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LOSSES IN SURFACE WATER ECOSYSTEM SERVICES CAUSED BY WASTE WATER DISCHARGE

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STRATY W ŚWIADCZENIACH EKOSYSTEMÓW WÓD POWIERZCHNIOWYCH SPOWODOWANE EMISJĄ ŚCIEKÓW

STRESZCZENIE: Zanieczyszczenia przedostające się do wód powierzchniowych powodują pogorszenie się jakości wody oraz zaburzenia w funkcjonowaniu ekosystemów wodnych i powiązanych z nimi ekosystemów lądowych. Skutki odczuwane są także przez ludność i gospodarkę narodową. Straty ponoszone przez ludność oraz poszczególne sektory gospodarki w związku z emisją ścieków są bardzo zróżnicowane. Na ich wielkość ma wpływ przede wszystkim sposób wykorzystania zanieczyszczonej wody. Straty te można podzielić na dwie podstawowe grupy: straty ponoszone przez użytkowników zanieczyszczonych wód oraz starty związane z funkcjonowaniem ekosystemów wodnych. Koszty, które muszą ponieść korzystający z zasobów wodnych, są jednocześnie stratami wynikającymi z ograniczonej możliwości świadczenia usług przez dany ekosystem wodny.
W artykule przedstawiono starty w świadczeniach ekosystemów wodnych spowodowane zrzutami ścieków oraz sposoby ich szacowania.

SŁOWA KLUCZOWE: świadczenia ekosystemów, wody powierzchniowe, odprowadzanie ścieków, szacowanie strat

Introduction

The natural environment is a place where humans exist. It is therefore a source for fulfilling their needs. With the development of science and technology, these needs started exceeding the basic physiological, hygienic and survival requirements. The development of economies and consumer society caused an increase in the requirement for natural resources. Currently, all types of ecosystems are being utilised. It can be said that the ecosystems provide a kind of a service. Due to this fact, a new concept was created, linking the natural environment and the way of utilizing it, called the concept of ecosystem services.

Common International Classification of Ecosystem Services (CICES) defines "as the contributions that ecosystems make to human well-being. These services are final in that they are the outputs of ecosystems (whether natural, semi-natural or highly modified) that most directly affect the well-being of people. A fundamental characteristic is that they retain a connection to the underlying ecosystem functions, processes and structures that generate them"[1].

Initial works on the concept of ecosystem services and their economic value date back to the mid-1960s and early 1970s[2]. Interest in this issue has increased in the 90s[3].

An important date in the development of the concept of ecosystem services was year 1997 and the publishing of an article by Costanza, in which he presents 17 types of ecosystem services and assesses their economic value in a global scale[4].

The important moment in the development of the concept of ecosystem services was the publication in 2005 Millennium Ecosystem Assessment (MEA), a work involving over 1300 scientists. One of the key results of the MA was the

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[1] *Common International Classification of Ecosystem Services (CICES)*: Consultation on Version 4, August-December 2013, Report to the European Environment Agency, Revised January 2013, p. I.

[2] R.T. King, *Wildlife and man*, "Conservationist" 1966 no. 20(6), p. 8-11; D.R. Helliwell, *Valuation of wildlife resources*, "Regional Studies" 1969 no. 3, p. 41-49; E.P. Odum, H.T. Odum, *Natural areas as necessary components of man's total environment*, Transactions of the 37th North American Wildlife and Natural Resources Conference, March 12-15, Washington D.C. 1972, vol. 37, p. 178-189.

[3] D.W. Pearce, *Economic values and the natural world*, London 1993; D. Pimentel, C. Wilson, *Economic and environmental benefits of biodiversity*, "Bioscience" 1997 no. 47(11), p. 747-758; R.S. de Groot, *Functions of nature. Evaluation of nature in environmental planning, management and decision making*, Groningen 1992; R.S. de Groot, *Environmental functions and the economic value of natural ecosystems*, in: A.M. Jansson (ed.), *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*, "International Society for Ecological Economics" 1994, p. 151-168; K.E. Limburg, C. Folke, *The ecology of ecosystem services: introduction to the special issue*, "Ecological Economics" 1999 no. 29, p. 179-182; M.A. Wilson, S.R. Carpenter, *Economic valuation of freshwater ecosystem services in the United States 1971-1997*, "Ecological Applications" 1999 no. 9(3), p. 772-783.

[4] R. Costanza et al., *The value of the world's ecosystem services and natural capital*, "Nature" 1997, p. 387-253.

finding that globally 15 of the 24 ecosystem services investigated are in a state of decline, and this is likely to have a large and negative impact on future human welfare[5].

Research into ecosystem services has flourished considerably since the publication of the MA, notably the ongoing Economics of Ecosystems and Biodiversity (TEEB) project which is making a compelling case for promoting conservation, by estimating the economic benefits of ecosystems to human welfare and the economic cost to society of ecosystem decline[6]. The TEEB study identified a set of 22 ecosystem services[7].

In MEA 2005, ecosystem services are divided into four groups: provisioning services, regulating services, supporting services and cultural services[8]. CICES proposes the following classification: provisioning services, regulating and maintenance, cultural services[9].

As a part of a project, partially funded by the European Union, studies were conducted which assessed the connection between ecosystems of larger areas and their capacity and possibilities of delivering environmental services and resources. New maps have been designed for Europe, which illustrate the possibilities of ecosystems for delivering resources and services in the next 20-30[10].

A very significant issue of the discussed concept is the economic pricing of the environmental resources and services of the ecosystems, as well as losses in these services, resulting from their lower quality. One of the most important ecosystems determining the life on Earth is the aquatic ecosystem. Aquatic ecosystems provide services to society, but also make it possible for many terrestrial ecosystems to provide their own services.

The aim of this article is to present the services of surface water ecosystems and the way in which losses in these services are shaped in connection with water resource pollution.

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[5] B. Fisher, R. Kerry Turner, P. Morling, *Defining and classifying ecosystem services for decision making*, "Ecological Economics" 2009 no. 68, p. 643.

[6] D. de Groot, *Protecting natural capital for human wellbeing and sustainable development*, Science for Environment Policy, DG Environment News Alert, Special ISSUE Ecosystem Services, May 2010, p. 1.

[7] TEEB, *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundation*, Earthscan, Cambridge 2010.

[8] MEA, *Ecosystems and Human Well-being: Current State and Trends*, vol. 1, Findings of the Condition and Trends, Working Group of the Millennium Ecosystem Assessment. Island Press Washington, Covelo, London 2005, p. 917.

[9] *Common International Classification*..., op. cit.

[10] *Mapping Europe's potential to provide ecosystem goods and services,* Science for Environment Policy, DG Environment News Alert, Special ISSUE Ecosystem Services, May 2010.

Surface water ecosystems' services

It is estimated, that wetlands occupy over 1,280 million hectares of landmass. These areas include surface waters, such as rivers and lakes as well as swamps and coastal waters (up to 6 m) but also anthropogenic forms such as reservoirs and rice fields[11].

The services of the surface water ecosystems can be discussed in any of the four categories mentioned earlier (Table 1). The most important from the perspective of human existence is the provisioning function. However, the ensuring of this service is often dependent on the regulatory function, which is the ability of waters to self-purification.

Table 1

Types of services of surface water ecosystems

Categories of ecosystem services	Ecosystem services
Provisioning Services	Water (quantity and quality) for consumptive use (for drinking, domestic use, and agriculture and industrial use) Water for non-consumptive use (for generating power and transport/navigation) Aquatic organisms for food and medicines
Regulatory Services	Maintenance of water quality (natural filtration and water treatment) Buffering of flood flows, erosion control through water /land interactions and flood control infrastructure
Cultural Services	Recreation (river rafting, kayaking, hiking and fishing as a sport) Tourism (river viewing) Existence values (personal satisfaction from free flowing rivers)
Supporting Services	Role in nutrient cycling (role in maintenance of floodplain fertility), primary production Predator/prey relationships and ecosystem resilience

Source: *Ecosystems and Human Well-being: Policy Responses, Chapter 7: Freshwater Ecosystem Services,* www.unep.org [07-09-2014].

The possibility of using the services presented in table 1 by the society is dependent on water quality. In years 2000 – 2012 the amount of industrial and municipal sewage discharged into the waters without prior purification was in constant decline (Figure 1). In 2012 the amount was equal only 48% of the sewage discharged in Poland in 2000.

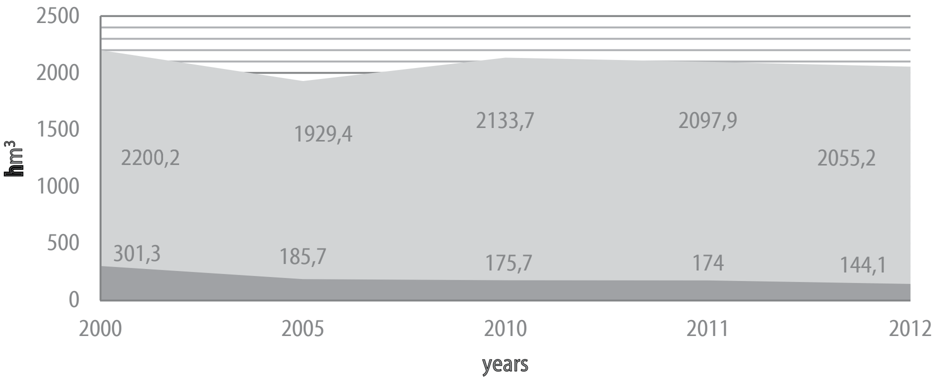
In Poland in 2012 untreated waste was also disposed via the sewage system. 28 hm^3 of waste was disposed of this way, which was 2.2% of all waste disposed of via sewage network[12].

However, from the perspective of losses in aquatic ecosystems, it is not only the amount of waste that is important, but also – and most importantly – the load

[11] MEA, *Ecosystems and Human Well-being: Wetlands and Water Synthesis*, Millennium Ecosystem Assessment, Washington D.C. 2005.

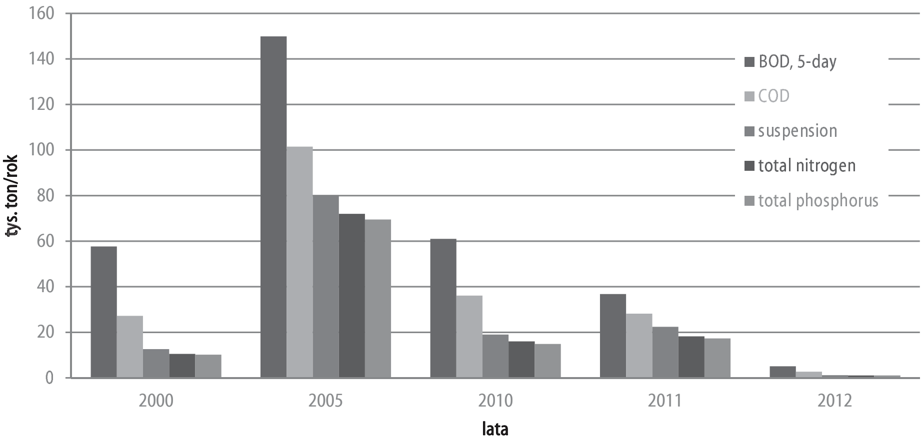
[12] *Ochrona Środowiska 2013*, op. cit.

Figure 1
Industrial and municipal sewage discharged into the waters in Poland in years 2000-2012



Source: own interpretation based on: *Ochrona Środowiska 2013,* Warszawa 2013.

Figure 2
Loads of pollutants discharged in treated waste in Poland in years 2000-2012



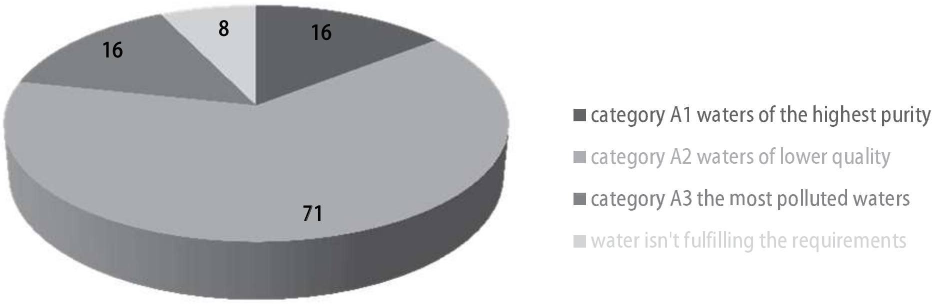
Source: own interpretation based on: *Ochrona Środowiska 2013*, op. cit.

discharged together with the waste. Figure 2 presents pollutant loads from treated waste in Poland in years 2000-2012.

Waste discharged into surface waters are a mixture of municipal and industrial waste. Based on the data published in the CSO (Central Statistical Office) statistical yearbooks[13] we can conclude that the untreated communal waste contribute to approximately 80%, and industrial to approximately 20% of the

[13] Based on average amounts in years 2000-2012 from: *Ochrona Środowiska,* op. cit.

Figure 3
The number of measurement points for water quality in the categories of water quality in year 2012



Source: *Ochrona środowiska 2013...*, op. cit.

amount of waste disposed of directly into surface waters without prior treatment. The analysis of statistical data has also shown that the largest amount of untreated waste comes from the food industry (excluding mining, which disposes mainly saline mine waters, in which the content of chlorides and sulphates is measured). An often used index of waste pollution is the 5 days biochemical oxygen demand (BOD5). Having the general amount of waste and wanting to determine approximate pollutant load amounts for BOD5 in the waste discharged into waters, it can be assumed that the concentration of pollutants in municipal waste is 333mg·dm-3, whereas in case of industrial waste it reaches 1000 mg·dm-3. While the composition of municipal waste is fairly constant, the concentration of pollutants in industrial waste is highly varied, which is why the assumption made above is just an approximation.

As it was mentioned before, the most analysed functions of ecosystems are the provisional functions, the most important of which is providing drinkable water. According to the laws in Poland and the European Union, drinking water is examined in three categories A1, A2 and A3[14]. The results of the analyses of water quality in relation to the category of drinking water are presented in figure 3.

Surface waters, which are or can be used as a source of drinking water, are divided into three categories: A1, A2 and A3. The A1 category includes waters of the highest purity, requiring only basic physical treatment through filtration and disinfection. The A2 category includes waters of lower quality, requiring multistage physical and chemical treatment, especially the occurrence of oxidation, coagulation, flocculation, decantation, filtration and disinfection. The A3 category

[14] Regulation of the Minister of Environment on the day of 27 November 2002 regarding the requirements, which should be fulfilled by surface waters used for providing people with water for consumption ("Journal of Laws" No 204, item. 1728).

includes the most polluted waters, requiring highly efficient physical and chemical treatment[15].

Disposal of waste into waters makes these water impossible to be used as sources of drinking water or increases the cost of benefiting from such service. In Poland, according to data of the Main Inspectorate for Environmental Protection on the basis of the results of the National Environmental Monitoring, in 2012 only in 16 locations, out of 111 water supplies, the quality of water was that of A1 category, which meant it could be used for drinking water provisioning with no additional cost. In 8 locations, the water did not fall into any of the mentioned categories.

Discharge of waste into surface waters, especially those not treated or treated insufficiently, causes losses in the possibility of utilising the water aquatic ecosystem services. Ecosystem services and these losses can be estimated, based on the six major economic valuation techniques when market valuations do not adequately capture social value:

- Avoided Cost,
- Replacement Cost,
- Factor Income,
- Travel Cost,
- Hedonic Pricing,
- Contingent Valuation [16].

Monetary values for fresh water (rivers, lakes) ecosystems service are presented in table 2.

Table 2

Monetary values for fresh water (rivers, lakes) ecosystems service per biome [values in Int.$/ha/year,2007 price levels]

Provisioning services	food	106
	water	1808
Regulating services	waste treatment	187
Cultural services	recreation	2166

Source: R. de Groot et al., *Global estimates of the value of ecosystems and their services in monetary units,* "Ecosystem Services" 2012 no. 1, p. 50-61.

In table 2 are presented monetary values based on The Ecosystem Service Valuation Database (ESVD). The ESVD is a relational database, which links information on the publication, with the value estimates and the case study locations.

[15] Ibidem.

[16] S.C. Farber, R. Costanza, M.A. Wilson, *Economic and ecological concepts for valuing ecosystem Services*, SPECIAL ISSUE: The Dynamics and Value of Ecosystem Services: Integrating Economic and Ecological Perspectives, "Ecological Economics" 2002 no. 41, p. 375-392.

De Grot presenting valuation of fresh water ecosystems services used 665 values from ESVD. The geographic distribution of the valuation data included in the database shows a distribution over the continents: 28% from Asia, 26% from Africa, 14% from Europe, 12% from Latin America and the Caribbean, 12% from North America, and 8% from Oceania[17].

Loss estimates in aquatic ecosystem services

Each person who benefits from the values and resources of surface water ecosystems, perceives the losses connected with the inability or limited ability to benefit from the ecosystem services differently. The size of these losses will vary depending on the section of the economy utilizing the polluted water resources. Taking this into account, the loss criterion caused by water pollution is divided into the following groups:

- Losses resulting from providing people with water,
- Losses in industry,
- Losses in agriculture and silviculture,
- Losses in fishery economics,
- Losses in aquatic constructions,
- Losses connected with sport and leisure,
- Losses connected with widespread using of water,
- Losses resulting from the decreasing ability of waters to self-purify,
- Losses resulting from the destruction of nature and landscape[18].

In order to estimate the losses in aquatic ecosystem services existing methods of pricing environmental resources and services can be used, which include the direct and indirect estimate methods, and calculations utilising item indicators.

One of the frequently used methods is the indicator method. This method utilizes determined unit costs connected with additional actions related to utilizing water resources or estimates the incurred losses in relation to a natural unit i.e. one m^3 of polluted water, one kg of pollutant load. Such indicators are suggested by Miłaszewski[19], Famielec[20], Małecki[21].

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[17] R. de Groot et al., op. cit.

[18] A. Symonowicz, *Straty wynikające z zanieczyszczenia zasobów wodnych i niewłaściwej nimi gospodarki*, in: *Ekonomiczne problemy ochrony środowiska*, Materiały Sesji Rady Zarządu Głównego Ligi Ochrony Przyrody, Warszawa 1983, p. 53-56.

[19] R. Miłaszewski, *Pertes economiques resultant de la pollution des eaux de surface*, „Ekonomia i Środowisko" 2013 no. 2(45), p. 37; R. Miłaszewski, K. Rauba, *Koszty środowiskowe spowodowane zanieczyszczeniem wód powierzchniowych*, Materials from Nationwide Symposium „Hydroprezentacje IX 2006, Śląska Rada NOT-FSNT, Katowice 2006.

[20] J. Famielec (ed.), *Straty gospodarcze spowodowane zanieczyszczeniem środowiska naturalnego w Polsce w warunkach transformacji gospodarczej,* cz. 1, Kraków 2001.

[21] P. Małecki, *Straty ekologiczne powodowane zasoleniem Wisły w regionie krakowskim*, rozprawa doktorska, Kraków 2002.

As mentioned earlier, an important provisioning service of aquatic ecosystems is providing people with drinking water. Due to using category A2 and A3 waters for drinking purposes, waters not fulfilling the requirements of any category, units providing the service of supplying drinking water have to bear additional cost of water purification. These costs can be understood as losses related to the waters' limited ability to fulfil its provisioning function. A loss would be the cost of removing pollutants to a concentration respective to A1 category. These losses can be determined based on unit costs of water purification using specific methods of pollutant reduction.

Another provisioning function of aquatic ecosystems is providing us with aquatic organisms. Fishing losses can be observed, when the quality of the water makes it unable for fish to inhabit a certain area, or there is a decrease in the fish mass. The loss in this service can be identified as loss of income based on the difference between the amount of fish caught in good quality waters and waters polluted by waste, in which the concentration of pollutants makes it impossible for fish to live. Unit indicators related to such losses are described in other texts[22].

The indicator method can also be used in relations to estimating the losses resulting from a limited regulatory function of an aquatic ecosystem, which is self-purification. The costs connected with the decrease in water's ability to self-purify are resulting from discharging additional loads of pollutants into water-dwellings and watercourses. Self-purification of water can only occur up to a certain borderline amount of pollutants. The losses are therefore generated by insufficiently treated or completely untreated waste. In order to estimate such losses, it can be assumed that the losses connected to the introduction of an additional load of pollutants into the surface waters corresponds to the costs required to reduce it. The average cost of removing of 1 kg of pollutant load by a water treatment facility can be assumed as a unit loss indicator[23].

Another of the ecosystem services are also the cultural services, which mainly are connected to tourism. In this case, the losses depend on the function of a given water-dwelling or watercourse (whether it is a bathing location, or used for sailing or recreational fishing). The losses will be resulting from the decrease in the number of tourists using a given resource. The losses in this service can be determined through analyzing current data In order to establish how many tourists have resigned from coming to a given water-dwelling due to its increasing pollution and multiplying that number by the amount of money each tourist would have spent. The losses connected with tourism will occur for example, when the waters, due to the waste being discharged into them, cannot fulfil the conditions of bathing waters anymore. The losses can also be observed, when the quality of water will not allow for the existence of fish, which in turn will make it impossible for the waters to serve their recreational function i.e. fishing[24].

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[22] *Straty gospodarcze spowodowane…*, op. cit.

[23] E. Rauba, *Metoda określania opłat za usługi wodne*, rozprawa doktorska, Warszawa 2006.

[24] R. Miłaszewski, *Zastosowanie modeli decyzyjnych w programowaniu inwestycji ochrony wód*, „Materiały Badawcze, Seria: Gospodarka Wodna i Ochrona Wód" 1993 no. 15.