ECONSTOR
Make Your Publications Visible.

A Service of

ZBW Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Mesjasz-Lech, Agata; Bajdur, Wioletta M.

Conference Paper

Assessment and analysis of the application of sewage treatment technologies in Poland

53rd Congress of the European Regional Science Association: "Regional Integration: Europe, the Mediterranean and the World Economy", 27-31 August 2013, Palermo, Italy

Provided in Cooperation with:
European Regional Science Association (ERSA)

Suggested Citation: Mesjasz-Lech, Agata; Bajdur, Wioletta M. (2013) : Assessment and analysis of the application of sewage treatment technologies in Poland, 53rd Congress of the European Regional Science Association: "Regional Integration: Europe, the Mediterranean and the World Economy", 27-31 August 2013, Palermo, Italy, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:
https://hdl.handle.net/10419/123923

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

WWW.ECONSTOR.EU

Mitglied der Leibniz-Gemeinschaft

Assoc. Prof. Ing. Wioletta M. Bajdur Ph.D.
Assoc. Prof. Agata Mesjasz-Lech Ph.D.
Częstochowa University of Technology, Faculty of Management

Assessment and analysis of the application of sewage treatment technologies in Poland

Abstract

Environmental pollution is a serious problem in highly industrialized countries, as it may pose a threat to the human health and life. For these reasons, entities responsible for polluting the environment and its natural resources undertake pro-environmental actions that involve reduction of the negative impact of the activities of human beings and businesses on the environment. Such activities are aimed at the application of low and no-waste technologies. Unfortunately, it is impossible to completely eliminate pollution from the human activity. This article focuses on sewage treatment technologies, the purpose of which is to eliminate the already existing pollution. Therefore, the analyses were limited to water and sewage treatment technologies, as the growing demand for water, its constantly deteriorating purity and requirements as regards its quality, force changes in the water resources management system.

In various provinces in Poland, environmental protection is being implemented more or less successfully. It is necessary to apply the principles of environmental protection to the human behavior and activity of business entities, because there are more and more activities particularly harmful to the natural environment. The implemented modern technologies aimed at the elimination of (or eliminating) the negative impact of human and business activities on the natural environment, are bringing the desired results as far as the protection of individual natural resources is concerned. One of the fundamental imperfections of the market is a lack of environmental resources, such as air or water. Inability to define the economic value of the natural resources results in their constant, excessive exploitation and degradation. However, the growing awareness of the environmental issue in Poland is resulting in the application of technologies that protect individual natural resources.

This paper attempts to determine the measures of pro-environmental activities in the scope of sewage treatment, undertaken on the territory of individual provinces, and to classify the provinces in accordance with the achieved level of application of sewage treatment technologies. For this purpose one has used the numerical taxonomy methods, and in particular the methods of linear ordering of objects (that involve projection of the objects

from a multidimensional space of features onto a straight line), called the methods of multidimensional comparative analysis. The measures were designed based on available statistical data from 2011. The purpose of this article is to find out which provinces are similar to each other in terms of the application of sewage treatment technologies, and to find a province that has managed to achieve the best results in this regard.

Keywords: environmental pollution, sewage treatment, multidimensional comparative analysis.
JEL code: F64

Introduction

Threat to human existence on Earth, observed increasing pollution of the environment as well as uncontrollable increase in the consumption of electricity in the highly industrialized countries, develop a new, superior canon – dogma, which is a low and no-waste technology. Although the concept itself appeared to be quite obvious from the very beginning, the practice proved that it was difficult to support it with concrete results of the scientific research, especially when one considers the technologies and their impact on the environment in global terms.

A growing demand for water, its constantly deteriorating purity and requirements as regards the quality of not only the drinking water, force changes in the water resources management system. Therefore, it is necessary to manage water more efficiently and reuse it. Due to a limited access to water that can be used without pretreatment and increasing requirements as regards the quality of the sewage disposed to watercourses, one can see an increased interest in modern materials and solutions that would accelerate the process of sewage treatment, reduce the moisture in sludges, and dewater or filter the sludges. Water pollution takes the form of suspensions or solutions, including colloidal solutions with the size of particles of above one micrometer, of usually negative charge. The described pollution is usually removed in the process of filtration, coagulation, flocculation, sedimentation, flotation and disinfection.

In the process of sewage and water treatment, coagulation is still of key importance. Polyelectrolytes are the compounds that support the process of coagulation.

Application of inorganic chemical compounds (coagulants) to carry out the process of coagulation as far as the sewage treatment is concerned dates back to the second part of the

19th century. At the beginning of the 20th century, as a result of the general application of biological sewage treatment methods, the chemical treatment lost its importance mainly because of the necessity to use large dosages of chemicals and consequently due to the increased operating costs.

In the eighties, due to an increased concentration of organic compounds, nitrogen, phosphorus and heavy metals in water, the chemical and biological methods were used in parallel, in order to reduce the concentration of pollutants in the sewage discharged into the receiver.[1]

One can notice that in an increasing number of cases, chemical and biological technologies are used to ensure an effective sewage treatment. A combination of these technologies usually improves the quality of the water obtained in the sewage treatment process. Chemical treatment of sewage with metal salts (Fe, Al) contributes to the increase of insoluble pollutants (emitted in the sewage treatment process) of various dispersion states[2] . Coagulation depends on various parameters (physical and chemical composition and temperature of the water, type and dose of the coagulant, hydraulic parameters of the process and many others), and it is a complex process, however it's possible to optimize the above parameters to increase the effectiveness of the process.[3]

Improving the quality of water is usually associated with the necessity to invest in new processes connected with water and sewage treatment. Meanwhile, modernization of the water treatment technologies and selection of coagulants that would ensure a proper course of the entire water treatment process, not only contribute to the final quality of the water, but also reduce the costs

Individual processes applied in water and sewage treatment

The variety of pollutants generally makes it impossible to eliminate them in a single technological process. To achieve particular objectives, it is necessary to combine various technologies and systems, and therefore various sewage treatment processes.

---

[1]Metcalf & Eddy, Wastewater Engineering, Treatment, Disposal and Reuse, McGraw-Hill, Inc., New York, 1991; Murcott S., Harleman D. R. F., Chemically Enhanced Primary Treatment. CEPT. The Water Mirror, The Magazine of the Water Supply from Kemira Kemwater, Conference, Sweden, 1994, p. 3-5; Karlsson J., Chemical Sorage Treatment In Combination With And Wilhoust Biological Treatment. Flocculants. Coagulants And Precipitans In Water Treatment, Conference, Atlanta, Georgia, October, 1994, p. 17-21.

[2]Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Edition 1, Warsas 1996, Edition 5 revised, Warszawa 2007.

[3]Bajdur W. M., Sułkowski W. W., Polyelectrolytes from NS novolak prouction waste, J. Appl. Polym. Sci., 2003, 89, p. 3000-3005.

The processes applied in water and sewage treatment can be divided into physical, chemical and biological ones. These processes can be incorporated into physical-chemical, physical-biological and chemical-biological systems.[4] Each individual process, apart from its key function, also plays an additional role, for example: reduction of pathogenic bacteria and viruses in water.

The following individual processes are usually applied in water and sewage treatment: *1) Aeration and gas stripping.*[5] This method enables one to eliminate from water dissolved gasses (CO_2, H_2S, CH_4 and other compounds that taste and smell) and volatile organic compounds, and to increase the level of oxygen. Elimination of CO_2 leads to increased water pH. Addition of dissolved oxygen to water creates conditions for hydrolysis and oxidation of iron and manganese compounds and prevents development of a reductive environment that negatively affects the taste and smell of water. Aeration is an energy consuming process (e.g. in the sewage treatment plants the requirements of energy for aeration system amount to 50% - 90%).

2) Coagulation. It is a method applied to eliminate from water colloidal fragmented particles. This method ensures destabilization and aggregation of both organic and inorganic colloidal particles, that, by forming larger agglomerates, can be eliminated from water in the process of sedimentation, flotation and filtration. Coagulation may be applied together with filtration.[6] After completion of the coagulation process with the application of aluminium and iron salts, it is usually necessary to bind an aggressive carbon dioxide that gives the water a corrosive character. Coagulation consists of two phases: destabilization and flocculation. In the process of sewage coagulation, polyelectrolytes are used in combination with aluminium sulphate and iron or calcium salts, to support flocculation. The polyelectrolytes are also used to eliminate disruptions in case of sewage treatment carried out at low temperatures.

3) Sedimentation, flotation. These processes ensure elimination of suspensions from raw (untreated) water or water after the process of coagulation or chemical precipitation.[7] During the process of sedimentation, suspensions whose specific gravity is higher than that of water are eliminated. In the process of flotation it is possible to eliminate from water particles of specific gravity lighter or heavier than water, when one applies air to the flotation.

---

[4]Bartkiewicz B., Oczyszczanie ścieków przemysłowych, Wydawnictwo Naukowe PWN, Warsaw 2002.
[5]Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Edition 1, Warsaw 1996, Edition 5 revised, Warsaw 2007.
[6]Bajdur W. M., Eko-polielektrolity syntetyczne redukujące ładunki zanieczyszczeń w ściekach i wodach przemysłowych Wyd. Instytutu Gospodarki Surowcami Mineralnymi i Energią PAN , Kraków 2011.
[7]Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Edition 1, Warsaw 1996, Edition 5 revised Warsaw 2007.

Sedimentation is sometimes replaced by flotation in the water treatment processes, particularly in case of removing the slowly-setting suspensions, like algae or particles coagulated in low-temperature water. Taking into consideration the method of generation of air bubbles (gas), the flotation process can be divided into: pressure and non-pressure flotation, electroflotation, and microflotation - which is an intermediate solution.

4) Filtration. This method eliminates suspensions and associated compounds that pollute water, and the viruses.[8] In terms of water technology, there are two types of filtration (fast and slow). In the recent years a membrane filtration has been applied to disinfect sewage that has previously been treated with mechanical and biological processes. Fast filtration is usually carried out after previous water treatment processes. In some cases, a direct filtration (without previous purification) is carried out through multi-layer filter beds. The effectiveness of slow filtration is a total sum of results obtained during fast filtration and biochemical processes that occur with the participation of saprophytic bacteria in the slow filtration filter bed.

5) Ion exchange. This method is used to eliminate water from dissolved substances.[9] Depending on various types of ion exchange resins, cations or anions are exchanged for active ions of functional groups of ion exchangers. Cation exchangers ensure the exchange of cations, whereas anion exchangers are responsible for the exchange of anions. Application of adequate system of cation and anion exchangers ensure a proper demineralization of water. In Poland ion exchange is applied in the conditioning of water used mainly for industrial purposes (in particular for power engineering) to eliminate compounds responsible for water hardness and to conduct the process of water desalting or demineralization.

6) Chemical precipitation. This method is applied to eliminate certain ions from water. It involves precipitation of poorly soluble compounds of the ions to be eliminated.[10] Precipitating compounds serve as sorbents for other organic and inorganic pollutants as well as for bacteria and viruses. After chemical precipitation (just as in the case of coagulation), it is necessary to conduct the process of sedimentation, filtration or pH correction. The described process in Poland is usually applied in the treatment of water used for industrial purposes. In some cases, chemical precipitation is conducted together with coagulation. In the world, the above process is also used to eliminate excessive carbonate hardness or general hardness of water intended for water supply systems.

---

[8]Toczyłowska B., Skuteczność usuwania zawiesin w złożach filtrów DynaSand i Dynamik, Ochrona Środowiska, 2005, 3, p. 51.

[9]Nawrocki J., Biłozora S., Uzdatnianie wody. Procesy chemiczne i biologiczne, Wydawnictwo Naukowe PWN, Warsaw-Poznań 2000.

[10]Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Edition1, Warsaw 1996, Edition 5 revised Warsaw 2007.

7) Activated carbon sorption. This method is generally applied to eliminate dissolved organic compounds[11], including products of their incomplete oxidation. It is also possible to dechlorinate water with the application of activated carbon. An activated carbon is also effectively used to reduce the amount of pollutants responsible for the taste and smell of water.

8) Chemical oxidation. This method is applied to:[12]

- eliminate coloured compounds and those responsible for taste and smell of water,
- oxidize organic compounds and other compounds which are difficult to eliminate during the individual processes,
- support flocculation,
- oxidize iron, manganese and protective colloids,
- disinfect and incapacitate algae.

The following oxidants are usually applied in the water treatment technology: chlorine, ozone, chlorine dioxide and potassium manganate (VII). Application of chemical oxidation is considered appropriate only in case when it doesn't generate products which are more harmful than oxidized substrates. Due to the possibility of generating the above mentioned harmful compounds, chemical oxidation should be preceded by effective processes the purpose of which is to eliminate pollutants which are precursors of oxidation by-products. Additionally, after chemical oxidation, sorption should be applied to eliminate possible oxidation products.

9) Membrane processes. These processes find their main application in the water desalting process and in special technologies (e.g. technologies used to provide super pure water). In Poland the described processes are not commonly used in the water treatment plants that provide water for water supply systems. In the world there are some water supply plants that use the above technologies. The membrane processes include[13]:

- reverse osmosis (RO),
- electrodialysis (ED),
- reverse electrodialysis (RED),
- ultrafiltration (UF),

---

[11]Chand B.R., Goyal M., Adsorpcja na węglu aktywnym, Warsaw 2009.

[12]Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Edition 1, Warsaw 1996, Edition 5 revised Warsaw 2007.

[13]Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Edition 1, Warsaw 1996, Edition 5 revised Warszawa 2007; Konieczny K., Bodzek M., Zastosowane techniki membranowe – teoria i praktyka, Inż. i Ochr. Środ, 2001, 3-4, p. 413.

– nanofiltration (NF).

Ultrafiltration and nanofiltration are used to eliminate from water coloured compounds, precursors of trihalomethanes (THM) and certain inorganic pollutants (that may cause water hardness) or viruses and bacteria.

Depending on the type of membrane, one can eliminate from water various dissolved impurities and pollutants. However the above processes are usually performed during water desalting. Reverse osmosis achieves the highest value of separation of organic (including bacteria and viruses) and inorganic pollutants. Application of membrane processes requires (considering the protection of the membranes) a preliminary treatment of water to ensure a maximal removal of suspensions, colloids and dissolved additives, which, by concentrating on the membrane surfaces, may "clog" the membrane pores.

10) Disinfection. The purpose of this process is to destroy microorganisms that can be found in water, and to ensure a good sanitary quality of water in the water-pipe network. Disinfection is usually applied in the final stage of the water treatment process. In some cases disinfection agents are added to water at the beginning of the water treatment process, e.g. in the process of intake of water rich in various microorganisms, usually algae. In the above described cases, one has to apply disinfection agents that generate as few disinfection by-products as possible. The purpose of the final stage of disinfection is the destruction of microorganisms that can be found in water after previously conducted treatments, and to protect water against a secondary development of living organisms, mainly bacteria, in the water-pipe network. The effectiveness of disinfection depends on the type of the applied disinfection agent. The following compounds may be used as disinfection agents: chlorine, chloramine-B and chloramine-T, chlorine dioxide, UV radiation, ozone, bromine, iodine. Chlorine is the most common agent. However, it was found that using chlorine as a disinfection agent may result in the development of chlorinated organic compounds. Therefore, currently other disinfection agents are used increasingly more often.[14]

Limited resources of water and a considerable share of the industrial activity in polluting the surface and ground water, pose the main threat to the hydrosphere of our country. Increased danger stimulates progress in research that constitute a basis for the development of technologies used in small and medium-sized sewage treatment plants, in probably one of the fastest-growing sectors of market economy (apart from water supply systems), i.e. in the area

[14]Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Edition 1, Warsaw 1996, Edition 5 revised, Warsaw 2007; Adamski W., Modelowanie jednostkowych procesów oczyszczania wody, Wydawnictwo Naukowe PWN, Warsaw2002.

of environmental protection engineering. We need to bear in mind that water resources in Poland are among the smallest in Europe. Therefore, the analysis of water resources as well as assessment of results of the application of sewage treatment technologies, become an essential decision-making instrument, enabling one to examine the actions undertaken in this respect

Comparative analysis of the scale of the application of sewage treatment technologies in the Polish provinces.

Province is one of the units of the territorial division of Poland. Provinces differ in terms of the level of industrialization, and in consequence in the scale of actions undertaken in the scope of sewage treatment by individual local government units. Hence, it is quite important to assess actions undertaken in particular provinces. The multidimensional data analysis methods may serve as the assessment tool. The multidimensional comparative analysis enables one to compare the objects characterized by several features. It is applied for the analysis of complex phenomena, described with at least two features. This analysis allows one to find out how the situation of particular objects from the analysed territory has developed with respect to each other, in the analysed period[15]. The multidimensional data analysis methods involve taxonomic methods that allow one to:[16]

1. analyse similarities between objects based on determined features (grouping methods),
2. classify objects based on determined features (linear ordering methods).

The features on which the analysis is based form a set of variables.

The linear ordering methods allow one to classify the analysed objects from the best one to the worst one, according to the criterion which is the level of the complex phenomenon. One of the linear ordering methods is the development model method This method is based on variables that serve as stimulants (their increased value may indicate an increased level of the analysed complex phenomenon) or destimulants (their decreased value may indicate an increased level of the analysed complex phenomenon). The values of the variables are standardized. The development model method has been implemented in three stages:

1. determination of an abstract object, the so-called development model with the best values for each variable,

[15]Zawada M., Zastosowanie wybranych metod wielowymiarowej analizy statystycznej w procesie inwestowania na rynku kapitałowym w Polsce, [in:], Nowoczesne instrumenty zarządzania, scientific editor Mesjasz-Lech A., Sekcja Wydawnictw Wydziału Zarządzania, Częstochowa 2009, p. 73.

[16]Dziechciarz J. (Ed.), Ekonometria, Wydawnictwo Akademii Ekonomicznej im. Oskara Lanego in Wrocław 2003; Ostasiewicz W. (Ed) Statystyczne metody analizy danych, AE Wrocław, 1999.

2. analysis of a similarity between the objects and the abstract (the best) object, by calculating the gap between the particular objects and the development model,
3. determination of the following development measures for each particular object:

– the higher the level of the complex phenomenon, the higher the measure,
– values of the measures are in the range [0; 1].

In order to standardize the units and orders of magnitude of the variables, one should normalize them. As a consequence of the process of standardization, the values of all variables are not denominated and included in the range [0;1].

As a result of adjusting the Polish law to the EU standards, the entities conducting business activity have to fulfill many various obligations in relation to the environment protection. The framework of activities undertaken by them in this area is determined by the applicable law. In order to achieve the set environmental goals, the entities conducting business activity have to use effective instruments and measures.[17] Projects undertaken in the scope of environmental protection and water management, and in particular in the area of sewage treatment, can be described with various variables. Taking into consideration the administrative division of Poland, one can compare the individual provinces in terms of the achieved environmental protection standards in the scope of sewage treatment. With this purpose in mind, one should determine the variables that describe this particular level. The analysis involves the following ten variables:

X_1 – amount of industrial and municipal sewage discharged into water or ground (in cubic hectometers),

X_2 – amount of treated industrial and municipal sewage discharged into water or ground (in cubic hectometers),

X_3 – number of sewage-discharging plants, equipped with sewage treatment plants,

X_4 – number of sewage-discharging plants, not equipped with sewage treatment plants,

X_5 – amount of sludge (coming from industrial and municipal sewage treatment plants) used in ground rehabilitation (in thousands of tons of dry mass),

X_6 – amount of sludge (coming from industrial and municipal sewage treatment plants) used in agriculture (in thousands of tons of dry mass),

X_7 – amount of sludge (coming from industrial and municipal sewage treatment plants) used in plant cultivation (in thousands of tons of dry mass),

[17]Mesjasz-Lech A., Ecological Activity of Waste Management as a Component of Reverse Logistics, Polish Journal of Environmental Studies, Vol.20 no. 4A 2011, p. 237-242.

X_8 – amount of used (heat-treated) sludge coming from industrial and municipal sewage treatment plants (in thousands of tons of dry mass),

X_9 – amount of used (stored) sludge coming from industrial and municipal sewage treatment plants (in thousands of tons of dry mass),

X_{10} – amount of used (temporarily stored) sludge coming from industrial and municipal sewage treatment plants (in thousands of tons of dry mass).

The year 2011 was the subject of the analysis. In order to ensure a better data comparability, these data have been calculated based on one hundred thousand of inhabitants of the province. Moreover:

- Industrial sewage is not domestic sewage or rainwater or melted water. This is sewage resulting from commercial, industrial, storage, transport or service activities conducted by industrial plants. Industrial sewage also refers to a mixture of the above sewage with sewage of another entity, discharged through the sewage systems of a given industrial plant.
- Data concerning industrial sewage relate to sewage discharged from entities that according to the Polish Classification of Activities were assigned to the category of "Industry" (which includes the following sections: "Mining and extraction", "Industrial processing", "Manufacture and supply of electricity, gas, steam, hot water and air to air conditioning systems", 'Water supply; sewage and waste management and rehabilitation-related activities") and to other sections whose percentage share in the discharged sewage was minor (in 2011 it amounted to mere 0.6%). Data on the equipment with sewage treatment plants also refer to the mentioned entities.
- It was assumed that industrial sewage that requires treatment is sewage discharged by manufacturing plants through the system of channels and open ditches directly into water, ground or sewerage system (including contaminated water coming from mine drainage and water used in the industry for cooling purposes).
- Municipal waste refers to domestic sewage or mixture of domestic sewage and industrial sewage, or domestic sewage and rainwater or melted water, discharged through the systems used for the purposes of implementation of the commune tasks in the scope of sewerage system and municipal waste treatment.
- Data concerning municipal waste include sewage discharged through a sewerage system by the units under the control of water and wastewater facilities and companies, whose founding body is the Governor (or by units under management of local authority) and

since 1994 also by units under the control of all authorities supervising a collective discharge of sewage through a sewerage system (including housing cooperatives, water works, water services facilities, employment establishment, etc.).

– Municipal waste treatment plants include all sewage-treatment plants based on sewerage system, except for the domestic sewage-treatment plants (homestead sewage-treatment plants) or sewage-treatment plants designed for transported sewages (i.e. sewage-treatment plans which are not based on a sewerage system).

The variables include stimulants (X_1, X_3, X_5, X_6, X_7, X_8, X_{10}) and destimulants: X_2, X_4, X_9. Table 1 presents particular provinces ordered according to developmental measures, i.e. taking into consideration the results of application of sewage treatment technologies.

Table 1 Developmental measures for the provinces

Province	Distance of the objects from the model	Developmental measures
Lubuskie	5.7113	0.4348
Warmińsko-mazurskie [Warmian-Masurian]	5.7113	0.4348
Łódź	6.4556	0.3611
Wielkopolskie [Great Poland]	6.4556	0.3611
Opole	6.5140	0.3553
Lublin	6.5251	0.3542
Świętokrzyskie	6.5251	0.3542
Kujawsko-pomorskie [Kuyavian-Pomeranian]	6.8109	0.3259
Śląskie [Silesian]	6.8109	0.3259
Dolnośląskie [Lower Silesian]	7.2375	0.2837
Pomorskie [Pomeranian]	7.2375	0.2837
Podkarpackie	7.3342	0.2741
Podlaskie	7.4011	0.2675
Małopolskie [Little Poland]	7.4699	0.2607
Zachodniopomorskie [West Pomeranian]	7.4699	0.2607
Mazowieckie [Masovian]	7.8896	0.2192

Source: own study

Lubuskie province has achieved the best results in the scope of application of the sewage treatment technologies. However it cannot be considered a model for other provinces, because its value of the developmental measure is far from 1 (it amounts to 0.4348). This may result from a limited use of sludge generated by municipal and industrial sewage treatment plants. The provinces that achieved the worst results were Małopolskie [Little Poland], Zachodniopomorskie [West Pomeranian] and Mazowieckie [Masovian]. The values of

developmental measure in case of these provinces did not exceed 0.261. This situation may be explained by the fact that in the above regions, huge amounts of municipal and industrial sewage is discharged directly into water or to the ground. The presented data also prove that the scope of application of sewage treatment technologies in each of the analysed provinces is not satisfactory. Therefore, further investments in the water protection equipment seem to be necessary.

Based on the gap matrix, the provinces were grouped, which enabled one to determine groups of provinces with a high degree of similarity. Figure 1 illustrates similarities and differences between the provinces (the so-called dendrogram).

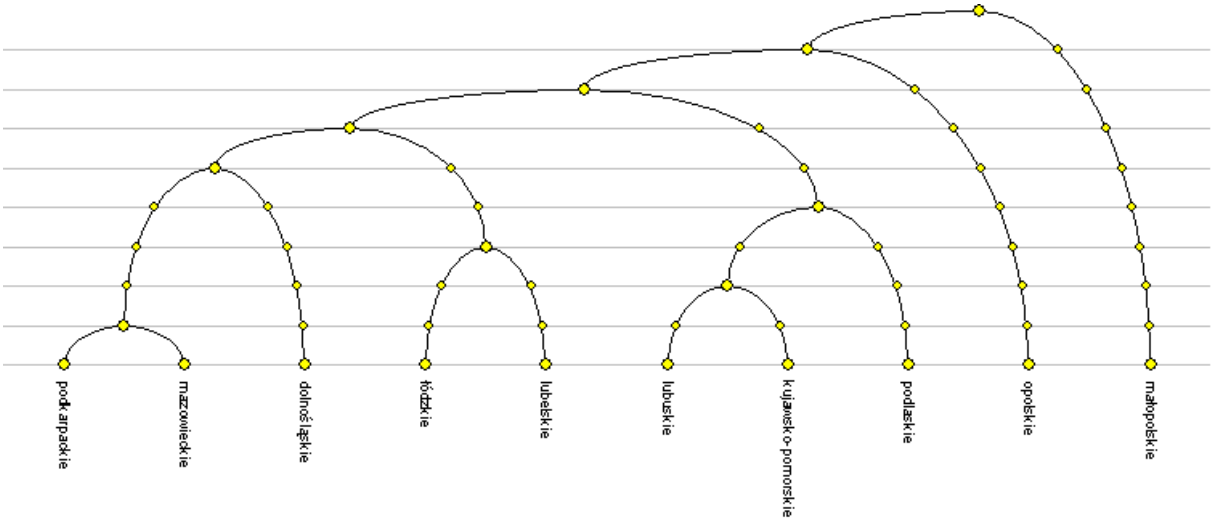

Fig. 1 Ward's Dendrogram for the provinces
Source: own study

The provinces have been classified into seven groups. Taking into consideration the analysed features, the following pairs of provinces: Podkarpackie and Mazowieckie [Masovian], Łódź and Lublin, and Lubuskie and Kujawsko-pomorskie [Kuyavian-Pomeranian] were the most similar to each other– gaps between these provinces are the smallest. It should be noted that provinces similar to each other in terms of the determined features, are very different when we compare their scale of industrialization or degree of economic development. This is because the comparison was based on features referring to entities conducting business activity on the territory of particular provinces, and on the human activity. Therefore, all activities that require application of sewage treatment technologies were taken into account.

4. Summary

Statistics provides various methods for the analysis of data concerning environmental protection. The linear ordering methods enable one to select the best unit from a group of analysed units and to describe its similarity to the model. Analysis of provinces in terms of the application of sewage treatment technologies constitutes a basis for comparing the differences in the effectiveness of environmental projects implemented in particular provinces (in the water protection area) and for undertaking decisions on further activities aimed at reducing the negative impact of economic processes on the environment.

The results achieved through the application of sewage treatment technologies vary for particular provinces. The developmental measure for the province that achieved the best results considering the assessed aspects amounted to 0.4348. In case of the province with the worst results in this area it was 0.2192. The above differences allow one to claim that many provinces cannot take a full advantages of the opportunities offered by sewage treatment technologies, and hence of the environmental results of the actions undertaken in this scope. The Lubuskie province (winner in this assessment) cannot be a model for the remaining provinces, as its developmental measure is far from unity.

Literature

1. Adamski W., Modelowanie jednostkowych procesów oczyszczania wody, Wyd. Nauk. PWN, Warsaw 2002.
2. Bajdur W. M., Eko-polielektrolity syntetyczne redukujące ładunki zanieczyszczeń w ściekach i wodach przemysłowych, Wyd. Instytutu Gospodarki Surowcami Mineralnymi i energią PAN, Kraków 2011.
3. Bajdur W. M., Sułkowski W. W., Polyelectrolytes from NS novolak prouction waste, J. Appl. Polym. Sci., 2003, 89, p.3000-3005.
4. Bartkiewicz B., Oczyszczanie ścieków przemysłowych, Wydawnictwo Naukowe PWN, Warsaw 2002.
5. Chand B.R., Goyal M., Adsorpcja na węglu aktywnym, Wyd. Naukowo-Techniczne, Warsaw 2009.
6. Dziechciarz J. (Ed.), Ekonometria, Wydawnictwo Akademii Ekonomicznej im. Oskara Lanego in Wrocław, Wrocław 2003.
7. Karlsson J., Chemical Sorage Treatment In Combination With And Wilhoust Biological Treatment. Flocculants. Coagulants And Precipitans In Water Treatment, Conference, Atlanta, Georgia, October, 1994.

8. Konieczny K., Bodzek M., Zastosowane techniki membranowe – teoria i praktyka, Inż. i Ochr. Środ, 2001, p. 3-4.
9. Kowal A.L., Świderska-Bróż M., Oczyszczanie wody, WN PWN, Ed. 1, Warsaw 1996, Ed. 5 revised, Warsaw 2007.
10. Mesjasz-Lech A., Ecological Activity of Waste Management as a Component of Reverse Logistics, Polish Journal of Environmental Studies, Vol.20 no. 4A 2011, p. 237-242.
11. Metcalf & Eddy, Wastewater Engineering, Treatment, Disposal and Reuse, McGraw-Hill, Inc., New York, 1991.
12. Murcott S., Harleman D.R.F., Chemically Enhanced Primary Treatment. CEPT. The Water Mirror, The Magazine of the Water Supply from Kemira Kemwater, Conference, Sweden, 1994.
13. Nawrocki J., Biłozora S., Uzdatnianie wody. Procesy chemiczne i biologiczne, Wyd. Nauk. PWN, Warszawa-Poznań 2000.
14. Ostasiewicz W. (Ed.) Statystyczne metody analizy danych, AE Wrocław, 1999.
15. Toczyłowska B., Skuteczność usuwania zawiesin w złożach filtrów DynaSand i Dynamik, Ochrona Środowiska, 2005, 3.
16. Zawada M., Zastosowanie wybranych metod wielowymiarowej analizy statystycznej w procesie inwestowania na rynku kapitałowym w Polsce, [in:] Nowoczesne instrumenty zarządzania, scientific editor: Mesjasz-Lech A., Sekcja Wydawnictw Wydziału Zarządzania, Częstochowa 2009.