

Review

Review of Methods for Assessing the Impact of WWTPs on the Natural Environment

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Abstract: Environmental management in facilities such as wastewater treatment plants (WWTPs) allows for the implementation of the Deming cycle, and thus the constant improvement of the mitigation of the environmental impact. The correct diagnosis of the current state of functioning of the WWTPs, the identification of aspects that may have a measurable impact on the environment, and their assessment are of key importance. The article discusses the possible causes of the impact of WWTPs on the natural environment. Among other problems, such issues as energy consumption, noise and the formation of bioaerosols and odor nuisances were taken into account. Different ways of assessing the impact of wastewater treatment plants on the environment were collated, taking into account the need to assess not only the technological process itself but also the buildings during their use. The results of methods for assessing the environmental impact of wastewater treatment plants in selected countries were also compared.

Keywords: wastewater treatment plant; environment; impact; life-cycle assessment; environmental impact assessment; green building; environmental management system; environmental aspects; wastewater technology; management tool



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1. Introduction

The natural environment is a good whose safety and proper protection should be taken care of in the course of social and economic development. In the era of dynamic technical and technological progress, this task is becoming more and more important. It is extremely important to take into account the environmental impact when planning any investment. For selected projects (which may have a significant or potentially significant impact on the environment), this is carried out by preparing an environmental impact assessment (EIA). Each country has appropriate procedures in this regard. In Poland, obligations in this respect are regulated by provisions [1,2]. Owners of various types of facilities can also apply for a green building certificate for new buildings. The BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design) are among the most popular multi-criteria assessment systems. However, the issue of environmental impact analysis should not be limited only to the design or construction stage. It should also apply to the process of using facilities and installations. In the case of buildings, the already mentioned green building certificates may be helpful, because some of the versions (called schemes) of these multi-criteria assessment systems are intended for already-existing buildings and require periodic renewal (BREEAM In-Use and LEED Existing Buildings Operation and Maintenance, LEED EB O+M). In turn, in the case of installation operation, both direct and indirect environmental management instruments are a solution. It is possible to mention here the necessity to obtain administrative permission (an emission permit or permit for

operation and rationing) or a special type of environmental permission, i.e., an integrated permit. Apart from the mentioned legal and administrative instruments, economic instruments, such as fees for using the environment, should also be mentioned. However, these solutions apply only to some cases of economic undertakings. Moreover, they usually refer to only one type of environmental impact (except for installations requiring an integrated permit). Here, environmental management and the tools at its disposal play a role. The tools related to this management include implementation tools, such as environmental management systems (including the Eco-Management and Audit Scheme—EMAS—or systems according to ISO 14001 [3]) and diagnostic tools. Among the latter, the following deserve attention: life-cycle analysis (LCA) or the aforementioned environmental impact assessments (EIA), which can also be (voluntarily) carried out for existing facilities [4]. The implementation of the environmental management system in an enterprise is associated with the implementation of the Deming plan, and thus guarantees the continuous improvement of the effects of mitigating the impact of the organization on the environment, while the above-mentioned diagnostic tools make it possible to recognize the current state in terms of environmental impact and identify environmental aspects that have or may have an impact on the environment. This type of approach ensures greater care for the state of the environment and is not limited only to selected issues.

Facilities such as wastewater treatment plants are classified in Poland as projects that can always have a significant impact or can potentially have a significant impact on the environment; therefore, they require or may require an environmental impact assessment at the design stage (in accordance with Polish regulations [1,2]). This requirement does not apply to installations intended to serve a population of less than 400 inhabitants equivalent in accordance with the Act [5]. Wastewater treatment plants also require a water permit. Moreover, some wastewater treatment plants (WWTPs) require an integrated permit according to [6]. It should be added that fees are charged for pollutants discharged in wastewater into surface waters and soil. However, these requirements relate to the construction planning stage (i.e., EIA) and only to the discharge of wastewater to water or land (i.e., water permits and pollutant emission charges). Of course, certain standards must be met, and the waste generated during the technological process must be managed in accordance with specific regulations. However, the progressive technical and technological development enables the performance of the tasks of the wastewater treatment plant to be conducted in a way that is more environmentally friendly than before and consists of the use of more effective devices and energy obtained from sustainable sources. It is important that existing wastewater treatment plants can use new technologies and the latest technological achievements. However, to use them, knowledge about them is necessary, which can inspire people responsible for management to look for sources of financing for this type of investment. A holistic approach to the assessment of wastewater treatment plants is also important, i.e., covering not only technological processes, but also the impact of buildings on the environment during their operation.

The aim of the article was to review the methods of assessing wastewater treatment plants and analyze the environmental impact of wastewater treatment plants. As part of this task, an overview of the environmental aspects and possible environmental impacts of wastewater treatment plants was made. Selected tools and methods for assessing the impact of the wastewater treatment plant on the environment (resulting from both technological processes and building operation) are also discussed. Moreover, selected analysis of the environmental impact of planned or already-located WWTPs was performed. The implementation of the above-mentioned objective will allow for the comparison of various methods of assessing wastewater treatment plants and, at the same time, will enable decision-makers to more consciously choose a method adequate for current needs.

2. Review of Environmental Aspects and Impact on Environment of WWTPs

Each wastewater treatment plant is treated as an environmental protection facility due to its function. Nevertheless, it should also be remembered that it is an object that affects or

may have a negative impact on the environment. The scale of this impact depends on many factors. The importance of the issue may be proved, *inter alia*, by the amount of treated wastewater or the degree of complexity of its treatment. Figure 1 shows the amount of treated municipal wastewater in Poland in 1998–2018, broken down by treatment method based on data from [7]. While the annual amount of wastewater fluctuates around the level of 1,200,000,000 m³, one can clearly observe an increasing share of wastewater treated with increased nutrients removal. In 1998, only 24% of all treated municipal wastewater was treated with increased nutrients removal, while in 2018, it was already 85%. This shows the accompanying trend in the increase in the number of treatment plants with highly efficient unit processes, which in turn may translate into a potential increase in the impact of these facilities on the environment (ignoring the obvious benefits of a higher degree of wastewater treatment).

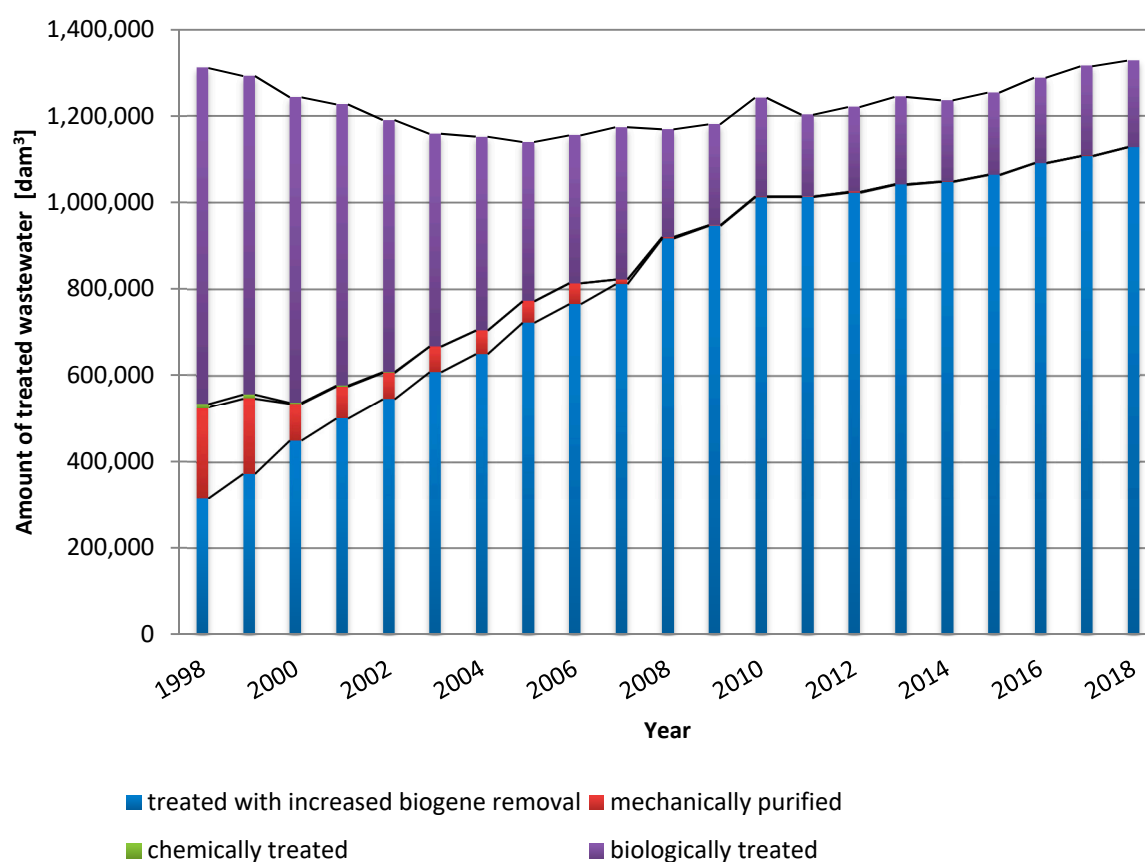


Figure 1. Change in the amount of municipal wastewater treated in Poland in 1998–2018, broken down by treatment method—own study based on data from [7].

The possible environmental aspects and the environmental impact of a wastewater treatment plant depend on several important factors. Among them, the most important are the type of treated wastewater; the location of the treatment plant, *i.e.*, the distance from buildings and the type of receiver; the technology for the wastewater treatment and sewage sludge processing; the number of stages of wastewater treatment; the method of sewage sludge management; and the chemicals used (including coagulants and flocculants). Currently, solutions used in the field of minimizing energy consumption and the use of renewable energy sources are also becoming very important, because thanks to them, even to a minimal extent, it is possible to try to limit further climate change.

An environmental aspect is defined as an element of an organization's activities, products or services that interacts or can interact with the environment [3] or that has or can have an impact on the environment [8]. Below, an overview of the environmental

aspects and environmental impacts typical of wastewater treatment plants is presented. At the beginning of the analysis, it is necessary to mention which components of the natural environment the WWTP has or may have an impact on. Figure 2 presents these elements of the environment, such as the air, surface and underground waters, soil, climate, landscape, fauna and flora, as well as human beings. Among the other elements that may be influenced and taken into account in some assessments, it is also worth mentioning material goods and monuments.

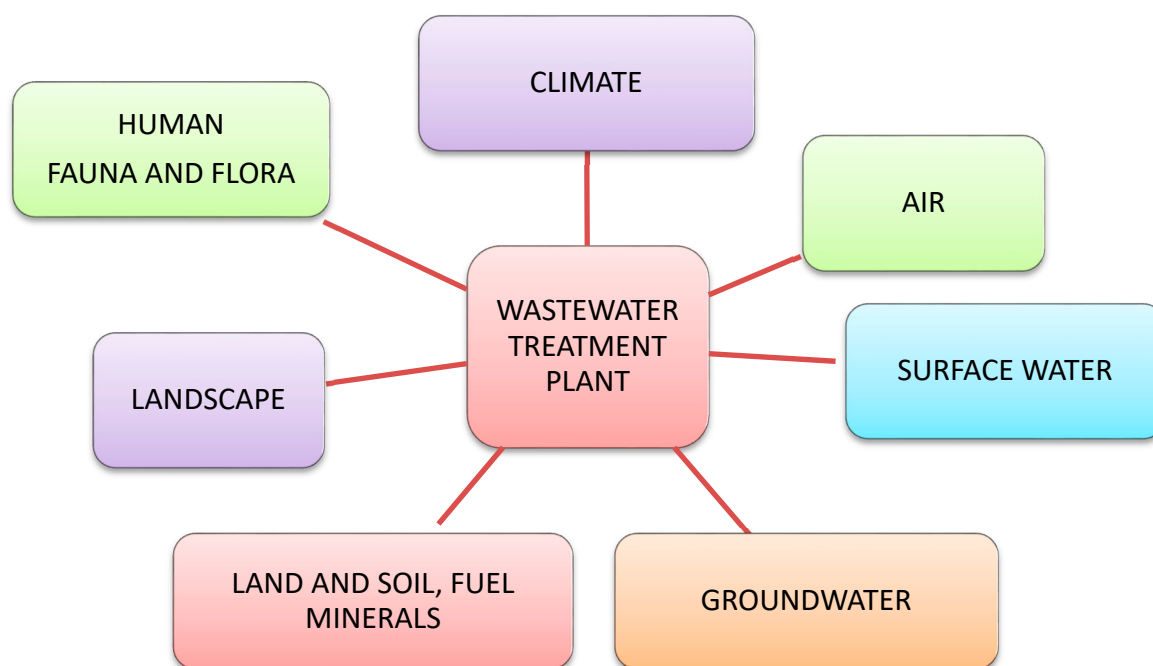


Figure 2. Environmental components influenced by the wastewater treatment plant during operation and/or failure.

One of the first problems associated with a wastewater treatment plant is the possibility of odors. The environmental aspect here is the release of odors, volatile organic compounds (VOCs) and bioaerosols from the conducted mechanical and biological treatment processes as well as sludge treatment processes. These bioaerosols contain microorganisms present in wastewater, while odors and VOCs cause discomfort to residents in the perception of the environment [9–11]. Bioaerosols settle on the surfaces of various elements (e.g., railings) or soil, or may be transferred with the wind to the surrounding areas. They spread about 800 m from the source of their formation [12]. Exposure to aerosols may pose a threat, first of all, to the employees of WWTPs and the population of nearby buildings [11,13], but also to animals [11]. They can also contaminate plants and surface waters [11]. It can be added that, also, the very presence of pathogenic microorganisms in wastewater and sludge is already an environmental aspect due to various possible routes of infection. Microorganisms can enter the human body through the respiratory tract, alimentary tract, mucous membranes or skin [11,14], and bioaerosol components are most often transported by air droplets or air dust [11]. The review of pathogens detected in wastewater treatment plants conducted by [14] mentions, among other things, viruses (e.g., enteroviruses, adenoviruses and rotaviruses), protozoa (e.g., *Giardia lamblia*), mold fungi (e.g., *Candida* spp.), mesophilic bacteria (e.g., *Pseudomonas* spp.), thermophilic bacteria (e.g., *Campylobacter* spp.), nematodes and tapeworms, and endotoxins. In addition to exposure to biological agents, there is also the threat of chemical substances. Among those to which workers of municipal wastewater treatment plants are exposed are heavy metals, volatile organic compounds, polychlorinated biphenyls, dioxins and polycyclic aromatic hydrocarbons [14].

Another environmental aspect related to the operation of wastewater treatment plants is noise generation. People (WWTP workers and the residents of nearby buildings) and animals can be susceptible to acoustic nuisance. The number of noise sources and the noise level depend, among other things, on the efficiency of the wastewater treatment plant, the applied technological cycle for wastewater treatment and the treatment of sewage sludge, the distribution of individual noise sources, and the technical advancement of the applied solutions. The noise at the wastewater treatment plant comes from working equipment, technological installations and means of transport. Noise is generated during mechanical and biological treatment processes as well as during sludge treatment. The acoustic nuisance is related, among other things, to the operation of pumps (including vacuum pumps), compressors, fans, centrifuges, means of transport for wastewater delivery, and the removal of screenings and sand [11,15,16].

Energy consumption is a very important environmental aspect related to the functioning of wastewater treatment plants. Energy is needed to carry out the treatment processes, transport of wastewater and sludge, and possible preparation for their reuse. Among the processes, energy is required for mechanical, biological and chemical treatment and disinfection. There is a demand mainly for electricity but also for gas and other fuels [17]. Energy consumption is associated with the depletion of non-renewable natural resources. Moreover, in the production of electricity in coal-fired power plants, pollutants are emitted to the atmosphere (including dust, sulfur dioxide, nitrogen oxides and carbon monoxide) [18,19]. These emissions also accompany vehicle traffic in the treatment plant, as well as transport related to the operation of the treatment plant (the delivery of wastewater, chemicals and waste disposal), and in this regard, the negative impact of this facility on the environment can also be noted (exhaust fumes from fuel combustion).

No less important an environmental aspect are the emissions of greenhouse gases from wastewater treatment plants. One of the greenhouse gases (N_2O) is mainly released from biological nitrogen removal processes in WWTPs with biological nutrient removal (BNR). The amount of N_2O emissions from wastewater treatment plants is estimated at about 2.8–3% of the total emissions of this gas from all anthropogenic sources. Moreover, global N_2O emissions from wastewater treatment were expected to increase by around 13% between 2005 and 2020 [20]. It is not the only emission, as municipal wastewater treatment plants with multistage activated sludge technology also generate methane (CH_4) and carbon dioxide (CO_2) [21]. Greenhouse gas emissions can come directly from the process units of a wastewater treatment plant, the effluent receiving environment, the biosolids receiving environment, as well as from greenhouse gas emissions related to the plant infrastructure, chemical consumption and operational energy consumption [22].

Taking into account the obvious benefits for the environment resulting from the operation of wastewater treatment plants, it should not be forgotten that when discharging treated wastewater into the environment (mainly surface waters), they also release substances into the environment (despite the compliance of the quality of treated wastewater with the established standards). This is especially true for pollutants such as suspended solids, organic compounds and biogenic compounds (in the case of municipal WWTPs). At industrial wastewater treatment plants, substances are also released into the environment, but their type depends strictly on the industry from which the wastewater comes.

Due to the fact that wastewater treatment plants are usually plants covering a large area of land and including cubature facilities, they have an impact on the landscape and the surface of the land (soil). Their construction reduces the biologically active surface. However, the impact on the landscape and the area of the land occupied must be analyzed at the stage of deciding on the location of the facility. At the operational stage, few actions to minimize such an impact can be taken.

Impacts on the land surface may occur in some sludge treatment or waste disposal processes in treatment plants (e.g., sludge plots and landfilling). On the other hand, in the case of the incineration of this waste and combustion of biogas resulting from sludge treatment, emissions to the atmosphere are recorded. This problem also applies to dewatered

sludge from wastewater treatment plants at printed circuit board (PCB) manufacturers. PCB manufacturing requires photochemical processes, which use photopolymers dissolved in alkaline solutions (Na_2CO_3 , K_2CO_3 , NaOH , KOH , etc.). The spent alkaline developing solutions are pre-treated in on-site wastewater treatment plants. This process consists of the precipitation of the photopolymers in an acidic environment (pH 2–2.5, by using conc. H_2SO_4 or HCl), filtration, and dewatering with filter presses or filter bags. The resulting leachate requires further treatment (e.g., by using advanced oxidation processes, AOPs), and the sludge is then either processed further or disposed of. The large amounts of organic compounds present (mainly polymers) can be converted using combustion or carbonization processes [23–25].

The problem of the content of organic pollutants in dehydrated sludge also applies to those cases where only coagulation and flocculation processes are used for wastewater treatment. These processes only remove organic pollutants (without their decomposition) from the liquid phase and increase their concentration in the dewatered sludge [26,27].

Particular attention should be paid to certain industrial wastewater treatment plants that, in their wastewater treatment processes, produce only partially dewatered sludge, which contains high concentrations of heavy metals. Therefore, in the case that the sludge is not properly stored, transported and processed, it may cause harm to the natural environment. Sludge containing high concentrations of heavy metals is usually linked to conventional electroplating processes and also the production of printed circuit boards (PCBs). The raw wastewater from these industries often contains high concentrations of heavy metals (Cu, Ni, Sn, Zn, etc.). As a result of treatment processes in on-site wastewater treatment plants (e.g., by using chemical precipitation), heavy metal ions are precipitated in the form of insoluble sludge. These precipitates are separated from the liquid phase (i.e., treated wastewater) in the sedimentation process on lamellar settling tanks, and then dewatered with filter presses or with the use of filter bags. The use of different drainage methods results in varied water contents in the precipitates and, consequently, varied concentrations of heavy metals. In addition, the composition and physicochemical properties of sludge strongly correlate with the technological processes used in the manufacturing plants, the procedures used for water and wastewater management (rinsing processes and water recovery technologies), and the technical and technological processes in on-site wastewater treatment plants [28–30].

The environmental aspects of wastewater treatment plants should be considered not only for normal operation, but also in exceptional circumstances. In the event of a failure or disaster, there is a possibility of the contamination of surface water and groundwater as well as soil through leaks. This especially applies to failures of facilities filled with wastewater (pipelines and reactors, and tanks) and chemicals. It should be added, however, that such a negative impact on the environment is taken into account, and the treatment plants have appropriate safeguards. The implementation of pipeline monitoring can also be considered for the continuous assessment of their operation and control of possible leaks. The risk of potential impacts on individual components of the environment, i.e., the risk of the contamination of surface water, groundwater and soil, should be assessed, taking into account, *inter alia*, an analysis of the water–ground subsoil (the groundwater table level and soil types—permeable/impermeable) as well as the location of the treatment plant in relation to floodplains and exposure to earthquakes, and the quality of the proposed security measure design. The possible risk of such a negative impact depends, to a large extent, on these factors.

An often overlooked or underestimated issue when identifying the environmental aspects of wastewater treatment plants is the operation of office buildings, laboratories and social and technical facilities. These facilities are not without impact on the environment. They require energy needed for lighting, air conditioning, heating and the exploitation of room equipment (including computer equipment). During their operation, users also need hot and cold water and, possibly, gas. The amount of utilities used often depends on the quality of the building and its equipment. Another issue is the question of employees'

commuting to work—the availability of, for example, bicycle paths or public transport. The above-mentioned issues are especially taken into account in a green building.

Figure 3 shows the more important environmental aspects of wastewater treatment plants. The diagram takes into account the effects on human beings, the air, surface water and the land surface and soil.

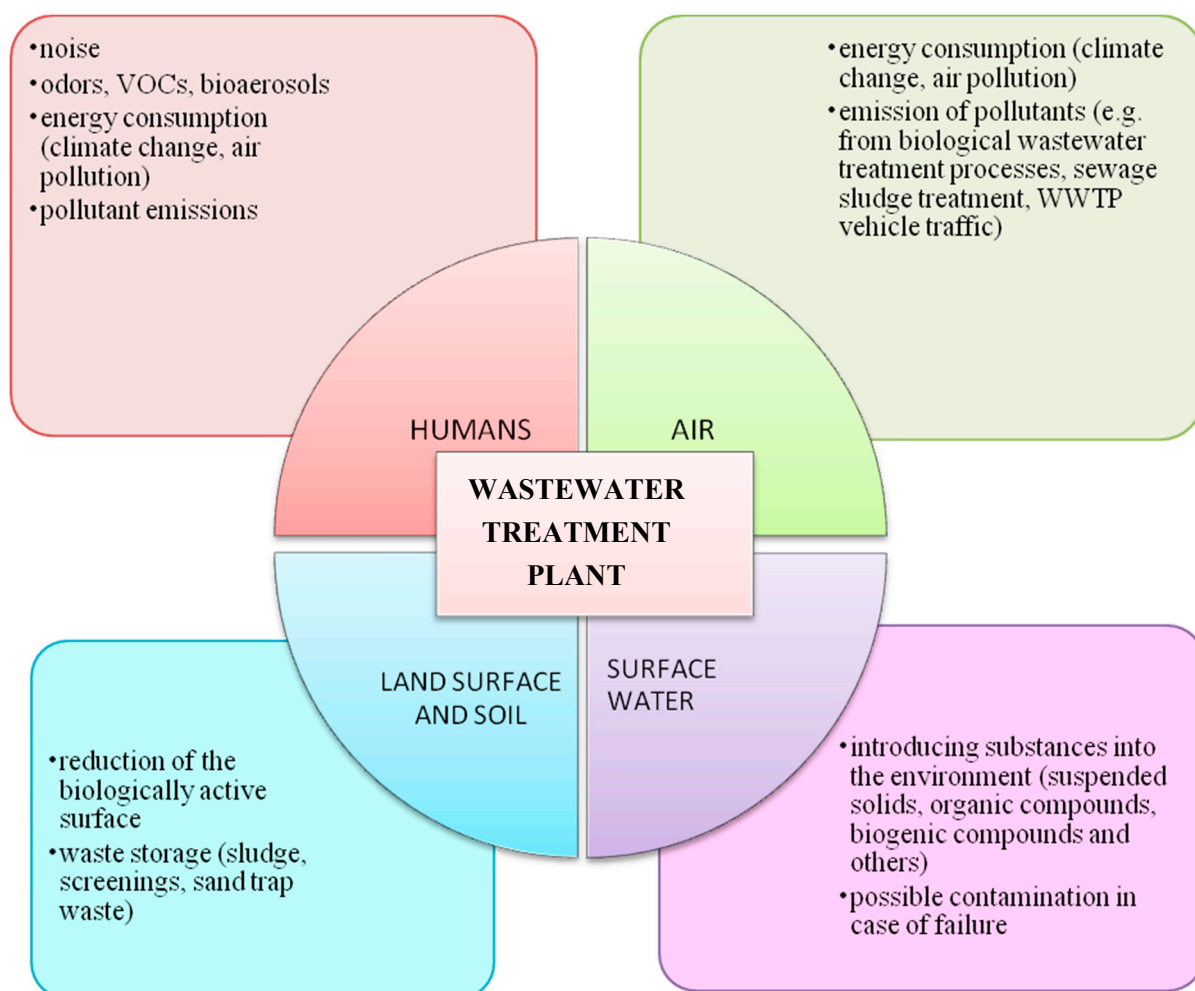


Figure 3. Main environmental aspects of wastewater treatment plants.

In summary, various types of processes are carried out at a wastewater treatment plant. These include mechanical treatment processes (screening, sedimentation and flotation), and chemical and biological treatment processes (including advanced nutrient-removal processes). Noteworthy are, among other things, nitrification (under aerobic conditions), denitrification (under anoxic conditions), biological dephosphatation (under anaerobic conditions) and chemical phosphorus precipitation. These processes lead to a reduction in, among other things, suspended solids, organic compounds and nutrients (nitrogen removal and phosphorus removal) in wastewater. As a result, the values of parameters such as biological oxygen demand and chemical oxygen demand are significantly reduced. An important aspect of the operation of a wastewater treatment plant is also the sludge treatment processes. Each of these processes has a different specificity and can also be carried out in a different way (e.g., by the activated sludge or bio-films in trickling filters). These processes generate different types of environmental impacts and with different scales of impact (different emissions, different compositions of waste, etc.), which depend on, inter alia, the composition of the wastewater. Thus, for mechanical treatment, the main impacts on the environment include the generated waste (screens and sand), noise, odors

and VOCs, and for biological treatment, they include noise but also gas emissions to the atmosphere, and sludge with a need to be processed (treatment of sewage sludge). These processes are also associated with the emission of odors and VOCs. At this point, it is also worth adding that the issue of odor and VOC emissions during wastewater treatment is gaining importance, and there are more and more articles on this subject in the literature. Examples include [31,32]—on the methods of their removal or the assessment of the health hazards due to emissions of them. Moreover, practically all the processes in the treatment plant are carried out with energy consumption.

3. Possibilities for Assessing the Impact of Wastewater Treatment Plants on the Environment

Many wastewater treatment plants do not examine and evaluate the potential sources of nuisance and negative effects on the external environment, and risk assessments related to biological agents harmful to the health of employees are carried out sporadically on the areas of wastewater treatment plants [11]. However, in the era of technical and technological advancement with simultaneously progressing climate change, it would be highly recommended to take action in this area.

The impact of wastewater treatment plants on the environment can be considered at the design and operation stage. In the design phase, environmental impact assessment reports are prepared, while for the analysis of the environmental impact of a wastewater treatment plant in the operational phase, various tools are available for conducting such an assessment, although an environmental impact assessment (EIA) can also be used here [4]. A popular tool used for wastewater treatment plants is the life cycle assessment (LCA) technique. The analysis by this technique can be performed using different software and different methods. In the case of existing wastewater treatment plants, a useful tool may also be the identification of environmental aspects performed as part of the implementation of environmental management systems. The following is an overview of the methods used to assess wastewater treatment plants at different stages of their existence.

Among the ways of analyzing the impact of projects on the environment, a group of diagnostic tools can be distinguished, belonging to the group of environmental management tools, alongside implementation tools. This group includes, *inter alia*, environmental impact assessments, life-cycle analyses and environmental audits [4,33].

One of the most frequently used methods for assessing the environmental impact of wastewater treatment plants is the environmental impact assessment procedure. This method of evaluating projects was introduced in highly developed countries, including the United States, in the 1970s [34]. This assessment is performed at the design stage of this type of facility, and the procedure for carrying it out is regulated by the relevant regulations of a given country. The regulations of individual European countries in this area are related to the relevant European directives, *i.a.* [35–37]. According to the European Community Directive (the latest consolidated version) [35], now out of force, the scope of the EIA covered the direct and indirect impacts of the project on human beings, fauna and flora, soil, water, air, climate, landscape, and material assets and cultural heritage, and the interactions between these factors. In the European Union directive [36] currently in force, this provision has undergone some changes. Instead of effects on human beings, the effects on population and human health have been included, while the effects on flora and fauna have been replaced with effects on biodiversity. The effects on soil were supplemented with effects on land. Additionally noteworthy is adding the adjective “significant” before the word “effects”. Currently, the scope of the impact assessment (according to the Directive [36]) should cover the direct and indirect significant effects of a project on factors such as population and human health, biodiversity, land, soil, water, air, climate, material assets, and cultural heritage and landscape, as well as the interactions between these factors. In addition, the impact on biodiversity should, in particular, take into account species and habitats protected under certain directives [37,38]. Among other, more important substantive EU environmental standards for wastewater treatment plants’ projects, the following should be mentioned:

- Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (establishes measures to assess air quality in the Member States on the basis of common methods and criteria) [39];
- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy (establishes a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater) [40];
- Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy (lays down environmental quality standards (EQS) for priority substances and certain other pollutants with the aim of achieving good surface water chemical status) [41];
- Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (establishes specific measures in order to prevent and control groundwater pollution) [42];
- Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control—lays down rules on the integrated prevention and control of pollution arising from industrial activities) [43];
- Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste (establishes the measures for protecting the environment and human health by, inter alia, preventing or diminishing the generation of waste, reducing the overall impacts of resource use, and improving the efficiency of such use) [44];
- Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances (sets up rules to prevent major accidents that involve dangerous substances, and limit their consequences for human health and the environment) [45];
- Council Directive of 21 May 1991 concerning urban wastewater treatment (91/271/EEC)—it concerns urban wastewater (collection, treatment and discharge) as well as wastewater from certain industrial sectors (treatment and discharge), and the objective of this act is protecting the environment from the adverse effects of these wastewater discharges [46];
- Council Directive of 12 June 1986 on the protection of the environment and, in particular, of the soil, when sewage sludge is used in agriculture (86/278/EEC)—the act aims to regulate the use of sewage sludge in agriculture in such a way as to prevent its harmful effects on soil, vegetation, animals and people, and thus encourage the proper use of such sewage sludge [47].

In the absence of a specific legal framework, EU soil protection policy is shaped by the EU Soil Thematic Strategy and the provisions of a range of other policy instruments, for example, the Environmental Liability Directive [48] and many others [49]. Current international conventions, in particular, those relating to nature protection, should also be taken into account. Environmental impact assessments carried out outside the European Union should be conducted in accordance with international (conventions), national and local regulations. For example, the procedure of Environmental Assessment for Wastewater System Improvements for the City of Sterling (Colorado) was performed in accordance with the Colorado Environmental Review Process and in conformance, inter alia, with the requirements of the National Environmental Protection Act (NEPA) [50].

Pursuant to Polish legislation [1], environmental impact assessment is a procedure for the environmental impact assessment of a planned project, including the verification of a project's environmental impact report, obtaining opinions and arrangements required by the act, and ensuring the possibility of public participation in the procedure. Such an assessment is carried out for objects that can always have a significant impact or can potentially have a significant impact on the environment. In Poland, according to [1], the environmental impact assessment for a project determines, analyzes and assesses the direct and indirect impacts of a given project on various factors (including the environment, popu-

lation and landscape), the risk of major accidents, and the risks of natural and construction disasters, as well as the possibilities and methods of preventing and reducing the negative impact of the project on the environment and the required scope of monitoring.

Another environmental management tool worth mentioning, introduced at the turn of the 1960s and 1970s, is the ecological audit. The group of audits, also known as environmental reviews or ecological reviews, includes post-completion reviews (concerning, inter alia, controlling the effects of risk mitigation measures) and impact reviews (comparing the predicted environmental impacts in the EIA report with the actual impacts) [4].

Environmental management systems (EMSs), such as, for example, ISO 14001 or EMAS, are implementation tools in environmental management; however, as part of their implementation, the identification/determination of environmental aspects is performed. The identification of environmental aspects and impacts is a crucial part of any EMS [51]. According to the requirements of ISO 14001 [3], it is necessary to determine environmental aspects (of products, services and activities) taking into account current and planned activities and including aspects that can be controlled and influenced. The impact of the aspects and the importance of these aspects and effects should be assessed. The organization should also consider, inter alia, indirect aspects; past, present and future aspects; and actual and potential aspects [52]. In turn, in an EMS compliant with the regulation [8], each organization implementing this system must perform an environmental review of all the environmental aspects of the organization. According to the definition [8], it is an initial comprehensive analysis of the environmental aspects, environmental impacts and environmental performance related to the activities, products and services of an organization. Annex I of the Regulation [8] sets out its constituent parts. One of its elements is the identification of direct and indirect environmental aspects along with the identification of those that are significant. Among the methods useful in obtaining information needed to develop an environmental review is the life cycle assessment (LCA) technique [53]. According to [54], an initial environmental review should always be carried out before establishing and implementing an EMS to assess the organization's position towards the environment. There are different approaches to identifying environmental aspects and impacts. The ways to facilitate this task include the following methods: grouping, surveying, mass balancing, back calculating and Potpourri (combining the grouping methodology with the surveying methodology) [51]. An important element of environmental management systems in organizations is also carrying out audits (in accordance with the Deming plan), which contribute to activities aimed at minimizing the impact on the environment. It can therefore be concluded that the introduction of an environmental management system at a wastewater treatment plant is a way of not only assessing its impact on the environment (as part of identifying environmental aspects and impacts), but also permanently controlling it as part of the PDCA plan (Plan Do Check Act).

The life cycle assessment (LCA) is a rather popular diagnostic tool that allows for the analysis of the processes carried out in the wastewater treatment plant. The standard [55] defines life cycle assessment (LCA) as the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle. The rules of its conduct, requirements and guidelines are regulated by appropriate standards [55,56]. This tool allows for the identification, quantification and assessment of the potential impact and for determining a method of improving the quality of the environment [57]. According to [18], it is a recognized research method aimed at determining environmental hazards and, at the same time, allowing determining ways to improve the quality of the environment. It allows, for example, determining the impact of the designed/implemented technology on the environment throughout its life cycle [57]. According to [55,56], LCA studies consist of four phases, and the scopes of the studies depend on their subjects and purposes (intended uses of the studies). The LCA phases include defining the goal and scope of the study (phase 1), analyzing the set of "inputs" and "outputs" (phase 2), assessing the impact of the life cycle on the environment (LCIA) (phase 3) and interpreting the results (phase 4) [55,56]. The third phase of LCA research can be carried out with the use of various methods,

often implemented into computer programs [57]. The method for carrying out an impact assessment (LCIA) is understood as a set of impact categories [58]. The methods differ in terms of categories but also in the parameters for characterizing the same categories, which sometimes leads to divergent results [57]. The following methods can be distinguished: Eco-Indicator 99, ReCiPe, CML (from the name of Centrum voor Milieukunde Leiden), IMPACT 2002+, EDIP, CED (Cumulative Energy Demand), Ecological Scarcity Method 2006, ILCD 2011 (International Reference Life Cycle Data System), TRACI (for the United States area), and USEtox [57–59]. Various programs are used to perform the LCIA phase. There are both commercial and free solutions. The programs used for this purpose include GaBi, SimaPro, TEAM, BEES, Umberto, ECO-IT, OpenLCA, and CMLCA, as well as Excel-based spreadsheets (MS Office package) or mathematical packages [59–62].

One of the most popular methods, Eco-Indicator 99, distinguishes three categories of damage—human health, ecosystem quality and resources [63]. Impact categories are assigned to each damage category. The human health category has the greatest number of impact categories. These are carcinogenic substances, organic and inorganic compounds that affect the respiratory system, ionizing radiation, ozone layer depletion and climate change. Ecotoxic substances, acidification and eutrophication as well as land management (land occupation and land conversion) have been assigned to the damage category “ecosystem quality”, and to the resources category, the extraction of fossil fuels and mineral resources have been assigned [18,57,63]. The categories of damage refer to different units (e.g., human health can be expressed in units: DALYs, which means disability adjusted life years). Therefore, in the next step, normalization is used to maintain dimensionless degrees of importance. The final stage is the weighting process—performed by multiplying by appropriate importance factors [57]. The results are given in eco-indicator points (Pt), where 1 Pt represents one thousandth of the annual load of the environment, for one European inhabitant [18].

When assessing the environmental impact of wastewater treatment plants, the environmental impact of buildings during their operation should also be taken into account. Here, multi-criteria certification systems can be used. They can be seen as methods of assessing buildings and their impact on environmental, social and economic aspects [64]. Among the multi-criteria building assessment systems that can be applied to the buildings of wastewater treatment plants, those previously mentioned—LEED and BREEAM—can be distinguished. According to [65], LEED is the most widely used green building rating system in the world. This American system was introduced by the U.S. Green Building Council (USGBC) in 1998 as a pilot version (LEED 1.0), and in 2001, another version was launched—LEED 2.0 [65]. Version 4 was updated on 25 July 2019 with addenda [66], while currently, LEED version 4.1 from July 2020 applies [67]. The system is present in 160 countries and territories through participating projects [65]. Facility designs are assessed in nine main areas that address the key aspects of green building. These include integrative process, location and transport, sustainable sites, water efficiency, energy and the atmosphere, materials and resources, indoor environmental quality, innovation and regional priority [65]. Each of these categories includes specific subcategories—requirements, called credits—and points are awarded for meeting them. Their choice is free and depends on the investor and consultant [64]. Depending on the number of points scored, a grade is awarded. The facility can obtain rating levels from certified, through silver and gold, to the highest—platinum [65]. It is important that almost all the categories have specific critical requirements, the fulfillment of which determines obtaining a certificate [64]. It should be mentioned that there are different schemes depending on what facility is assessed. We can distinguish here the Building Design + Construction (BD+C) scheme for new projects, and the previously mentioned LEED EB O+M, but also Interior Design + Construction (ID+C) for complete interior design projects; LEED Homes, for residential buildings up to 6 stories; LEED Neighborhood Development, intended for new projects of land development or redevelopment projects; LEED Cities and Communities, for entire cities and the parts thereof; and LEED Zero, a certificate linked to the targets for reducing carbon dioxide

emissions [68]. Among the mentioned systems for facilities such as wastewater treatment plants, the first-mentioned scheme can be mainly considered, as it is easier to meet these requirements at the design and construction stage of the facility.

Another very frequently used multi-criteria building assessment system is the BREEAM system. According to [69], this system is present in 87 countries, and almost 592,000 certificates have been issued to date. BREEAM certificates can be awarded to individual buildings, environments and infrastructure projects. There are a number of schemes and versions of this system depending, among other things, on the country, development phase and building function. There are technical standards for communities, infrastructure, new constructions, the in-use phase and the refurbishment and fit-out phase [69]. Another interesting solution is the “Bespoke” service offered by the system operator if it is not possible to find an appropriate technical standard for a given project. This requires, *inter alia*, adapting the criteria in the existing standards to a specific application [69]. The certification schemes are constantly evolving. From time to time, new and improved versions of the technical standards appear [70]. Among the latest versions of the schemes, the requirements for new structures in Great Britain from 2018 [71] can be distinguished. According to the source [69], categories such as energy, health and well-being, innovation, land use, materials, management, pollution, transport, waste and water are assessed during the certification process. Then, for each of these categories, the points obtained (called credits) are counted in relation to the achievable points. Each category is assigned a weight by which the obtained result for a given category is multiplied. The final grade is determined on the basis of the sum of the partial results. The building receives a grade depending on the results achieved. The field of grades ranges from acceptable (used only in the In-Use scheme), through pass, good, very good and excellent, up to the highest score—outstanding [69]. Besides an adequate number of points, the critical conditions and minimum requirements, which depend on the given certification level, must also be met [64]. Certificates that are issued for existing buildings (according to the BREEAM In-Use scheme) require periodical renewal. In turn, the certificates for new buildings are issued for an indefinite period (final certificates), but it should be noted that these are certificates issued in a specific version of a given scheme (that are modernized from time to time, as previously mentioned). As a result, in a sense, these final certificates may lose their validity and relevance after years. It is also possible to obtain a certificate at the design stage—a certificate called Interim [70].

In addition to the above-mentioned methods of assessing the impact of wastewater treatment plants on the environment, this group also includes articles, scientific papers and various types of expert opinions. They can be applied to virtually any aspect of WWTP functioning. The scope of the impact assessment is determined by the author or the customer and is usually related to the current problem at the wastewater treatment plant.

Table 1 presents the brief characteristics of various methods of assessing the environmental impact of an investment that can be applied to facilities such as wastewater treatment plants. The possibilities of applying a given assessment method (voluntary/obligatory and the type of an investment for which a given method is dedicated), the scope of the impact assessment and the forms of presenting the assessment are compared.

Table 1. Comparison of methods of assessing the impact of wastewater treatment plants on the environment.

Assessment Method	Application	Scope of the Impact Assessment	Type of Assessment	Source
EIA (Environmental Impact Assessment) (based on Polish regulations)	Planned investments for which EIA is required (obligatory) In the operational phase (voluntary)	<p>The direct and indirect impact of the project on:</p> <ul style="list-style-type: none"> • The environment • Population (health and living conditions) • Material goods • Monuments • Landscape (including cultural landscape) • Interactions between the above-mentioned elements • Availability of mineral deposits <p>and in addition:</p> <ul style="list-style-type: none"> - Risk of major accidents as well as natural and construction disasters - The potential for and ways of preventing and reducing the negative impact of the project on the environment - The required scope of monitoring 	Descriptive assessment in the form of an EIA report	[1,4]
LCA (Life Cycle Assessment)	Voluntary; for products (including services); carried out as part of the implementation of an EMS (Environmental Management System), or as part of scientific or other work for planned or existing plants	<p>Depends on the subject and purpose of the study; it covers 4 phases: defining the purpose and scope of the study, analysis of the set of “inputs” and “outputs” (analysis of the inventory), assessment of the impact of the life cycle on the environment (LCIA) and interpretation of the results; for example, in the Eco-Indicator 99 method, there are 3 categories of damage and the corresponding impact categories (in brackets):</p> <ul style="list-style-type: none"> - Human health (carcinogenic substances, organic and inorganic compounds affecting the respiratory system, ionizing radiation, ozone layer depletion and climate change) - Ecosystem quality (eco-toxic substances, acidification and eutrophication, and land management—land occupation and land conversion) - Resources (extraction of fossil fuels and mineral resources) 	Depending on the chosen method for the 3rd phase, e.g., in the Eco-Indicator 99 method, normalized and then weighted results are obtained in points for each damage category. Phase IV is the descriptive interpretation of the results.	[18,55–57,63]
EMS EMAS (Eco-Management and Audit Scheme)	Voluntary, existing organizations	Identification of all direct and indirect environmental aspects having a positive or negative impact on the environment with appropriate qualification and quantification; determination of significant aspects.	Descriptive assessment—environmental review combined with the assessment of environmental aspects through, for example, FLIPO forms (point assessment) and determination of significant environmental aspects; FLIPO (Flow—Legislation—Impact—Practices—Opinion)	[8,53]
EMS ISO 14 001	Voluntary, existing organizations	Identification of environmental aspects (products, services, activities) taking into account current and planned activities and including aspects that can both be controlled and influenced; assessing the impact of aspects and the significance of these aspects and effects; considering, inter alia, indirect aspects; past, present and future aspects; and actual and potential aspects.	Descriptive assessment—identification of environmental aspects	[3,51]

Table 1. Cont.

Assessment Method	Application	Scope of the Impact Assessment	Type of Assessment	Source
BREEAM (Building Research Establishment Environmental Assessment Method), various schemes	Voluntary; for: - New construction - Existing buildings - Infrastructure - Mixed use (bespoke projects) but also available for: - Refurbishment and fitting out - Communities	Several dozen sub-categories are assessed, grouped into the following categories: energy, health and well-being, innovation, land use, materials, management, pollution, transport, waste and water.	A certified rating (acceptable—only for In -Use scheme—pass, good, very good, excellent, outstanding) and percentage score and certificate with star rating	[64,69]
LEED (Leadership in Energy and Environmental Design) (v4)	Voluntary; for: - New buildings (Building Design and Construction) - Existing buildings (Building Operations and Maintenance) but also includes other types of projects (interior design and construction, neighborhood development, cities and communities, homes) and LEED Zero	Compliance with the creditsgrouped in 9 areas is assessed: - Integrative process - Location and transport - Sustainable sites - Water efficiency - Energy and atmosphere - Materials and resources - Quality of the internal environment - Innovations - Regional priority	Number of points and the corresponding rating level (certified, silver, gold, platinum) and certificate	[64,65]
Other—scientific articles and studies, expert opinions	Voluntary	Depending on the authors or the customer, usually related to specific problems occurring in the facility	Descriptive assessment	i.a.: [72–74]

4. Review of Environmental Impact Analyses of Wastewater Treatment Plants Conducted in Various Parts of the World, with Particular Emphasis on Poland

The authors, based on the available literature, selected analyses of the impacts of wastewater treatment plants on the environment to review. Both analyses performed at the investment planning stage or its expansion and modernization, and assessments carried out during operation, were taken into account. Examples of assessments of wastewater treatment plants performed with different methods, which are discussed in the previous chapter, were selected. Particular attention was paid to examples from Poland, due to the availability of information in this regard.

The environmental impact assessment (EIA) of a wastewater treatment plant is one of the most frequently used methods of the assessment of the impact of a wastewater treatment plant on the environment, which is related to its obligatoriness. They most often concern the construction of a wastewater treatment plant or its extension or modernization. Both over the years and across countries, differences in the approaches to environmental impact assessments and their structure can be observed, although they basically all contain the same elements. Depending on the region of the world, attention is paid to other issues related to local conditions. For example, in the environmental impact assessment of a wastewater treatment plant located in the Port Said region [75], in the identification of possible environmental impacts, the possibility of mosquito breeding and the risk of disease transmission associated with it (mainly malaria) were taken into account. This part of the study also highlighted the (positive) impact of the treatment plants on bathing water quality and tourism. The environmental assessment of the wastewater system

improvements for the County of Logan in the United States (including the modernization of the wastewater treatment plant) took into account the possible impact of the project on the wetlands in these areas, as well as on floodplains and their management [50]. In turn, the impact assessment of the reconstruction of the wastewater treatment plant for Minsk (Belarus) included, in addition to the part on environmental impacts, a part on social impact [76]. There are also differences in the level of detail of impact assessments, partly related to the scope of the assessed investment and its size. There are reports that are very detailed and those prepared in a brief and laconic manner. Depending on the scope of the investment, there may be impact assessments for improvements to the wastewater system e.g., [50], the wastewater treatment plant only e.g., [75,77,78] or the stage of its expansion or modernization e.g., [79,80].

Due to the importance of environmental impact assessment procedures, work has also been conducted to analyze or evaluate these impact assessments, as well as to propose necessary changes. The analysis presented in [81] of 11 selected Polish reports on the impact of wastewater treatment plants on the environment shows that these elaborations, assessed according to the proposed criteria, are far from complete descriptions of the variables, and the conclusions are too general for carrying out an objective decision-making process. This study [81] shows that the authors of the reports were the least in depth when describing and analyzing cumulative impacts, threats to groundwater and losses of material goods. However, the impact of the wastewater treatment plant on changes in the acoustic climate, air quality and surface waters was assessed in detail. It should be added that the impact on the acoustic climate, according to the study [81], was analyzed by the authors in the most comprehensive way (in relation to other variables). In the work [82], 33 processes of the environmental impact assessment of wastewater treatment plants in Spain were reviewed through records of decision (RODs). The most frequently identified impacts during the operation of a WWTP were odors from the depuration process and the sludge treatment, noise from pumps and the visual impact of the facilities. The negative impact on water quality was also mentioned. It was indicated that in some cases, an amount of total nitrogen that causes eutrophication could be generated.

Article [81] points to the need for creating facilitating tools for decision-makers to help them to make choices, but with the assumption that these instruments will constitute a reliable source of knowledge. Due to the need for comprehensiveness when deciding on environmental projects such as wastewater treatment plants, and the need to take into account environmental, sociopolitical and economic factors, in addition to mandatory environmental impact assessments, the paper [83] proposes the use of the decision support concept. The developed concept based on multi-criteria methods (analytic hierarchy process, AHP, and preference ranking organization method for enrichment evaluations, PROMETHEE) was used on a specific case study—choosing the location of a sewage treatment plant for the city of Kutina in Croatia.

The LCA technique can also be considered as a decision support tool in the field of the environmental improvement of an operated wastewater treatment plant, an example of which is the work [84]. The currently conducted technological processes as well as the management of byproducts (sludge and biogas) can be assessed and compared in this way [84–87]. Typically, the LCA technique is used when considering possible options for modernizing an existing wastewater treatment plant. The studies [84,88] can serve as an example here. In [84], the current situation of a wastewater treatment plant was assessed, and alternatives for improvement were identified, while in [88], the LCA technique made it possible to compare the environmental performance of five wastewater and sludge management scenarios in a WWTP in Italy. This technique can also be used when selecting a technology variant for a planned wastewater treatment plant. In Poland, the LCA technique is used to assess the production of alternative flocculants and the treatment of industrial wastewater with their use. The paper [89] describes the use of the LCA technique to identify the sources and assess the impact on the environment of the stage of the potential production of new-generation flocculants synthesized from post-production polystyrene

waste and the stage of wastewater treatment with the use of synthesized products. In turn, in [90], the LCA technique was used to evaluate the impact of a new flocculant used in the treatment of wastewater from the metallurgical industry, taking into account the impact of the flocculant production process on the environment. It presents the results of an analysis carried out with the LCA technique for the appraisal of the environmental impact of the modified waste phenol–formaldehyde resin (which is called Novolak) [90].

It should be added that apart from the various types and scopes of assessments using this technique, there was also a proposal of a new methodology for conducting LCA for wastewater treatment plants in [91]. Its purpose is to avoid limitations in the interpretation of LCA results. It is based on an evaluation of the net environmental benefits (NEB) and requires an assessment of the potential impacts of wastewater discharge without and after treatment, in addition to the life-cycle impact assessment of the wastewater treatment plant [91].

The way to conduct regular assessments, but for existing wastewater treatment plants, is to implement an environmental management system. An example of this may be the implementation of the ISO 14001 system. It is also observed that many entities decide to integrate the environmental management system with another management system (for quality and/or safety), thus creating an integrated management system. ISO 14001 certificates are issued for wastewater treatment plants, an example of which is the “Klimzowiec” wastewater treatment plant in Poland [92], or for water supply and sewage companies, usually covering the production and supply of water as well as the collection, treatment and discharge of wastewater, e.g., [93–95]. Another example is the EMAS scheme. This management system is not yet very popular in Poland, as evidenced by the number of registered organizations, but several wastewater treatment plants carry out this method of assessing their environmental impact. According to the register [96], the Polish wastewater treatment plants implementing the EMAS environmental management system include the final wastewater treatment plant of PGE GiEK S.A. in Brzezine near Opole, wastewater treatment plants managed by the Water Supply and Sewage System Company of the Częstochowa District (joint-stock), wastewater treatment plants in Suszec and in Ornon-towice managed by the Enterprise of Water Management and Reclamation (joint-stock) in Jastrzębie Zdrój, the wastewater treatment plant in Tychy, and the “Hajdów” wastewater treatment plant in Lublin. Due to the fact that the EMAS system is, in simple terms, an extension of the ISO 14001 system, it is possible for a wastewater treatment plant to have more than one environmental management system. This is the case for the “Hajdów” wastewater treatment plant in Lublin. The fact that WWTPs have the ISO 14001 certificate or have been entered into the EMAS register proves that the environmental aspects of the wastewater treatment plant have been identified at least once. On the other hand, maintaining and perfecting the environmental management system allows for the constant monitoring of the impact of a WWTP on the environment. For example, in the Water Supply and Sewage System Company of the Częstochowa District (joint-stock), which has an implemented EMAS system, in the scope of wastewater collection and treatment, the following environmental performance indicators are checked: energy efficiency, material efficiency (flocculants, coagulants and chlorinated lime), water consumption, the mass of generated waste (total and hazardous) and emissions [97]. Moreover, by comparing the situation before the implementation of the system and after 8 years of its operation, a significant reduction in the amount of waste from wastewater treatment processes that is subjected to landfilling was observed [97].

In a holistic approach, to assess any environmental impacts of a wastewater treatment plant, it is also necessary to consider buildings and their impacts. For this purpose, multi-criteria evaluation systems are used, e.g., BREEAM or LEED. There is no wastewater treatment plant in Poland with buildings certified by the BREEAM or LEED system. Only a few wastewater treatment plants in the world are certified with these systems, but important is that such facilities do exist. A project worth mentioning is the new Aériss wastewater treatment plant for Cagnes sur Mer in France. At the beginning of 2018, it obtained the BREEAM Interim certificate in the International 2013 New Construction

scheme for industrial projects, achieving a result of 56.5% and a very good rating [98]. The treatment plant is located between a railway line and a motorway to minimize its impact on residents and the environment. According to the plans, in the event of heavy rainfall, the treatment plant will treat the wastewater produced by the equivalent of 160,000 inhabitants. It is called a net positive energy wastewater treatment plant due to the fact that, ultimately, the plant will use less energy than it produces [99].

There are wastewater treatment plants, their selected buildings or buildings of water and sewage companies certified with the LEED system or under certification, as evidenced by the LEED project databases [100,101]. Among the facilities of the LEED certified WWTPs, the wastewater treatment plant in Dryden, Canada, deserves special attention. According to Dryden's Public Works Manager the Dryden Wastewater Treatment Plant is a LEED-certified structure which covers the building, and also the processes and the plant [102,103]. While other facilities have buildings that have obtained LEED certificates, the designers of the company responsible for the design of the Dryden plant believe it is the first entire WWTP in North America to achieve LEED certification [103]. One of the factors contributing to the certification is an in-floor heating system, which takes heat from the treated wastewater before it is discharged [102]. Other solutions that deserved credit -towards LEED include reusing treated wastewater to wash down and clean the facility, reusing heat generated by blowers, minimizing light pollution, having storage for bicycles, having showers for the crew, promoting green modes of transport, and diminishing water consumption through the use of water fittings such as waterless urinals or low-flow showers, sinks and toilets [103].

Table 2 presents basic information on selected certified facilities related to wastewater treatment plants in the United States and Canada. Data such as the scheme in which they were assessed, the year of issuing the certificate, the number of points (scored and the maximum possible) and the requirements for which individual objects obtained points in selected categories were compared. Selected areas, especially those associated with the impact on the environment, are included, i.e., sustainable sites, water efficiency, and energy and the atmosphere. In addition, points earned in the innovation category were also included. Credits such as those for indoor air quality and materials and resources were omitted. When analyzing the data contained in the table, it can be observed that the buildings of the wastewater treatment plant have received different ratings, but these are rather lower ratings (certified or silver level). It should be added that the mere obtaining of the certificate proves that all the critical requirements specified in the individual categories are met. It can be seen that the wastewater treatment plants in the United States scored points on different requirements, while the Canadian facilities obtained points on almost the same credits. Almost all the WWTPs received points for choosing a location, alternative transport and reducing water consumption. A frequently fulfilled requirement (but to different extents, i.e., with different numbers of points scored) was that to optimize energy efficiency.

Table 2. Data on LEED certification for selected facilities related to wastewater treatment plants.

Project	Scheme	Score, Certification Level, Year of Certification	Selected Credits with Points Awarded	Source
Sanford Wastewater Treatment Plant, Sanford, United States	LEED BD+C, New Construction, v2 LEED 2.2	38/69 points, silver, 2015	<ul style="list-style-type: none"> - Sustainable sites (site selection, alternative transportation, stormwater design—quantity control) - Water efficiency (water-use reduction, water-efficient landscaping) - Energy and atmosphere (optimize energy performance, enhanced refrigerant management) - Innovation (innovation in design) 	[100]

Table 2. Cont.

Project	Scheme	Score, Certification Level, Year of Certification	Selected Credits with Points Awarded	Source
Central Wastewater Treatment Plant Maint, Dallas, United States	LEED BD+C, New Construction, v2 LEED 2.1	27/69, certified, 2009	<ul style="list-style-type: none"> - Sustainable sites (site selection, alternative transportation, reduced site disturbance—development footprint and heat island effect—roof and non-roof, light pollution reduction) - Water efficiency (water-efficient landscaping) - Energy and atmosphere (optimize energy performance, additional commissioning) - Innovation (innovation in design) 	[100]
Triangle Wastewater Treatment Plant, Durham, United States	LEED BD+C, New Construction, v2 LEED 2.0	27 points, certified, 2005	No data available	[100]
Florence Regional Wastewater Management Facility, Florence, United States	LEED BD+C, New Construction, v2 LEED 2.2	39/69, gold, 2013	<ul style="list-style-type: none"> - Sustainable sites (site selection, alternative transportation, site development—maximize open space, heat island effect—roof) - Water efficiency (water-use reduction, water-efficient landscaping) - Energy and atmosphere (optimize energy performance) - Innovation (innovation in design) 	[100]
Control Building for Sewage Treatment Plant	LEED BD+C: New Construction v2—LEED 2.2	36/69, silver, 2011	<ul style="list-style-type: none"> - Sustainable sites (site selection, alternative transportation, site development—maximize open space, stormwater design—quality control, heat island effect—roof, light pollution reduction) - Water efficiency (water-use reduction, water-efficient landscaping) - Energy and atmosphere (optimize energy performance, enhanced refrigerant management, green power) - Innovation (innovation in design) 	[100]
City of Dryden Wastewater Treatment Plant, Dryden, Ontario, Canada	LEED Canada NC 1.0	33/70, silver, 2016	<ul style="list-style-type: none"> - Sustainable sites (site selection, alternative transportation, heat island effect—roof, light pollution reduction) - Water efficiency (water-use reduction, water-efficient landscaping, innovative wastewater technologies) - Energy and atmosphere (optimize energy performance, ozone protection, green power) - Innovation (innovation in design) 	[101]
Wood Buffalo Wastewater Treatment Facility, Fort McMurray, Alberta Canada	LEED Canada NC 1.0	29/70, certified, 2012	<ul style="list-style-type: none"> - Sustainable sites (alternative transportation, stormwater management—rate and quantity, treatment) - Water efficiency (water-use reduction, water-efficient landscaping, innovative wastewater technologies) - Energy and atmosphere (optimize energy performance, ozone protection, green power) - Innovation (innovation in design) 	[101]

In addition to the mentioned environmental impact assessment (EIA) prepared in accordance with local or national regulations, environmental impact assessments of wastewater treatment plants are also carried out as part of various types of expert investigations e.g., [72] and research. This type of work is observed in numerous scientific articles, for example, [12,73,74,104 or 105]. Their scope, structure and level of detail are determined by the authors of the publications and often result from current problems occurring in the facilities. In articles on the assessment of the impact of wastewater treatment plants on the environment, the LCA technique is often the research method—used alone [104,105] or in combination with other methods—such as in [74] with material flow analysis (MFA) and energy analysis (EA). For example, the work [74] analyzed the environmental impact of energy and chemical consumption at wastewater treatment plants in Oslo, Norway. According to this study, global warming and acidification were the dominant effects from the chemicals and energy, respectively. In turn, the work [105] discusses the environmental assessment of wastewater treatment plants for Al-Hilla City in Iraq with the use of LCA. The greatest impact was recorded in terms of global warming, the influence of inorganic substances on the respiratory system and the consumption of non-renewable energy sources. Other methods of environmental impact assessment are also used, such as in [73], where the Fine–Kinney method was used to compare three versions of a technological system for treating wastewater from meat-processing plants. Some of the assessments of wastewater treatment plants in scientific articles are carried out in the context of energy consumption and its optimization. This is related to the ongoing climate change and the attempts to minimize the amounts of greenhouse gases produced. The articles [106,107] are examples here. The work [107] shows a multi-step methodology for the appraisal of the energetic aspects of wastewater treatment, introduced at a wastewater treatment plant in Italy. In turn, the article [106] proposes a multi-step simulation-based methodology for fully relating treatment processes to energy demand and energy production. This work also assumes a scenario-based optimization approach and applies it to the same facility (the WWTP in Castiglione Torinese, Italy). There are also assessments that take into account only one type of environmental impact—e.g., noise in [72] or odors [108]. The work [108] shows the findings of the appraisal of the odor intensity (conducted via sensory studies according to a six-stage scale) and the measurement of odor concentration (with the use of portable field olfactometers) after the finishing of a modernization project, and compares them with similar research carried out before the start of this investment. After modernization, a meaningful diminution in the concentration of the odor emitted from the sludge dewatering building, sludge containers and sewage channel was determined [108].

5. Conclusions

A wastewater treatment plant has an environmental impact during both construction and operation. Therefore, there is a need to assess this impact not only at the design and construction stage, but also at the facility operation stage. While such assessments are frequent at the investment planning stage, they tend to be neglected in the operational phase. On the other hand, control activities are carried out in the context of compliance with certain regulations concerning, for example, emissions.

Various methodologies are available for assessing the environmental impacts of wastewater treatment plants. Their scopes and degrees of detail vary. Although some of them are applicable to both designed and existing facilities (e.g., EIA, LCA, and green building certification systems), their use is often limited to the planning and design stage. The reason for this can be associated with two main factors—the obligation of assessment for planned facilities and the difficulty of meeting individual green building requirements for existing buildings. Here, the environmental management systems for existing facilities and functioning companies managing wastewater treatment plants seem to be a solution. These systems are voluntary, while the incentive for owners is the prestige from their implementation and the savings (by reducing the use of energy, raw materials and water) that go hand in hand with minimizing the impact on the environment. Moreover, these

systems make it possible to organize and systematize the introduction of innovations in wastewater treatment plants and stimulate the constant search for new solutions and improvements. An interesting solution is LCA analysis, which is gradually gaining more and more interest. It is used both for the assessment and comparison of various technological cycles for planned wastewater treatment plants, and for the evaluation and comparison of existing facilities. The need to purchase software may be a problem, but there are also free programs. On the other hand, the assessments carried out by scientists are relatively rare cases, with scopes adapted to the current needs of the wastewater treatment plants and the problems to be solved.

Conducting environmental impact assessments of WWTPs during their operation seems to be a good course of action for the future. It is important to treat this issue as a whole, i.e., to take into account, apart from the typical impacts of WWTPs on environmental components, the impacts generated by the operation of their buildings. A problem may be the lack of sufficient incentives and motivation to carry out such environmental assessments once the facility is in place. The introduction of obligatory inspections of WWTPs covering all environmental aspects may be considered, but it seems much more appropriate to lead activating activities for the voluntary assessment of these facilities. It is from such cases that one can expect breakthrough solutions that will also inspire other decision-makers.

It should be emphasized that each activity aimed at assessing the impact of the operated wastewater treatment plant, regardless of the scale and scope, has a potential environmental benefit. Moreover, the analysis of the available environmental impact assessments carried out by WWTPs can provide an impulse and invitation to modernize other existing treatment plants and introduce technical and technological innovations in these facilities, all for the benefit of the environment. It should be remembered that the best available techniques (BAT) used at the time of designing the treatment plant may sometimes become obsolete after years of operation of the facility.

The suggested direction of development for the assessment of the environmental impact of wastewater treatment plants is the improvement of the LCA technique, and the implementation of environmental management systems, with the supplementation of these actions through green building certification. Only a holistic approach to the issue will enable all the environmental aspects to be taken into account and thus contribute to the maximization of the subsequent environmental benefits. It is also advisable, if possible, to take steps to develop and implement a unified method of assessing the impact of sewage treatment plants on the environment. At the same time, activities that encourage and stimulate the uptake of such challenges should be introduced. By taking such steps, in the future, the processes carried out in wastewater treatment plants will become even more “clean”, and the treatment plants themselves will become more environmentally sustainable facilities. In this aspect, the introduction of circular economy solutions in wastewater treatment plants is also of great importance.

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