medicinal purposes (in drinking and bathing treatments).

In Poland, a country with poor water resources, the problem of water scarcity due to climate change may even increase. One solution to this problem may be the increased use of Polish groundwater resources. Hydrogeological conditions favorable to the construction of drill wells, detailed identification of available groundwater resources throughout the country and the low degree of their usage (25% on average) make it possible to increase the intake of groundwater to cover this water deficit, especially in periods of drought.

Keywords: extreme weather conditions, groundwater, water supply, Poland

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1. INTRODUCTION

Water is essential for the life of all living organisms and, as well as supporting vital functions, it is used in every sector of the economy [19].

The main reason for the increasing demand for water is the growth of the world's population. Currently, the number of people inhabiting our planet is close to 8 billion. Population growth, economic development, striving to improve living standards, as well as increasing public awareness all mean that the demand for water is increasing. Thus, water consumption increases faster than it would result from population growth alone. In the 20th century, the population of our globe increased threefold, while water consumption increased six times [6].

Water covers 2/3 of the globe's surface but unfortunately the vast majority of it is salt water (seas, oceans). Non-saline water accounts for only 2.5% of global resources. On the other hand, among the water resources commonly referred to as fresh water, surface waters constitute only 0.3% and groundwater 30.0% [20]. Although the possibilities of using saline water are considered and will be the subject of further research in the future, these waters cannot be used directly for municipal purposes or with the use of simple and cheap technologies. The waters introduced into municipal systems as a result of sea water desalination differ from fresh water, both in terms of their organoleptic properties and chemical composition (higher concentrations of disinfection by-products, including those considered mutagenic) [14]. The problem of water scarcity is currently being discussed on both a global scale [18, 23] and a regional scale [41].

The article discusses the role of surface and underground waters in water supply using the example of Polish resources. The impact of meteorological phenomena on the quality of surface waters is presented and groundwater is indicated as an alternative to water supply in the conditions generated by climate change.

2. POLAND'S WATER RESOURCES AND THEIR USE

Poland is classified as one of the countries with poor water resources. The average annual outflow of surface waters, including inflows from abroad, in the years 1985–2019 amounted to 60.0 km^3, which, taking into account the population, corresponds to 1,600 m^3/inhabitant. Freshwater resources in European Union countries are very diverse. The average amount of water per inhabitant in Europe is 2.5 times greater than in Poland and amounts to approx. 4,500 m^3/year. In the Czech Republic, Cyprus and Malta, this index is lower than in Poland and equals 1,500 m^3, 400 m^3 and 200 m^3, respectively [36].

Poland's water resources are characterized by high seasonal variability and uneven territorial distribution. This is the result of regional differentiation of the elements of the water balance – precipitation, evapotranspiration and runoff (surface, subsurface and underground) related to climatic differences and land cover. Annual precipitation totals range from 500 mm (in Kuyavia and Greater Poland) to over 1000 mm (in the Tatra Mountains) [10, 28]. The area with the lowest water abundance is central Poland, covering the areas of Regional Water Management Boards in Poznań and Warsaw [34]. Retention reservoirs in Poland can only capture 6% of the annual water runoff in the country, which does not provide sufficient protection against periodic water excesses or deficits [1].

Surface waters in Poland are of unsatisfactory quality in most cases. The assessment of the general status of river waters carried out for 1,159 surface water bodies (SWB) in 2017 showed that a good condition was found only in 0.3% of SWB, while in the case of 99.7% it was in a bad condition [43].

Globally, 70% of water resources are used by agriculture, 19% by industry, and 11% by the municipal economy. In Poland, industry uses 67.82%, agriculture 9.15%, and municipal purposes 23.03% of resources [37].

3. CLIMATE CHANGES AND THEIR IMPACT ON THE CONDITION OF WATER RESOURCES

An increase in air temperature has been observed since the beginning of the 20th century, but its intensity has been visible since the 1970s [42]. The rise in air temperature has an influence on the increase of surface water temperature. Over the past 100 years, temperatures in major European rivers such as the Rhine and Danube have increased by 1–3°C [43]. Temperature increases have also been reported in the streams of Scotland [18] as well as in Switzerland at all altitudes [10]. In Poland, in the years 1971–2015, the increase in the average temperature in rivers was from 0.2°C to 0.4°C per decade [8].

In recent years, the world, including Europe, has seen a much greater number of cases of extreme weather conditions including torrential rains causing floods, and a greater number of days with extremely high temperatures, which results in droughts [35].

In Poland, on the basis of 200 years of observations, and data from the last 40 years, the following has been noticed: high variability of air temperature from year to year; the temperature trend which was systematically growing since the mid-19th century. The last 40 years have been the warmest period in the history of instrumental observations in Poland. The greatest impact on climatic conditions is exerted by extreme phenomena, the increase in the number of occurrences of which noticeably changes the dynamics of climate features in Poland. In most of the territory of Poland, there has been a change in the structure of precipitation consisting in a significant increase in the number of days with daily precipitation of high intensity [45].

Climate change has an impact on the state of water resources and will continue to have [2, 29]. Climate influences the water flow regime in rivers and the quality of water resources [7, 22, 31]. Ocean air fronts control the type and structure of precipitation. Precipitation affects the supply of waters in the active water exchange zone, including surface waters. Temperature affects the course of processes modifying the composition of water. An rise in air temperature increases the temperature of surface waters and increases the level of ocean waters. The increase in the level of ocean waters causes the ingression of sea waters, which may have an impact on quality (the salinity of aquifers in coastal regions).

Downpours increase the suspended solid content in surface runoff waters [25]. There is a relationship between the hydrological regime and the concentration of total organic carbon [3] and between dissolved organic matter, temperature, and surface runoff intensity [11].

Dry seasons have a negative impact on the quality of surface waters due to the increase in pollutant concentration, temperature rise and the effects of algae blooms [28]. Temperature rise, the modification of rainfall structure and frequent extreme weather conditions affect the amount of dissolved organic matter. Most of the organic matter is washed out of the soil, and heavy rainfall can lead to an increase in organic matter in surface runoff and surface water.

Climatic conditions in the future may cause the accumulated organic compounds in the soil to penetrate the aquatic environment more intensively than before. Extreme weather phenomena, such as heavy rains, may result in an increased inflow of organic matter, and droughts and the accompanying low water level may result in a high concentration of polluted waters in the total water mass. Treatment of poor-quality waters with a higher concentration of organic matter and temperature are associated with the risk of generating more disinfection by-products (both those for which parametric values have been established and those for which the impact on human health has not yet been investigated).

The deteriorating condition of surface waters has been observed over a long period of time and an increase in salinity observed in the surface waters of many regions of the world [13].

It is expected that the impact of climate change on water resources in Poland will be noticeable in the functioning of many sectors of the economy. The most severe changes will relate to agriculture where, due to the projected lengthening of the periods without rainfall, one should expect a decrease in yields and an increase in water demand (e.g. for the artificial irrigation of fields). Droughts and the decreasing groundwater level will also increase the risk of natural forest fires. On the other hand, in the energy sector, the increase in the temperature of surface waters and lowering their level will limit the possibilities of their use for cooling power plants. In the summer season, the demand for electricity is expected to increase due to the increase in the frequency of heat waves [46].

4. POLISH GROUNDWATER RESOURCES AND THEIR USE

In Poland, mainly surface waters are exploited. Their consumption is at the level of approx. 8,000 hm^3, while groundwater consumption is below 2,000 hm^3/year. Nevertheless, the uptake of groundwater in relation to surface water is systematically increasing (Fig. 1). Although surface waters predominate in water abstraction, groundwater in Poland covers over 70% of the water demand for food and household purposes. The proportions between the consumption of groundwater and surface water in individual regions of Poland are varied. In provinces in the south of Poland (Lesser Poland, Silesia and Subcarpathia) surface waters are mostly used for municipal purposes [9, 37].

The available groundwater resources for management in the entire country are, as of December 31, 2017, approximately 12.73 km^3/year (approximately 35 million m^3/day) [43]. The amount of available groundwater in Poland amounts to nearly 33.7 million m^3/day as of December 31, 2019. Waters come mainly (66%) from the Quaternary, 10% are the waters of the Palaeogene and Neogene, 14% of the Cretaceous, and 10% of the waters from older strata [21].

Surface waters are directly exposed to the influence of anthropopressure and the action of meteorological factors. Extreme flood phenomena (droughts, floods, torrential rains) have a direct impact on the condition of surface waters (both their quantity and pollution). In the case of groundwater, the influence of anthropogenic factors is limited and to a greater extent controlled than in the case of surface waters. The results of monitoring studies may confirm the better quality of groundwater. In 2017 good chemical status was found in 66% of the groundwater bodies tested [43].

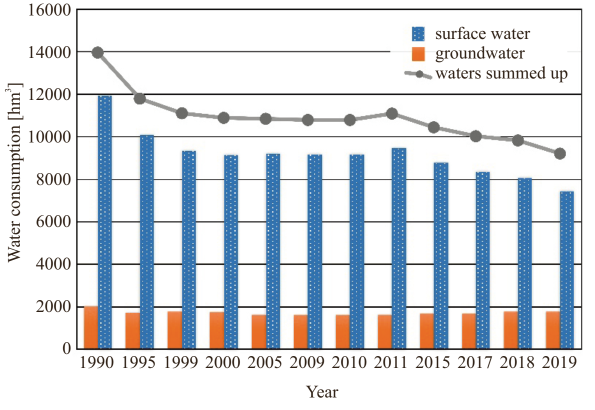

Fig. 1. The proportions between the consumption of groundwater and surface water in Poland in years 1990–2019 [37]

Only in water balance areas, which together constitute approx. 3% of the country's area, does intensive groundwater abstraction exceed 60% of the available groundwater resources (Fig. 2) [12].

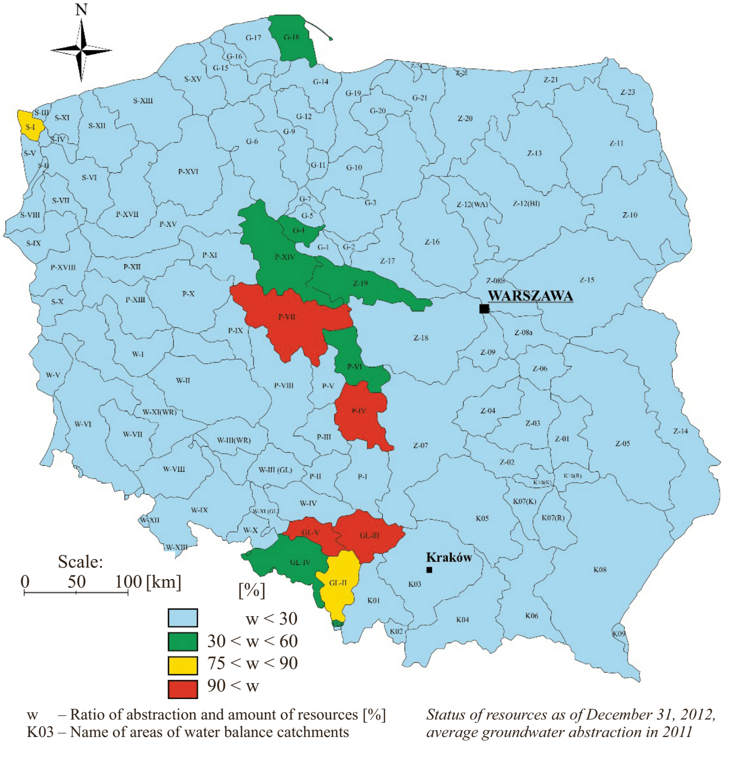

Fig. 2. The rate of use of groundwater resources available for development (as ratio of abstraction and amount of resources) in areas of water balance catchments (after [12], simplified)

Groundwater resources could be used to a greater extent. Providing access to groundwater resources is related to the construction of intakes, preceded by hydrogeological drilling. In Poland, over a thousand hydrogeological wells are drilled every year. In 2016, this number was over 1,600, and their total length was over 85,000 m (Fig. 3) [33].

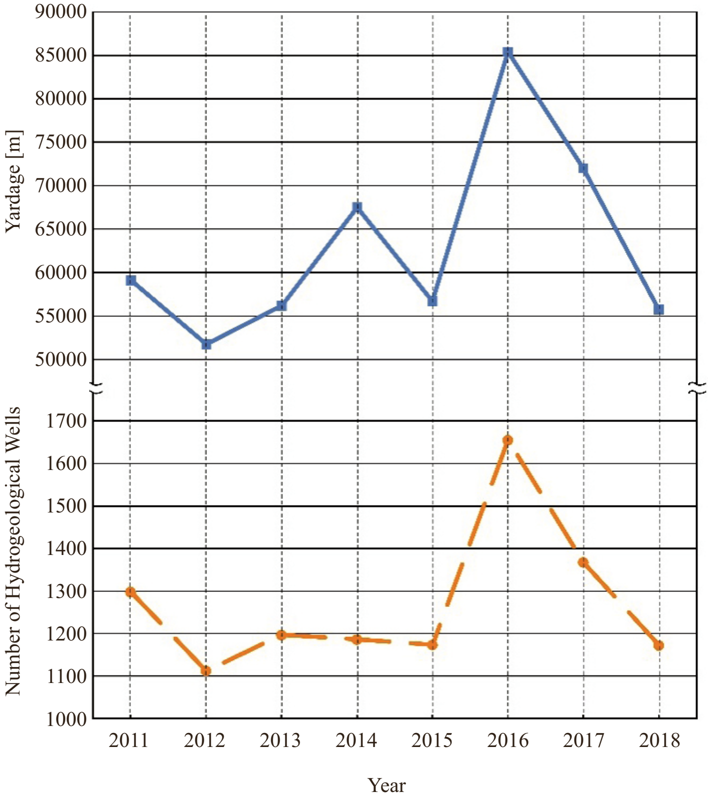

Fig. 3. Number of hydrogeological wells with their yardage drilled in Poland in years 2011–2018, after [33]

Groundwater plays an important role in water resources. Underground water recharge in the territory of Poland and in average hydrological and meteorological conditions constitutes 52.5% of the annual volume of river outflow. The amount of groundwater retained in aquifers is comparable to the hundred-year runoff of river waters to the Baltic [45]. The fact that they are poorly managed (25% on average) indicates that it is possible to increase their use in periods of water scarcity, especially in periods of drought.

Groundwater is recharged by precipitation. In the northern regions of Poland, the multilayer aquifers of the Quaternary and Paleogene-Neogenestratais beneficial due to the retention point of view, protecting them against the direct impact of the periodic deficit of precipitation during droughts. In the Central Poland highland, the lack of a precipitation supply does not affect the abundance of fractured Mesozoic formations, the thickness of which is considerable [38].

Groundwater intakes not only include water supply, but also the exploitation of curative and mineral waters, brines and thermal waters. Mineral waters are available in intakes or in their immediate vicinity, in the pump rooms of health resorts. They are used for drinking and bathing treatments or are bottled for commercial sale. Chemically and microbiologically pure groundwater is distributed in the form of: natural mineral, spring and table waters sold individually packaged. The consumption of bottled water is increasing, with this phenomenon observed in many countries around the world, including Poland [16, 24].

The available groundwater intakes can be an alternative to water supply and conditionally used for drinking purposes. One example are public springs, such as the Jurassic water intakes in Kraków, previously very popular as a source of drinking water. At present they are used as emergency intakes [5, 15, 26].

Groundwater with a temperature above 20°C is referred to as thermal water and is used for balneotherapy, recreation, and heating purposes. Saline groundwater can be used for therapeutic and recreational baths, but also for the production of salt aerosol and inhalation in brine graduation towers. This applies to both the waters accessible through boreholes (for example in Poland: Ciechocinek, Gołdap) and the waters from the drainage of deposits (for example in Poland: Wieliczka). It should be noted that the interest in this way of using water has recently increased, with a concomitant rise in the number of facilities built for both therapeutic and recreational purposes.

Saline waters and brines occurring in deep geological structures, apart from their high concentrations of basic components, are also characterized by higher concentrations of microelements compared to ordinary groundwater. These waters can be of industrial importance and serve as a source of valuable elements. An example would be the Permian waters of the Fore-Sudetic Monocline, in which bromide and magnesium ions are locally present in concentrations indicating the profitability of the recovery of both of these elements [4, 30]. High concentrations of boron have also been identified in selected therapeutic waters of Poland [30].

5. CONCLUSIONS

In recent years, the world, including Europe, has seen a much higher incidence of extreme weather phenomena. These include heavy rainfall causing floods, or more days with extremely high temperatures, which in turn cause droughts. The ongoing climatic changes have a direct impact on the condition of surface waters, with groundwater less affected by anthropogenic pollution than surface water. Changes in the state of water resources caused by possible extreme weather conditions are also smaller. Groundwater can be used both in distribution systems for municipal purposes, for food purposes, sold in unit packages, and for medicinal purposes (in drinking and bathing treatments).

In Poland, a country with poor water resources, the problem of water scarcity due to climate change may even increase. One solution to this problem may be the increased use of Polish groundwater resources. Hydrogeological conditions favorable to the construction of drill wells, detailed identification of available groundwater resources throughout the country and the low degree of their usage (25% on average) make it possible to increase the intake of groundwater to cover this water deficit, especially in periods of drought.

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