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Changes in sewage management in Poland in the years 1990-2012 and their consequences

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***Abstract**. The article reports on the changes which have taken place in sewage management in Poland since 1990. The amount of industrial and municipal sewage which needed treatment was observed to have declined from 4.11 km^3 down to 2.50 km^3 in a year. Furthermore, changes in wastewater structure were analysed with respect to the degree and methods of treatment. The amount of untreated wastewater was reported to have decreased considerably from 33 to 6.6%, whereas the share of wastewater treated with heightened removal of biogenes was found to have increased. That resulted from the construction of new sewage treatment plants, particularly municipal ones whose number rose from 588 up to 3191. Individual household sewage treatment plants became a new trend in wastewater management (over 57 thousand plants were constructed in the years 1994-2012). Financial outlays directed to sewage management and their structure were presented. The rising role of foreign subsidies whose share in total costs increased from some to over 30% in the years 2000-2012. The final part of the article indicates that despite considerable financial outlays and improvements in surface water quality there is still a relatively big inflow of polluted rivers into the Baltic Sea. In general, the load of nitrogen (from 100 to 200 thousand tons a year) remains at the same level as 20 years ago. This proves that the problem of water pollution with biogenic substances in rural areas is still unsolved. These substances are currently the main "sources" of the inflow of biogenes into river and lake waters, and consequently to the Baltic Sea.*

***Keywords:** pollution, wastewater, sewage, protection of water.*

Introduction

The early 1990s witnessed political and economic transformations in Poland. The environment was in a poor condition with particularly strong pollution of surface waters. With respect to physicochemical properties, over 35% of the total length of rivers was considered excessively polluted (did not meet any norms). More than 80% of rivers did not comply with sanitary norms [4]. In the period 1991-1995 over a third of the number and total volume of the studied lakes did not comply with any norms. Merely 1.5%. of the lakes belonged to the first class of purity [6]. The content of total phosphorus was high (mean 1.65 mg P·dm^{-3}, up to 8.20 mg P·dm^{-3} maximum). So was the content of total nitrogen (mean 2.25 mg N·dm^{-3}, up to 22.05 mg N·dm^{-3} maximum) and chlorophyll "a" (mean 29.5 mg·dm^{-3}, up to 263.2 mg·dm^{-3} maximum). Furthermore, water transparency was low, and equaled 1.6 m on average, and below 1.0 m in numerous lakes [2]. Many lakes lost their recreational value which brought about crisis in the tourist sector in the lakelands. Such big pollution resulted from untreated or only mechanically treated wastewater having been discharged into surface waters. As many as 289 lakes received point discharges of sewage, and the discharge of the load of pollutants expressed in BZT_5 reached over 100 tons O_2 per day. At present no sewage is discharged into lakes from the point sources of pollution.

In the years 1990-2003 Poland received 7 billion euro from the European Commonwealth (later the European Union) within the pre-accession funds. It was a non-refundable financial assistance directed through special programmes at the future member of the European Union. These funds were to prepare Poland for membership in the European Union, and help to balance economic differences. As a member of the European Union since 2004 Poland has benefited from structural funds and the Cohesion Fund. A significant part of the pre-accession and post-accession (membership) fund was and still is directed to environmental protection, including water protection and sewage management. European funds may only constitute a part of the means devoted to an investment, and the rest must come from national sources. The integration of Poland with the countries of the European Union, and the introduction of the Water Framework Directive, have all contributed to the improvement of surface water quality [7].

The ecological fund constitutes an important national source of financing, among others. It is accumulated from the fees charged for using natural environment and introducing changes into it, including the intake and exploitation of waters and discharging wastewaters.

The article presents changes in sewage management in Poland since 1990, the costs of their implementations, and the most important ecological consequences. It also shows further directions of activities in order to obtain a good ecological condition of waters.

Materials and methods

This study was prepared on the grounds of the statistical information over the period from 1990 to 2012 gathered from the Central Statistical Office in Poland [5]. Moreover, some data found in the publications of the Chief Inspectorate of Environmental Protection in Warsaw [6] were also used. A database concerning

wastewater management in Poland over the last 23 years was developed to include information on, among others:

- quality of rivers controlled according to a physicochemical criterion
- industrial and municipal wastewater requiring treatment and getting discharged into surface waters
- financial outlays for fixed assets to be used in sewage management
- financial outlays for fixed assets to be used in sewage management according to the directions of investments and financing sources
- pollutant loads introduced from the drainage basins of the Vistula and the Oder rivers, and the littoral rivers into to the Baltic Sea

The dataset concerning particular issues made it possible to determine the trends of changes in sewage management in Poland, and evaluate them.

Results and discussion

The amount of industrial and municipal sewage declined rapidly over the period from 1990 to 2000 (from 4.11 km^3 in 1990 down to 2.50 km^3 in 2000). Wastewater is discharged into surface waters, and in lower quantities into the ground [5]. The decline in the amount of sewage resulted from decreasing amount of water intake for industrial and municipal purposes. These two processes were related to the liquidation of unprofitable industrial enterprises, the introduction of modern technologies into industry (including closed water cycle systems), and a more widespread trend to save water after introducing water meters in households and increasing the price of water. Over the next years (2001-2012) the amount of industrial and municipal wastewater stabilised within the range from 2.3 to 2.1 km^3 (Fig. 1).

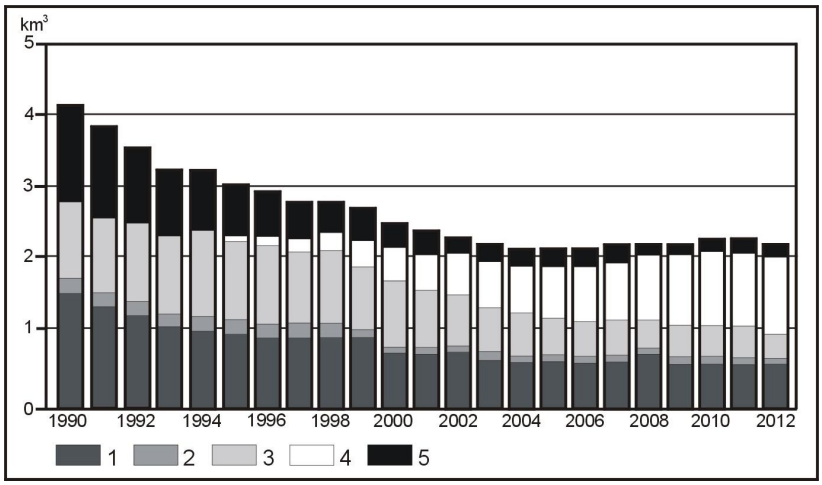

Fig. 1. Industrial and municipal wastewater requiring treatment discharges into waters or into the ground in the years 1990-2012. Explanations: 1. wastewater treated mechanically; 2. wastewater treated chemically; 3. wastewater treated biologically; 4. wastewater treated with increased biogene removal; 5. non-treated wastewater. Compiled on the grounds of the Statistical Information and Elaborations – Central Statistical Office in Warsaw.

During the analysed period there was a change in the structure of wastewater with respect to the degree and method of treatment. In 1990 as much as 1.34 km^3 of wastewater remained untreated (i.e. 33% of the total). This amount declined down to 0.3 km^3 in 2000 (14.1%) and down to 0.14 km^3 (6.6%) in 2012 [5]. So did the amount of wastewater treated only mechanically (from 1.46 km^3 to 0.57 km^3 in the years 1990-2012). The positive changes observed in wastewater structure included systematic increase in the share of sewage treated with increased biogene removal, from approx. 2% in 1995 to 47.6% in 2012 (Fig. 1). This change is particularly important when surface waters are generally endangered by eutrophication, and when it is necessary to restrain that threat.

Reducing untreated wastewater and increasing the amount of sewage treated with increased biogene removal could be achieved due to the construction of new sewage treatment plants and modernization or liquidation of outdated treatment plants. In the years 1990-2012 the total number of sewage treatment plants increased from 2885 to 4284 [5]. Yet, at the beginning of this period that number declined due to the liquidation of outdated plants, particularly in the group of industrial treatment plants (Tab. 1).

The number of industrial wastewater plants decreased by over a half. Some got liquidated alongside industrial enterprises or because new sewage treatment sub-plants opened up (these are not discussed in the article) from which wastewater is directed to municipal sewage treatment plants. However, the number of municipal sewage treatment plants rose several times from 588 to 3191 [5]. Among these there were 820 new plants with increased biogene removal, and nearly 2000 new biological treatment plants (Tab. 1).

Table 1.

Changes in the number and types of sewage treatment plants in the years 1990-2012. Symbols: ME – mechanical; CH – chemical; BI – biological; IBR – with increased biogene removal. Compiled on the grounds of the Statistical Information and Elaborations – Central Statistical Office in Warsaw.

Year	Total	Sewage treatment plants									
		industrial					municipal				
		total	ME	CH	BI	IBR	total	ME	CH	BI	IBR
1990	2885	2297	nd	nd	nd	0	588	205	0	382	0
1995	2825	1599	515	144	940	0	1226	174	6	977	69
2000	4043	1626	601	133	860	32	2417	135	17	1844	421
2005	4257	1326	463	130	768	55	2931	86	0	2125	720
2010	4291	1155	389	114	602	50	3136	59	0	2263	814
2012	4284	1093	367	104	575	47	3191	55	0	2316	820

Municipal sewage treatment plants were constructed predominantly in rural areas and in smaller towns where they did not exist at the start of the 1990s. These are, however, small plants of the capacity of <500 m^3 per 24 hours. Currently, they constitute approximately 58% of all municipal sewage treatment plants.

In recent years the number of individual household sewage treatment plants has been rising, particularly in the rural areas with dispersed settlement. Most of them were constructed in 2011 (Tab. 2). In total, 57677 individual household sewage treatment plants were built in the years 1994-2012 [5]. They are of a total capacity reaching nearly 90 thousand $m^3 \cdot day^{-1}$ (this capacity corresponds to the capacity of a sewage treatment plant operating in a town of 250 thousand inhabitants). The biggest number of individual household sewage treatment plants was built in the central part of Poland, in fact in the areas which are predominantly agricultural [1]. These objects play an important role in the protection of waters in the rural areas, and especially in protecting waters against eutrophication.

Table 2.

Number of individual household sewage treatment plants in the selected years in the period 1994-2012 and their total capacity ($m^3 \cdot day^{-1}$).

Year	1994	1997	2000	2003	2006	2009	2010	2011	2012
Number	55	875	578	1150	1815	3128	10159	14688	11791
Capaciti	·	1472	502	1188	2214	4272	19250	28492	22657

Numerous investments in wastewater management required high financial outlays. Four characteristic periods of outlays for fixed assets applied to sewage treatment can be distinguished in the years 1990-2012. In the first period (1990-1999) financial outlays increased from approx. PLN 200 million to PLN 3700 million. In the years 2000-2005 investment stabilised at the level of approx. PLN 3250 million. In 2005 another period with increasing financial outlays began which lasted up to 2010 when this investment reached the value of over PLN 7206 million [5]. Since 2010 financial outlays have been declining (Fig. 2). That fall results from reaching a relatively good condition of infrastructure in wastewater management, though there are still various needs in the field. Generally unsatisfactory condition of surface waters in Poland proves this fact.

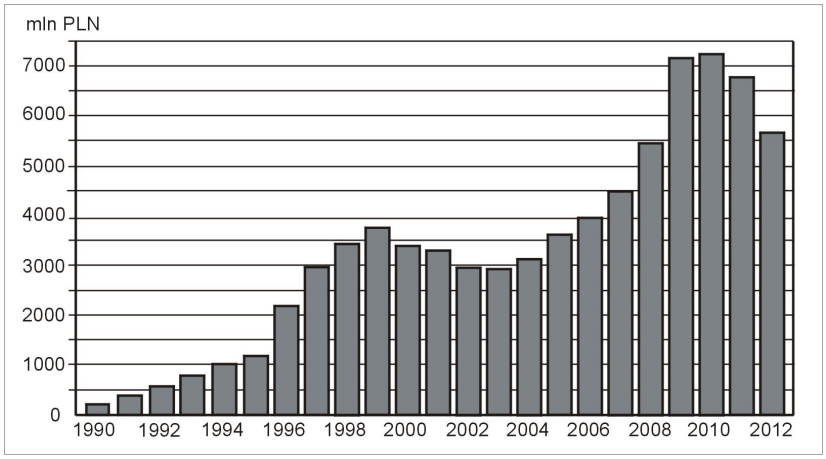

Fig. 2. Structure of outlays on fixed assets in wastewater management in the years 1990-2012 (current prices).

Considerable increase in financial outlays for sewage treatment involved finding appropriate funds. Most money came from the so-called own funds of administrative units, such as towns and gminas. The ecological fund also constitutes a very significant financing source. It is accumulated from the fees charged for using

natural environment in any way, and introducing changes into it. Yet, undoubtedly financial means obtained from abroad, mainly from the European Union (Tab. 3), belong to the most important support. Their share increased from several up to nearly 30% of the total funding.

Table 3.

Financial outlays for fixed assets in wastewater management according to the sources of financing in the years 2000-2012

Specification	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
total (mln PLN)	3341	3277	2834	2915	3127	3616	3939	4477	5433	7120	7206	6753	5657
own funds (%)	48.3	50.7	45.6	40.1	40.5	40.8	39.1	41.3	42.5	35.0	36.2	39.4	37.7
from abroad (%)	4.2	2.3	3.2	13.4	16.7	21.7	25.9	20.4	21.3	24.0	26.8	26.5	30.1
from budget (%)	7.0	6.0	6.2	3.8	2.6	2.6	2.6	2.5	3.4	3.3	3.7	5.5	5.1
ekological funds (%)	26.1	28.2	32.8	29.2	27.3	24.1	19.6	22.9	19.2	22.3	16.0	15.4	16.8
domestic credits (%)	6.8	6.9	6.4	7.4	7.5	7.0	8.9	9.1	9.3	11.4	15.1	11.1	8.6
other funds (%)	7.6	5.9	5.8	6.1	5.4	3.8	3.9	3.8	4.3	4.0	2.2	2.1	1.7

Costs incurred for sewage management comprise the construction of new sewage treatment plants and development of sewerage systems where wastewater is carried off to a sewage treatment plant, and where precipitation water is drained. In the years 1997-2012 financial outlays for sewerage systems increased three times, from PLN 1184 million to PLN 3486 million annually [5]. At the same time financial outlays for drain systems grew faster out of proportion from PLN 146 million to PLN 839 million annually (Fig. 3).

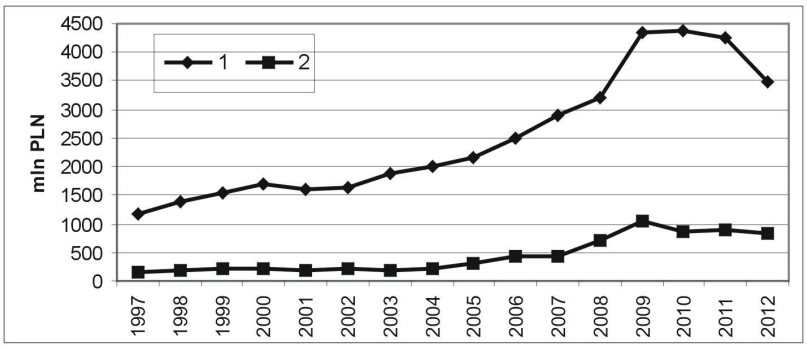

Fig. 3. Financial outlays for the construction of sewage and rainwater drainage systems. Explanations: 1. sewage drainage systems; 2. rainwater drainage systems. Compiled on the grounds of the Statistical Information and Elaborations – Central Statistical Office in Warsaw.

Despite that, there is still definite dominance of urbanized areas where sewerage system is shared by sewage and precipitation waters. This unnecessarily increases operating costs for sewage treatment plants where precipitation water is discharged. Precipitation water does not require such a high level of treatment as municipal or industrial wastewater. The share of precipitation waters in sewage discharged into treatment plants may exceed 10% in particular years [3].

Have positive changes in sewage management in Poland contributed to improving the quality of surface waters in any way? In order to answer that question it is necessary to analyse changes in the quality (pollutants) of the main rivers which run off into the Baltic Sea. Such an analysis can be carried out for the period 1990-2003 during which rivers were classified according to Polish methodology. Waters were classified into one of the three purity classes (class I – the best) independently according to a physicochemical criterion, and according to a biological one. Excessively polluted waters, which are of practically no economic importance were defined as those not fulfilling the norms. Since 2004 the quality of rivers is classified according to the EU Water Framework Directive, and its results are incomparable.

Sections of the main Polish rivers were systematically examined in the years 1990-2003. The total length ranged from 9122 to 6175 km, and since 1993 the total length of the studied rivers has been almost the same. 43-33% of river waters classified according to a physicochemical criterion were considered to be excessively polluted in the years 1990-1995 (Fig. 4). That percentage declined to 13% in 2003 as a result of the positive changes in sewage management presented above. Unfortunately during the analysed period the proportion of waters of the best quality (class I) did not grow. They constituted merely from approx. 2 to 7%.

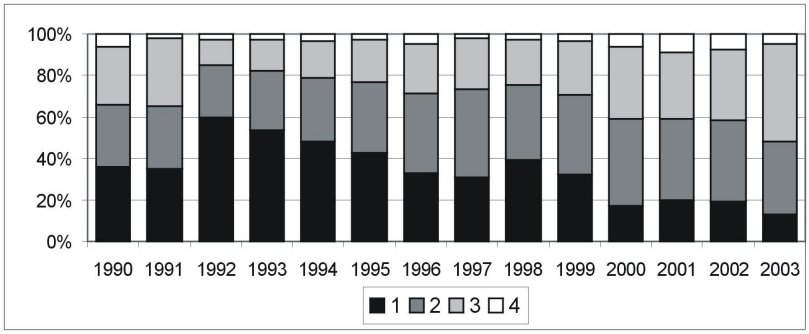

Fig. 4. Quality of river waters according to the physicochemical criterion in the years 1990-2003. Explanations: 1. excessively polluted waters, which do not fall into any quality class; 2. third class of quality; 3. second class of quality; 4. first class of quality. Compiled on the grounds of the Statistical Information and Elaborations – Central Statistical Office in Warsaw.

The share of waters classified into the purity class III stayed at a similar level (30-43%). However, the proportion of waters of the purity class II rose from approx. 20 to 47%.

With respect to the biological criterion, the classification of river waters in Poland is noticeably worse. Faecal coliform bacteria is the main parameter that is considered. According to these criteria, 80-84% of river waters did not comply with any norms in the years 1990–1997 [6]. The situation slightly improved in the subsequent years, when the share of excessively polluted waters determined according to a biological criterion lowered down to 40% in 2002. At the same time the proportion of waters of the purity class III rose to approx. 50%. Declining pollution of surface waters in Poland contributes to reducing the amount of pollutants discharged in the Baltic Sea. The evaluation of the load of pollutants discharged into the Baltic Sea in the years 1990–2012 may, therefore, be very useful in drawing conclusions on the effects of changes in sewage management over that period. These effects are definitely satisfactory in the case of some elements, including heavy metals. The annual loads of zinc, lead or cadmium introduced through rivers into the Baltic Sea declined significantly in the years 1990–2012 (Fig. 5).

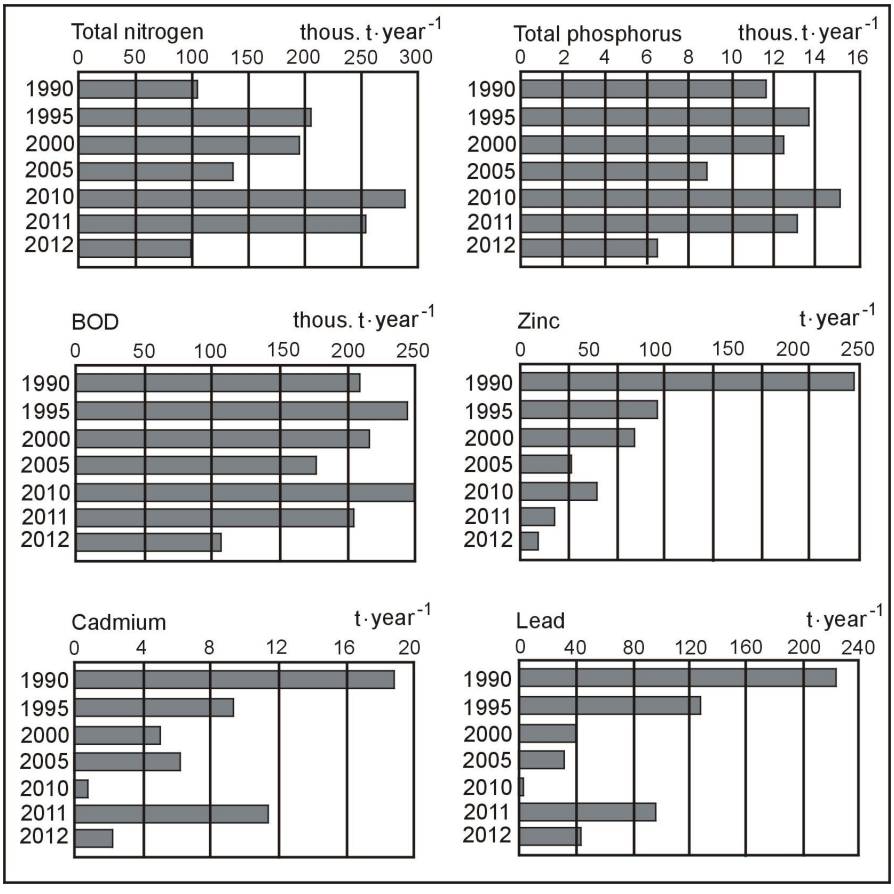

Fig. 5. Pollutant loads introduced into the Baltic Sea through rivers from the drainage basins in Poland in the hydrological years 1990-2012. Compiled on the grounds of the Statistical Information and Elaborations – Central Statistical Office in Warsaw.

Unfortunately these positive changes did not take place in the case of biogenic substances. Nitrogen in the yearly amount of 100 thousand tons, and even over 200 thousand tons in some years is discharged from Poland into the Baltic Sea. This means that despite considerable restraint of pollutants coming from urbanized areas and industrial enterprises, reduction of biogenic substances remains an unsolved problem. These substances flow into rivers and lakes from agricultural areas avoiding wastewater treatment plants, and they belong to the so-called “non-point pollution” group which is difficult to eliminate mechanically. Therefore, in the coming years more attention and more funds should be devoted to rural areas, which pose the biggest threat to surface and ground waters. Intensified works on the construction of sewerage systems in rural areas must result in further improvement. These investments are of the first priority at present, and they contribute to the improvement of living conditions for rural population.

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Аннотация. *В. Маршэльэвски, А. Пиасэцки* ***Изменения в экономике сточных вод в Польше в периоде 1990-2010 и их последствия.*** *В статье представлены изменения, которые произошли в экономике сточных вод в Польше после 1990г. Обращено внимание на уменьшение количества стоков промышленных предприятий и коммунальных стоков, требующих очищения, с 4,11 км^3 до 2,5 км^3 в течение года. Проведен анализ изменения структуры сточных вод в отношении степени и способов очистки. Подчеркнуто существенное снижение количества неочищенных сточных вод (с 33 до 6,6 %), а также увеличение объема очищенных сточных вод с повышением степени удаления биогенов. Это стало возможным благодаря строительству новых очистных сооружений для сточных вод, в том числе, особенно коммунальных, общее число которых выросло с 588 до 3191. В число направлений в экономике сточных вод включено строительство очистных сооружений для жилых домов (свыше 57 тысяч штук в период с 1994г. до 2012г.) Представлены также величина и структура капиталовложений в экономику сточных вод, а также указана роль средств из-за рубежа, доля которых в общих расходах в период с 2000 по 2012г. возросла от нескольких процентов до более 30_%. В конце статьи подчеркнуто, что, несмотря на большие финансовые расходы и улучшение качества поверхностных вод, по-прежнему удерживается относительно большой приток загрязнений из рек, впадающих в Балтийское море, а количество азота (со 100 до более 200 тысяч тонн ежегодно) в основном сохраняется на том же уровне, что и 20 лет тому назад. Это свидетельствует о том, что еще осталась неразрешенной проблема загрязнения вод биогенными веществами на сельскохозяйственных площадях, которые являются главным источником притока биогенов в воды рек и озер, а впоследствии в Балтийское море.*
Ключевые слова: *загрязнения, сточные воды, охрана вод.*

Анотація. *В. Маршельевскі, А. Піасецкі* ***Зміни в економіці стічних вод у Польщі в періоде 1990-2010 та їх наслідки.*** *У статті представлено зміни, які відбулися в економіці стічних вод в Польщі після 1990р. Звернуто увагу на зменшення кількості стоків промислових підприємств і комунальних стоків , що вимагають очищення, з 4,11 км3 до 2,5 км3 протягом року. Проведено аналіз зміни структури стічних вод щодо ступеня і способів очищення . Підкреслено істотне зниження кількості неочищених стічних вод (з 33 до 6,6 %) , а також збільшення обсягу очищених стічних вод з підвищенням ступеня видалення біогенів. Це стало можливим завдяки будівництву нових очисних споруд для стічних вод, у тому числі, особливо комунальних , загальне число яких виросло з 588 до 3191. У число напрямків в економіці стічних вод включено будівництво очисних споруд для житлових будинків (понад 57 тисяч штук в період з 1994р. до 2012р.) Представлені також величина і структура капіталовкладень в економіку стічних вод, а також зазначена роль засобів за кордону, частка яких у загальних витратах в період з 2000 по 2012р. зросла від декількох відсотків до більше 30%. У кінці статті підкреслено , що , незважаючи на великі фінансові витрати і поліпшення якості поверхневих вод, як і раніше утримується відносно великий приплив забруднень з річок, що впадають у Балтійське море, а кількість азоту (з 100 до понад 200 тисяч тонн щорічно) в основному зберігається на тому ж рівні, що і 20 років тому. Це свідчить про те, що ще залишилася невирішеною проблема забруднення вод біогенними речовинами на сільськогосподарських площах, які є головним джерелом припливу биогенов у води річок і озер, а згодом у Балтійське море .*
Ключові слова: *забруднення, стічні води, охорона вод.*

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