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THE IMPLICATIONS OF ECONOMIC DEVELOPMENT, CLIMATE CHANGE AND EUROPEAN WATER POLICY ON SURFACE WATER QUALITY THREATS

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Abstract. The paper presents historical background, up-to-date situation and future perspectives for the development of nutrient pollution threats to European surface water quality, as well as the evolution of the approach to water pollution. Utilized agricultural area in European countries is slightly diminishing, however the consumption of mineral fertilisers is steadily increasing. The consumption in Europe in the years 2015–2030 is projected to increase by 10%, and in the world by 20%. Both climate changes leading to the increase of temperature even of ca. 6°C (in comparison to the pre-industrial period) and accelerated soil erosion due to high intensity rainfall cause increased productivity of water ecosystems. Those aspects have to be taken into consideration in water management. Due to legal regulations introduced in the last twenty years, wastewater treatment has been made more effective and population connected to wastewater treatment systems has increased. The improvement has been seen mainly in eastern and southern parts of Europe. After the implementation of Water Framework Directive theories regarding modern water management have been developed, with the aim to increase the ecosystem's capacity and its resilience to climate changes and anthropopressure.

Key words: eutrophication, mineral fertilisers, nitrogen, phosphorus, surface water pollution, wastewater treatment

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INTRODUCTION

Eutrophication is a global threat to the quality of surface water. It is considered as the main obstacle to obtain good water status within the Water Framework Directive (WFD). All surface water undergoes natural nutrient enrichment, however for many years the process has been notably accelerated due to human actions (cultural eutrophication). Excessive amounts of nutrients, mainly nitrogen and phosphorus, get to water primarily from runoff from agricultural lands, untreated or insufficiently treated wastewater effluent and with precipitation. Eutrophication causes changes in ecosystem structure and limits ecosystem services, enabling rapid growth of cyanobacteria, algae and aquatic plants, decrease in fauna and flora species diversity, general water quality detriment, limited use of water resources, increased cost of water treatment [Correll 1998, Rabalais 2002, Moss et al. 2011, Orzepowski et al. 2014, Withers et al. 2014, Kanownik and Policht-Latawiec 2015, Policht-Latawiec et al. 2015, Dąbrowska et al. 2016, Sharpley 2016, Bouwman et al. 2017].

Nowadays, predicted climate changes – temperature rise, higher frequency of droughts, floods, high-intensity rainfalls and related accelerated erosion processes – are perceived as an important element of water resource management. Observed climate changes result in increasing aquatic ecosystems productivity and in necessity to further limit nutrient loads contaminating water [Jeppesen et al. 2009, 2011, Rolighed et al. 2016, Wdowikowski et al. 2017].

At the end of the 1990s the concept of ecohydrology appeared in literature. Both researchers and practitioners emphasised the importance of process-oriented thinking instead of structure-oriented one, as well as the holistic approach to surface water quality. Modern water resources management aims at increasing the ecosystem's carrying capacity through simultaneous improving of water resources quality, preserving and recovering biodiversity, providing ecosystem services to the society, building resilience to climate changes and anthropopressure, from molecular to landscape scale (WSBR+C – *water, biodiversity, ecosystem services, resilience, cultural heritage*). The integration of ecohydrology, engineering and biotechnology in a catchment is crucial for water quality. It is supposed to limit the costs, increase effectiveness of actions undertaken for improving water quality and building resilient systems. By conscious use of correlations between hydrological and biological processes, the capacity, resilience and flexible response of ecosystems to threats can be increased [Zalewski 2000, 2013, 2014, Gallopin 2006, Izydorczyk et al. 2015, Mander et al. 2017, Marcinkowski et al. 2017].

The aim of the paper is to analyse the development of threats to surface water quality in the years 2000–2017 with a perspective for the next several dozen years. Dynamically developing agriculture was chosen from the branches of economy that may negatively influence water quality. Moreover, the progress in urban wastewater treatment was analysed and the influence of potential climate change on water quality was taken into account. Legal solutions and new theories of holistic and transdisciplinary approach to water management were considered as factors supporting water protection.

SOURCE MATERIAL

To achieve the aims of the paper, statistic data available in European and world databases and in literature written after the year 2000 were used, the data came from the World Bank, Eurostat, Fertilizers Europe, FAO, WHO, the UN, the IPCC and others. Research concentrated mainly on EU28 countries. The analysed tendencies were discussed at European level in relation to global changes. For agriculture, the consumption of mineral fertilisers was analysed, as well as the utilised agricultural area (UAA) and gross nutrient balance. The focus was placed on the countries with the largest UAA in the EU, such as France, Spain, the United Kingdom, Germany, Poland, and Romania. The analysis of changes in sewage management included the assessment of the general number of people connected to wastewater treatment plants (WWTPs) as well as the population connected to urban wastewater treatment plants with at least secondary treatment in the most populated countries in the EU: Germany, France, the United Kingdom, Italy, Spain, Poland.

RESULTS AND DISCUSSION

Economic development – agriculture and wastewater treatment

Thanks to the legal regulations introduced within the last 30 years, it was possible to improve wastewater treatment and increase the population connected to wastewater treatment systems. According to the European Environment Agency, a significant limitation of the negative impact of wastewater on water quality pertains mostly to the eastern and southern parts of the continent, which noticeably stood out from the well-developed North and West. In the years 2005–2014 in Bulgaria and Romania the percentage of population connected to wastewater treatment systems increased from 72 to 82% and from 29 to 49%, respectively. At the same time in highly developed Norway a rise was noted, from 96 to 97%, and in the Netherlands in the whole period 100% of the population used wastewater treatment plants. In 4 out of 6 largest EU countries (Germany, France, the United Kingdom and Spain) in 2013 over 99% of the population was connected to WWTPs, in Poland 70%, and for Italy there is no data available [Eurostat 2017]. From the WHO data it may be concluded that especially in Romania, Bulgaria, Poland, Finland and Hungary there are significant differences in the development of wastewater treatment systems in urban and rural areas [WHO 2009]. In the 6 most populated EU countries (Fig. 1, the countries arranged in descending order of population), the percentage of people connected to urban wastewater treatment plants with at least secondary treatment equals at least from 70% (Poland) to 100% (the United Kingdom) whereas the data for Italy raise doubt both as regards quantity and quality of gathered information and thus were excluded from the comparisons. The lowest results were noted in countries other than the 6 most populated ones, namely in Romania and Bulgaria, 35 and 55% respectively. It should be added that the countries with quite low percentages of population connected to WWTPs in 2013, such as Poland, Romania and Bulgaria, increased the number of people connected to wastewater treatment systems in the years 2004-2013 by 24, 43 and 109% respectively [Eurostat 2017].

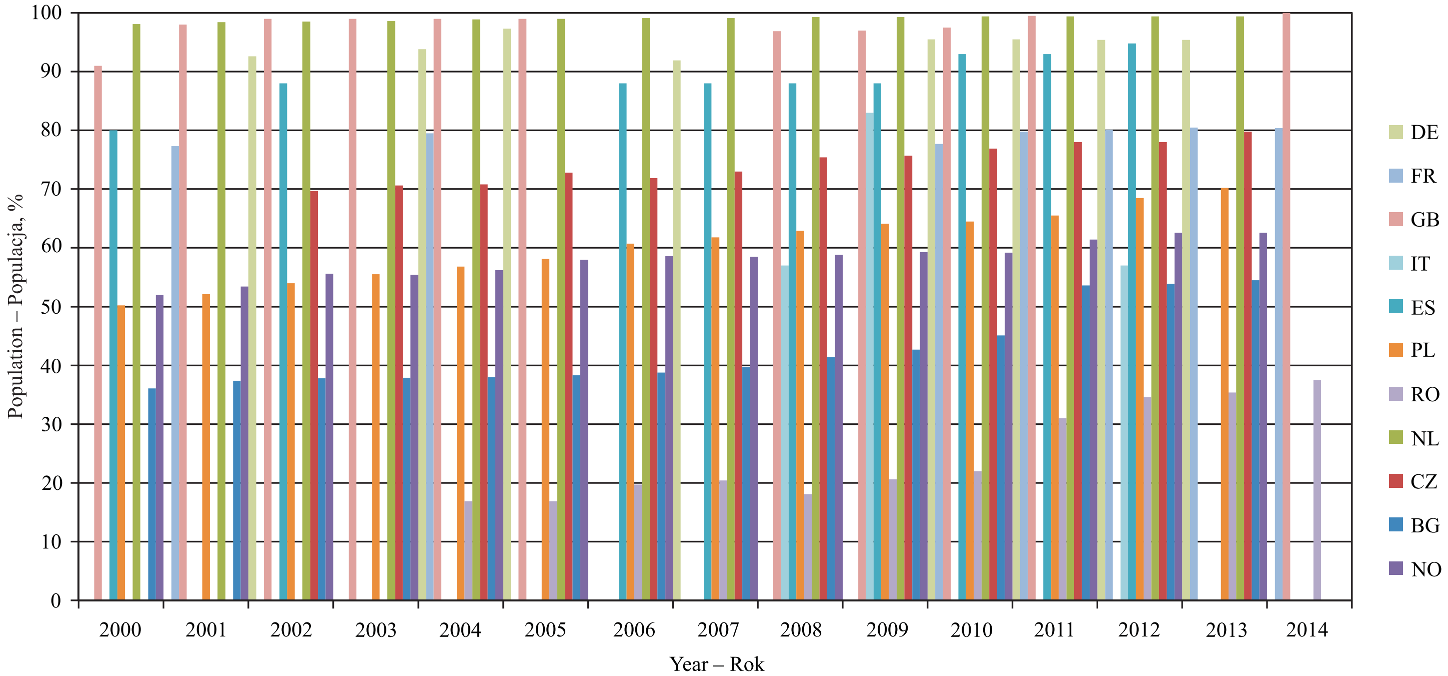

Fig. 1. Population connected to urban wastewater treatment with at least secondary treatment according to Eurostat data, country codes according to ISO-3166 Alpha-2

Ryc. 1. Procent populacji podłączony do komunalnych oczyszczalni ścieków z oczyszczaniem przynajmniej w stopniu biologicznym na podstawie danych Eurostatu, kody państw według ISO-3166 Alpha-2

Globally, the problem is the lack of information and coherent statistics as regards wastewater treatment. Only 55 out of 181 countries analysed by a team of international researchers possess reliable statistics regarding generation, treatment and use of wastewater, 69 countries possess data comprising 2 aspects, and for 57 countries there is no information available [Sato et al. 2013]. It is predicted, however, that in developed countries the percentage of untreated wastewater will decrease from 30% in 2015 to 15% in 2030, and in low income countries from 92% to 46% respectively [WWAP 2017].

The problem of insufficient treatment of wastewater is systematically being solved in EU countries, as construction and modernization of wastewater plants improves the quality of water resources. However, further studies are needed in the area of watercourses capacity to receive loads connected with human activities. Even modern, highly efficient WWTPs may be detrimental for water quality if the recipient has little self-purification capacity in comparison to the load introduced [Dąbrowska et al. 2017, Robinson et al. 2016].

Nowadays, agriculture is the main source of nutrient pollution. Due to the dispersed nature of agricultural pollution, it is difficult to use technological devices to neuter it. The global problem of rising population that needs to be fed entails intensifying agricultural production. According to the United Nations data [United Nations 2017] in the year 2000 the population of the world stood at 6.1 billion, in 2017 it is 7.5 billion, in 2050 it may reach 8.5 billion, and in 2100 – 11 billion people. For Europe, demographic projections predict a decline, from 730 million people in 2000, 740 million in 2017, to, in further perspective, probably 716 million in 2050 and 650 million in 2100. The analyses of data from the years 2000–2014 show that in the 6 countries with the largest agricultural area 7.35 million Mg of nitrogen fertilisers and 80 thousand Mg of phosphorus fertilisers are used annually, which constitutes almost over 65% of total consumption in EU28. Germany and the United Kingdom are among the countries with the highest consumption of fertilisers per hectare of UAA, but the greatest values were noted for the Netherlands, the 21st country as regards UAA (Fig. 2) [The World Bank 2017].

According to the projections up to the year 2030, global fertiliser consumption will systematically rise. An increase by ca. 20% is estimated, in comparison to the year 2015, with the greatest rise predicted for India and China, the smallest for highly developed countries of Europe, South America, the Republic of South Africa and Australia. The estimated increase for Europe is 10% [Total... 2007, Drescher et al. 2011]. A global economic crisis in the years 2008–2010 reflected on fertiliser consumption in agriculture. In the EU countries the influence is more noticeable than on a global scale (Fig. 2). In 2012, the increase in nitrogen fertilisers consumption in the EU was predicted at 1%, and phosphorus at 6.7% till 2023 [Forecast… 2012], however it is hinted that agriculture is more dynamically rising after the crisis that it was projected [Heffer and Prud'homme 2016]. The analysis prepared for the years 2014–2019 shows the increase in fertiliser demand in Europe (3.5% N, 8.5% P_2O_5), with a division for a decline in the West (–5% N, –1.5% P_2O_5), increase in the central part (8% N, 17% P_2O_5), and the most dynamical increase in the East (13% N, 20% P_2O_5) [Food... 2016]. In a global scale, the consumption of phosphorus fertilisers is influenced by the depletion of phosphate rock resources, and thus the rise of their production costs [Van Vuuren et al. 2010].

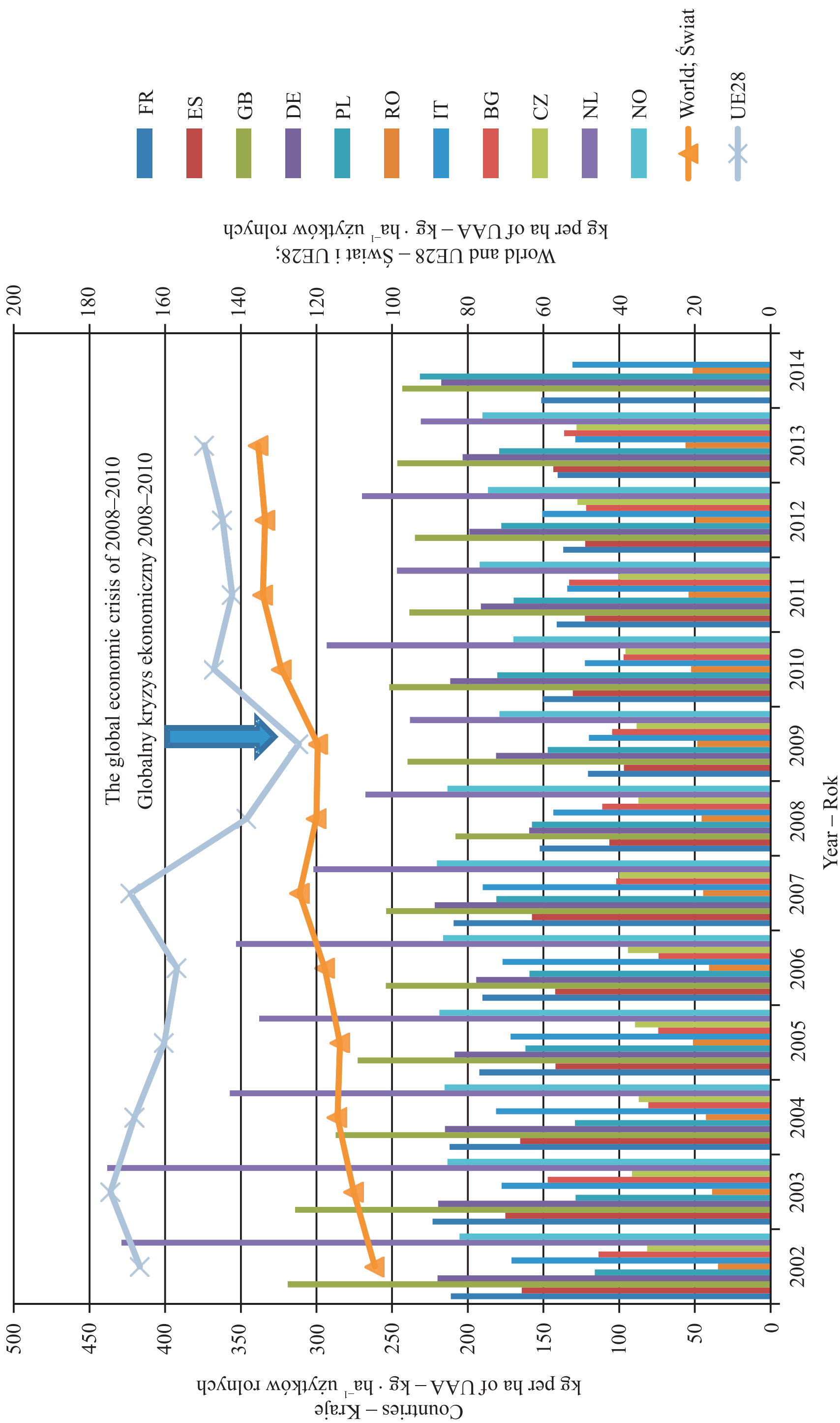

Fig. 2. Mineral fertiliser consumption in the World and selected European countries in the years 2002-2014 according to The World Bank data (kg per ha of UAA), country codes according to ISO-3166 Alpha-2

Ryc. 2. Zużycie nawozów sztucznych na świecie i w wybranych krajach europejskich w latach 2002-2014 na podstawie danych Banku Światowego (kg · ha^{-1} użytków rolnych), kody państw według ISO-3166 Alpha-2

In the years 2000–2014 the utilized agricultural area in the world diminished by ca. 0.5%, and the same tendency may be observed in Europe [Eurostat 2017, The World Bank 2017]. At the same time, the increase in fertiliser consumption indicates the intensification of plant production. Globally, there is a noticeable rise in population per hectare of UAA. As far as meat production is concerned, there is a predicted growth by 135% until 2050, which (population rise considered) gives production increase by 68% per person, in 2005–2050 time range [Elam 2006, Eurostat 2017, The World Bank 2017].

Gross fertiliser balance value for EU28 in the years 2004–2013 stood in the range of 48–58 kg N and 1–4 kg P per hectare of UAA. The analyses show that in the 6 countries with the largest UAA in the EU (Fig. 3 presents EU28 countries in descending order of UAA) nitrogen and phosphorus surplus is average or low in comparison to the other countries, and in particular years of the studied decade balance values for given countries did not differ considerably [Eurostat 2017]. Low values of nutrient surplus do not immediately translate into smaller risk of eutrophication. The amount of nutrients getting into water depends on, apart from the surplus of nitrogen and phosphorus, agricultural practices and extreme weather events as well.

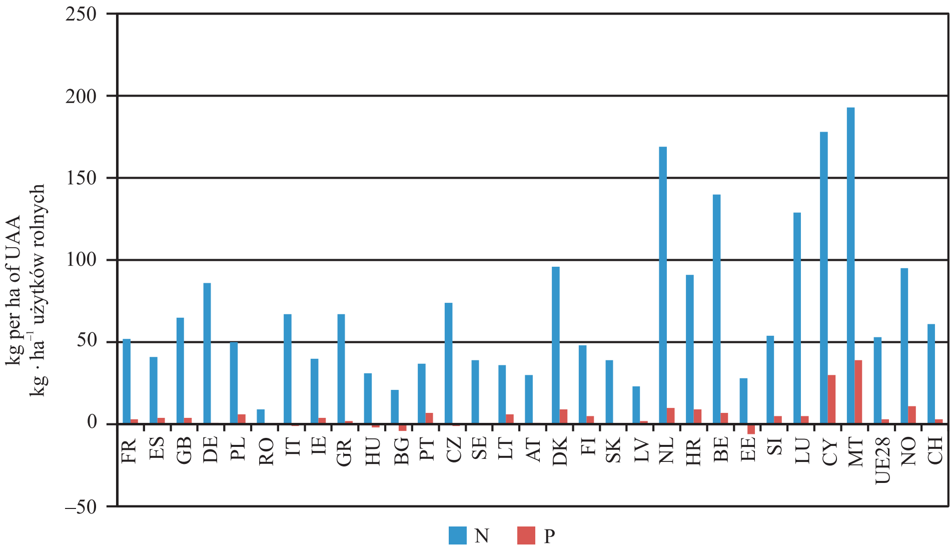

Fig. 3. Gross nutrient balance in selected European countries – the average from 2004–2013 according to Eurostat data [kg per ha of UAA], country codes according to ISO-3166 Alpha-2

Ryc. 3. Wielkość bilansu nawozowego brutto dla wybranych krajów europejskich – średnia z lat 2004–2013 na podstawie danych Eurostatu [kg · ha^{-1} użytków rolnych], kody państw według ISO-3166 Alpha-2

Climate change

The causes and projected effects of climate change are presented in the reports by the Intergovernmental Panel on Climate Change (IPCC) which has been preparing them since 1990. The last report was published in 2014 [IPCC 2014]. The predictions on climate changes are performed with the use of General Circulation Models (GCM) and greenhouse gases and aerosol precursor emissions described in Special Report on Emissions Scenarios (SRES). The scenarios are grouped into four narrative storylines: A1, A2, B1 and B2. Each of them assumes changes of a different kind influencing greenhouse gases emissions, such as: population increase, technological and economic development, leading policies and energy consumption [IPCC 2000]. The changes of climate conditions are relevant in the process of catchment outflow formation, especially in generated quantity of surface runoff influencing the amount of nutrients reaching the recipient. Simulations show that even up to 20% of global population lives in areas in which extreme rainfall frequency will considerably rise till 2080 [IPCC 2008]. Thus, the increase of nutrient content in surface waters may be expected. At the same time, rainfall characteristics projected for Poland show longer precipitation-free periods, greater annual maximum daily rainfall and shorter snow cover period [Brown and Mote 2009, Sadowski 2013]. Moreover, hydrological drought in the summer is predicted to be more common, which will additionally increase negative tendencies as regards quality and availability of water resources.

The most negative scenarios predict average global surface temperature to rise by 6.1ºC till 2100 as compared to the preindustrial period. Studies on Danish lakes proved that in view of those negative predictions it is necessary to reduce nutrient load by 60% to retain current *chlorophyll a* in water. According to the simulations performed, global warming entails an increased amount of phytoplankton in surface waters and the dominance of cyanobacteria [Rolighed et al. 2016]. During one or two heavy intensity rainfalls 90% of annual phosphorus loads may get into surface waters. Phosphorus alone is responsible for the eutrophication of most freshwater ecosystems. Calculating actual phosphorus loads which get into watercourses during heavy intensity rainfalls and correct annual loads becomes a challenge for water quality protection. It is impossible with the use of data from environment monitoring, where measurements are taken monthly or less frequently, and do not translate fully into the dynamics of changes in concentrations and loads of phosphorus compounds in surface waters [Sharpley et al. 1999, Cassidy and Jordan 2011, Julich et al. 2017].

European water policy and the evolution of the approach to water quality and water resources management

In the 1970s and 1980s mostly economic usage of water was highlighted. To assess water quality, physical, chemical and microbiological indicators were used. Numerous technological methods for the rehabilitation of water reservoirs were developed at the time, concentrating on a watercourse or reservoir, and not on a catchment as a system which comprises them [Barroin 1991, Kajak 2002, Soszka 2002].

In the 1980s and 1990s a catchment was treated as a basic unit in which water management problems are solved. This approach became a foundation for integrated water resources management (IWRM) [Soszka 2002].

The Nitrates Directive 91/676/EEC and the Urban Waste Water Directive 91/271/EEC obliged the EU countries to limit the pollution of water with nitrates from agricultural sources and to make investments as regards the collection, treatment and disposal of wastewater, in order to minimize their negative influence on the environment. The change in the approach to the problem of water quality was introduced by Water Framework Directive 2000/60/EC, according to which water is no longer treated as economic resource, but rather as an element of the ecosystem. The classification of surface waters in WFD was based on biological elements and supporting chemical and physico-chemical elements. It is the result of several years of work towards creating common water policy in the EU and achieving a good status of water bodies in 2015/2021/2027 time range. During those years research developed, concentrating on the methods of water protection and reclamation based on biological processes – pre-reservoirs, riparian buffer zones, plant-based biofilters. In water management ecological engineering and ecohydrology developed, leading to designing sustainable ecosystems for the mutual benefit of people and nature [Benndorf and Putz 1987a, Benndorf and Putz 1987b, Mitsch 1998, Perrow and Davy 2002, Adynkiewicz-Piragas and Lejcuś 2010, Zalewski 2013, Jóźwiakowski et al. 2015, Gizińska-Górna et al. 2016].

The last 10 years was the period when the data on the environment became more available, due to (among others) implementing Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC and Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). This enabled the analysis of unified, easily accessible data collected in numerous European databases and a dynamic development of tools enhancing water resources management, based on spatial data and data from environment monitoring.

CONCLUSION

On the basis of the conducted studies and analysed literature it may be concluded that the European Union has witnessed substantial progress as regards wastewater treatment. The source of nutrients getting into surface water has been significantly limited. The progress has been observed especially in developing countries which joined the EU. The problem of wastewater treatment is being solved in Europe, although in a global scale untreated wastewater is still a significant nutrient source threatening water quality. Apart from the necessity to improve sanitation, a total lack of information on this topic must be noted, as well as inconsistent statistics on wastewater treatment. On a global scale, the intensification of agricultural production for growing population is predicted, and according to forecasts the consumption of fertilisers will have risen by 20% on average by 2030, with India and China dominating in this respect. On our continent a lower by half (10%) increase in fertilisation is anticipated, and prepared forecasts suggest a gradual decrease of the population. Europe, however, is divided into a stabilized western part and the other, central and eastern part, is expected to develop a more dynamic growth in the demand for fertilisers. Poland belongs to the largest 6 countries in the EU28, both regarding utilised agricultural area and population, and the percentage of population connected to urban wastewater treatment plants with at least secondary treatment is the smallest in comparison to the other five countries

(70%). The fertiliser consumption in Poland is expected to grow noticeably. According to simulations, climate changes will have an increasingly important influence on nutrient pollution of surface water which entails excessive growth of algae and cyanobacteria. Therefore, additional nutrient loads resulting from global warming and increased frequency of extreme weather events need to be considered in water management.

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ZAGROŻENIA JAKOŚCI WÓD POWIERZCHNIOWYCH W KONTEKŚCIE ZMIAN GOSPODARCZYCH, KLIMATYCZNYCH ORAZ EUROPEJSKIEJ POLITYKI WODNEJ

Streszczenie. W pracy przedstawiono rys historyczny, stan obecny oraz perspektywy rozwoju zagrożeń jakości wód powierzchniowych Europy związkami biogennymi oraz ewolucję podejścia do problemu ich zanieczyszczania. Powierzchnia obszarów przeznaczonych do rolniczego wykorzystania w krajach europejskich nieznacznie się zmniejsza, systematycznie jednak rośnie zużycie nawozów sztucznych. Prognozowany dla Europy w latach 2015–2030 wzrost ich zużycia wynosi 10%, a dla świata 20%. Zmiany klimatu prowadzące do wzrostu temperatury nawet o ok. 6°C w porównaniu z okresem przedindustrialnym oraz intensyfikacja procesów erozji gleb w wyniku opadów atmosferycznych o dużym natężeniu powodują zwiększanie produktywności ekosystemów wodnych, które należy uwzględnić przy zarządzaniu wodami. Dzięki wprowadzonym w ostatnim dwudziestoleciu regulacjom prawnym udało się usprawnić oczyszczanie ścieków i zwiększyć liczbę mieszkańców podłączonych do sieci kanalizacyjnych, poprawa nastąpiła przede wszystkim we wschodniej i południowej części Europy. Po wprowadzeniu w życie Ramowej Dyrektywy Wodnej rozwinęły się teorie dotyczące nowoczesnego zarządzania zasobami wodnymi, które ma na celu zwiększanie pojemności ekosystemów i ich odporności na zmiany klimatu oraz oddziaływania antropogeniczne.

Słowa kluczowe: azot, fosfor, eutrofizacja wód, nawozy sztuczne, oczyszczanie ścieków, zanieczyszczenie wód powierzchniowych

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