Ecological City – Types of Wastewater Treatment Plants in Poland: The Influence of Technology on Space

Agnieszka Wojtowicz-Wrobel

1 City Renewal Division, Institute of City and Region Planning, Faculty of Architecture, Cracow University of Technology, Cracow, Poland

awojtowicz@pk.edu.pl

Abstract. Newly designed structures that provide technical services to cities gain new spatial forms. In terms of their functional and spatial structure they often also fulfil new, additional functions. This is possible thanks to, among other things, new technical and technological solutions. A departure from the typical approach based on merely associating engineering structures with an envelope of technical solutions of sorts, without care for architectural form, detail or site development, brings positive effects in terms of spatial relationships. In the case of pro-environmental structures this also has a functional dimension—oftentimes these structures start fulfilling additional functions, e.g. as a part of ecological education. Simultaneously, we can observe that some structures that provide the engineering infrastructure to the city gain a new architectural form, new site development of the space that surrounds them or are being equipped with new, additional functions, more frequently than others. Without a doubt, influence on which structures are being transformed in accordance with the abovementioned directions, and which remain on the sidelines of new spatial, architectural and functional solution, is exerted by the primary function of the structure—which is in itself obvious. However, within the group of structures with the same functions we can also observe significant differences. One example of this are wastewater treatment and water purification plants. The goal of this article is to find the answer to the following questions: is the form of a structure and its site development determined by various types of technological solutions in wastewater treatment and water purification plants—and if so, then in what manner? Furthermore, do differences in technology have an impact on the immediate surroundings of the plants and—on a wider scale—on the space of the city? The results of the study will advance knowledge concerning the dependencies between technological solutions and architectural form, as well as spatial relations within the functional and spatial structure of cities.

1. Introduction
Contemporary economic transformations bring with them numerous new challenges—one of them being care for the natural environment, whose quality—due to man's harmful activity—is significantly degrading. Although we can state that the level of water, air and soil pollution is rising globally, it is most readily observable in areas of an urban character [2]. Awareness of the problem of the growing pollution of the environment of human life leads to numerous actions that are meant to effectively prevent this degradation. These efforts can be discussed in two groups:
a) Actions of an education-related, social and legal character—these are initiatives that are expressed both on the scale of raising the awareness of city residents ([11] ecological education), efforts by municipal authorities (pro-environmental actions on the urban scale—establishing regulations that protect the environment, lower exhaust emissions by supporting public transport or care for greenery [9] and others) or social actions (public initiatives meant to promote a healthy lifestyle, rational resource management on the scale of the resident or pro-environmental initiatives such as the joint clean up of open areas or planting trees). These efforts have a physical dimension, but are primarily significant in the social perspective.

b) Activities of a technical character, including three types:

— those that are meant to stimulate social activities (when technology creates new opportunities for public initiatives—e.g. a design of an education path in a newly-built pro-environmental building, creating new teaching possibilities);

— those that are an effect of social and legal actions (e.g. the necessity of adapting technological installations to newly introduced legal provisions);

— those that are the result of economic and financial calculations (the modernisation of technological installations, expansion or remodelling associated with improving performance, etc.).

Both of these types of actions, by becoming significantly more intense, can affect space in which they take place. Against this background, of particular note are urban engineering structures. The development of new technologies—and, as a result, new possibilities—provides an opportunity not only for more effective environmental protection or initiating new social actions, but also for the creation of good quality architecture [1]. Among buildings that feature pro-environmental engineering functions, the precursors of such actions appear to be thermal waste processing plants. In this case, due to their form and size, their spatial impact is significant and their technology determines their architectural solutions, although when appropriately used, it does not constitute an obstacle, fulfilling the function of a sort of guideline [10]. Other structures that are currently undergoing significant transformation in terms of technology are wastewater treatment plants—which are the subject of this text.

This study was conducted as a part of the cycle on structures that feature new pro-environmental functions and their significance in the space of cities and suburban areas. The research field includes two selected groups of structures: thermal waste processing plants and wastewater treatment plants (and in some case also water purification plants). The presentation of the subject in the form of a matrix, as shown in table 1 (cf. [6]) made it possible to display research results as divided into four groups. These are as follows:

a) Social issues—this group features published studies concerning thermal waste processing plants („The beauty of eco-technology – thermal waste processing plants as structures that increase the attractiveness of city spaces” – S/TWPP);

b) Architectural issues—this group features published research concerning thermal waste processing plants („The beauty of ecotechnology - thermal waste processing plants as an structures that increase the attractiveness of city spaces” – A/TWPP) and wastewater treatment plants („Beauty in eco-technology – a sewage treatment plant as a spatially attractive structure” – A/WTP);

c) Spatial issues—presented from two points of view: as the matter of accessibility and location, which features the publication of research results of a selected group of thermal waste processing plants („Thermal waste processing system structures. Questions of locations and accessibility – Polish experiences” – L/TWPP) and wastewater treatment plants („Accessibility
of sewage treatment plants - benefits and limitations associated with their location requirements” – L/WTP), as well as the subject of spatial relationships, in which research results concerning thermal waste processing plants were published (“On the cusp of the new spatial challenges – the thermal waste processing plant as an element of urban space”);

d) Technical issues and their impact on the shaping of space around structures—this group includes published research results concerning thermal waste processing plants („From technology to a landmark – selected thermal waste processing plants in Europe” – T/WTPP).

At the same time, this publication is a supplementation of this cycle of articles, meant to include wastewater treatment and water purification plants. A detailed scheme of the studies has been presented in the table below (table 1).

Table 1. Matrix structure of the research being conducted—presented as a table (original work, 2017).

| Group 1             | Group 2        | Group 3         | Group 4          |
|---------------------|----------------|-----------------|------------------|
| Social              | Architecture   | Locations/      | Urban Relations  |
|                     |                | Accessibility   |                  |
| Thermal Waste       | S/TWPP         | A/TWPP          | L/TWPP           |
| Processing Plants   |                |                 | U/TWPP           |
| Wastewater          | S/WTP          | A/WTP           | L/WTP            |
| Treatment Plant     |                |                 | U/WTP            |
|                     |                |                 | T/WTP            |

2. Historical background—the first wastewater treatment solutions

The beginnings of the contemporary problem of wastewater treatment can be dated similarly to attempts at stockpiling or—as it is presently done—neutralising waste. The necessity of solving the problem of sewage was forced by a switch from the nomadic lifestyle to a settled one by man. It was observed that the problem of disease is not only associated with "miasma", but also with polluted water. Attempts at stockpiling waste away from human settlements were an automatic solution. At the same time, attempts at solving the matter of sewage appeared to be more problematic. Although the problem of waste appeared to be less complicated (all it took was to place the removed waste sufficiently far from human dwellings), the problem of sanitary sewage was more complex. The first solution to the primitive treatment of sewage were "cesspits", placed in the outer areas of human settlements, far away from water sources. After they were filled, the water from them drained into the soil and the sewage inside underwent fermentation. The cesspits were then buried and new ones were dug. This solution worked on the small scale and resulted in problems concerning the placement of a new sewage deposit site (one that was close but did not result in inconvenience). In cities, systems of so-called gutters made it possible to drain sewage, pollutants and surface runoff outside of human settlements, but it did not solve the problem of the pollution of the city itself and the associated diseases. Furthermore, it did not operate during winter, when sewage froze and it was necessary to hack it into pieces and ship it outside of the settlement by hand [8]. The introduction of a system of enclosed gravitational sewerage solved some of the problems of sewage removal in cities. A separate matter was the social acceptance of constructing toilets in homes, which were initially met with significant opposition from residents as they were seen as unhygienic and harmful—only having been accepted over time. The first so-called "wastewater treatment plants" were located in the lowest parts of a city's limits or outside of them, and sewage was transported from homes using pipes that used gravitation to propel it. They were composed of two chambers:
− a sedimentation chamber (upper tank), where solid matter was separated from water through mechanical means, as well as
− a fermentation chamber (lower tank), which collected sediment and where its anaerobic digestion took place.

This type of mechanical treatment is called the Imhoff tank (patented at the start of the twentieth century) and is still used in contemporary wastewater treatment plants as one of the elements of the treatment process (after its adaptation to contemporary technological standards and modification attempts [5]). A sketch of the Imhoff tank has been presented on fig. 1.

![Figure 1. Scheme of the contemporary structure of an Imhoff tank, A – sedimentation chamber, B – digestion chamber, based on collected materials, (original work, 2019)](image)

Supplementing mechanical treatment with chemical treatment opened new possibilities, however, it was the introduction of biological treatment—in which appropriate bacteria cultures process a significant portion of chemical compounds that remain in the water that has already been subjected to mechanical and chemical treatment—that was a key breakthrough. The effectiveness of biological treatment has resulted in the necessity of adapting the treatment technology standard to it in, among other places, European Union member states. It is for this reason that Polish wastewater treatment plants that are the subject of this article were faced with the necessity of carrying out numerous modernisation projects associated with it. This took place at the start of the 1990’s, when Poland made its first attempts at entering European Union structures.

The fundamental reason for wastewater treatment has always been health (the obtainment of easily accessible, unpolluted water near human settlements), while over time, the protection of the natural environment itself became an equally important cause. At present, purified water, apart from sanitary considerations, is also important for the quality of Polish rivers—by draining biologically purified water into rivers, we can reduce pollution in the rivers themselves. At present, structures that comprise the engineering infrastructure of cities—including wastewater treatment plants—are facing new possibilities of technological transformation that also include the transformation of the forms of these structures. This creates not only opportunities, but challenges as well—largely depending on the type of technology being introduced.
3. Contemporary solutions—an outline of wastewater treatment technology

Wastewater treatment plants are composed of a complex of facilities and structures that are necessary for their correct operation. Among these there are: bar screen spaces, grit removal tanks, primary and secondary sedimentation and settling tanks, pump stations, bioreactors, digestion chambers, a sediment densification station, a dewatering station, a drying station, gas generation stations, administrative buildings, numerous laboratories, technological process control structures and other facilities. It can be concluded that the around a dozen structure types that make up a wastewater treatment plant form three groups of structures:

− structures whose primary function is the direct treatment of wastewater,
− structures that are meant to store the by-products of the primary process (screening wash presses, spaces for the storage, densification, dewatering and burning of sediment, digestion chambers or biogas burning facilities)
− administrative buildings—staff buildings, technological process control rooms, etc.

They also feature basic infrastructure (parking spaces, circulation on the plant grounds, etc.)

The wastewater treatment plants located in Poland can typically be divided on the basis of:

− the type of treated sewage,
− size (the amount of processed sewage), as well as
− installation type—treatment method (a sizeable portion of contemporary wastewater treatment plants are fitted with different types of installations, which means that treatment process types should be discussed rather than structure types).

Based on the type of sewage being treated, we can distinguish three most common types of structures:

− Municipal wastewater treatment plants—are complexes of structures that accept both household sewage from the municipal sewerage system, surface runoff and small amounts of industrial sewage mixed with the prior two, delivered both through combined sewerage and shipped from extractable tanks.
− Industrial sewage treatment plants—these are complexes of structures prepared to treat sewage from industrial processes. These structures are specifically adapted to these types of pollutants and must meet different requirements concerning treatment processes, safety, etc.
− Special-purpose sewage treatment plants—used to treat waste that is more demanding than that which can be processed by municipal or industrial sewage treatment plants in technological terms. These can include both hospital wastewater treatment plants that require particular attention because of the threats associated with them, as well as surface runoff treatment plants, which purify sewage that is less polluted than, for instance, that produced by households.

The division of wastewater treatment plants based on the amount of processed sewage is regulated in Poland by the "Ordinance of the Minister of the Environment of the 18th of November 2014 on the matter of conditions that need to be met when draining sewage into waters or into the soil, as well as concerning substances that are particularly harmful to the aquatic environment" [6]. In order to determine the amount of sewage that a wastewater treatment plant receives according to the act mentioned above, we are to use the Population Equivalent measure (Równoważna Liczba Mieszkańców, RLM), which has been defined in the "Ordinance of the Council of Ministers of the 2nd of March 1999 on the matter of the Polish Statistical Classification Concerning Activities and Machinery Associated with the Protection of the Environment, Dz.U. 1999, no. 25, pos. 218" [7]. This measure is expressed as a relation between sewage load size from sewage produced by industrial plants and service buildings over 24 hours to a unit load of pollutants found in household sewage (which is produced by a single resident over a period of 24 hours) [7]. According to the provisions of
the Ordinance, we can distinguish five size groups that differ in terms of requirements concerning the quality of wastewater that they receive.

- Below 2 000 RLM
- 2 000 - 9 999 RLM
- 10 000 – 14 999 RLM
- 15 000-99 999 RLM
- Above 100 000 RLM.

Due to the fact that the best treatment results can be obtained by using several combined methods, currently built or modernised Polish wastewater treatment plants, when meeting the required legal standards, most often operate by combining various treatment methods: mechanical, chemical and biological ones. It is for this reason that we can currently discuss the successive methods of wastewater treatment as a part of a single facility rather than separate facilities that operate using a single method. According to this principle, the process of wastewater treatment can be divided into 3 stages:

- Stage I: mechanical treatment;
- Stage II: biological or chemical treatment (equivalently or simultaneously);
- Stage III: water polishing.

Mechanical treatment, which constitutes the first stage, is based on separating solid bodies from the sewage using screens and filters. This type of treatment also involves grit separation using grit tanks and the separation of easily-settling solutions using sedimentation tanks. The sludge can also be initially separated from oils and grease. The waste obtained in the process of mechanical treatment is processed appropriately (solid waste is dried and pressed, while sand is washed) and later shipped to a waste disposal site or incinerated at an appropriately adapted installation.

The second stage of treatment is biological treatment (or an equivalent or simultaneous chemical treatment).

Biological treatment involves the dissolution of pollutants using biological oxidation processes using a mass composed of microorganisms. Two types of intensive biological treatment are used: oxidising beds (sprayed or washed beds, or rotary submerged contactors), as well as biological reactors (treatment using so-called activated sludge). Biological beds of both types are most often used in smaller plants with relatively small catchment and their prototypes were already used in the nineteenth century. Equipment that operates on the basis of activated sludge is configured to accommodate the type of wastewater that is introduced into it.

Chemical treatment is based on conducting a process of volume coagulation by the addition of coagulants (iron compounds, aluminium compounds, flocculants, sometimes also, regardless of needs, calcium compounds) [4]. This is aimed at lowering phosphorous content (chemical treatment is often called chemical phosphorous precipitation). Due to the place where coagulant is added in the technological cycle, we distinguish initial precipitation (when the coagulant is added to so-called raw sewage, prior to mechanical treatment), simultaneous precipitation (when the coagulant is added to the biological reactor or immediately prior to the sewage passing into the reactor—this way the chemical and biological treatments take place simultaneously) and final precipitation (when the coagulant is added to biologically treated sludge) [4].

Water polishing is the third stage of wastewater treatment, which, according to Polish regulations, is not a mandatory stage. It involves bringing the water to a standard in which it can be safely used as drinking water or within the household. The process of water polishing uses the same methods used in the treatment of underground or groundwater (disinfection, filtration, absorption, etc.).
4. The spatial significance of wastewater treatment plants: case study

Due to the variety of entities that are required to perform wastewater treatment according to legal regulations, as well as the variety and multiplicity of requirements associated with it, in order to unify the research field, only municipal wastewater treatment plants were analysed in the article, with a particular focus on treatment plants that can perform biological treatment. According to the report entitled „Gospodarka ściekowa w Polsce w latach 2015-2016” prepared by Państwowe Gospodarstwo Wodne „Wody Polskie” [3], towards the end of 2016 there were 1658 wastewater treatment plants capable of performing biological treatment in Poland, as well as 601 plants that could perform water polishing—biological treatment with increased phosphorous and nitrogen removal capabilities [3, p.34]. One example of this type of wastewater treatment plant is the Central Wastewater Treatment Plant in Koziegłowy, with a capacity of 260 000 m³/24 hours, which services Poznań. The plan of the construction of a wastewater treatment plant that could satisfy the needs of the Poznań agglomeration was formulated in the middle of the 1950's, however, its construction commenced twenty years later [13]. The plant became operational in 1984. Along with the first attempts by Poland to enter the European Union, regulations concerning the treatment and purification of water were subjected to significant changes—with new technologies simultaneously introducing new possibilities. Because of this, modernisation of the plant's existing technological line began at the start of the 1990's and in 1996 construction commenced on a biological treatment installation and the expansion of the existing mechanical treatment installation due to the planned processing capacity increase. Since that time the installations have been systemically modernised in order to improve the quality of purified water, whose parameters are currently better than those of the receiver to which it is delivered (the Warta River).

![Figure 2](image_url) Operation scheme of a sewage treatment plant using two-step treatment (mechanical and biological treatment). A—bar screen space, B—grit removal tank, C—pre-settling basin, D—bioreactors, E—secondary settling basins, F—receiver (river), G—sediment densifiers, H—sediment densification station, I—fermentation tanks, J—gas generator station, K—sewage dewatering station, L—thermal sewage sludge drying plant, M—granulate, N—accompanying buildings (administrative buildings, laboratories, technical facilities, etc.; original work based on available materials [13] (original work; 2018)

Above is a presentation of a wastewater treatment plant operation scheme, based on the scheme of the Central Wastewater Treatment Plant in Koziegłowy (fig. 2), which can serve as a standard example of the technological scheme of a treatment plant fitted with a mechanical and biological installation. Based on this scheme and an assessment of the structures themselves, an analysis of the types of structures was performed, rating their impact on space in the visual sense. Each wastewater treatment
plant element has been listed below, along with an assessment of its impact rated on a three-point scale (table 2).

**Table 2.** Assessment of the impact of individual elements of a wastewater treatment plant on space: A – high, B – medium, C – low; (original work, 2019).

| Structure/installation element     | Technological identifiability (visual impact of technology on the plant) | Assessment of the element's visual impact on the surroundings |
|------------------------------------|------------------------------------------------------------------------|-------------------------------------------------------------|
| Bar screen space                   | B                                                                      | A                                                           |
| Grit removal tank                  | A                                                                      | B                                                           |
| Pre-settling basin                 | A                                                                      | B                                                           |
| Bioreactor                         | A                                                                      | B                                                           |
| Secondary settling basin           | A                                                                      | B                                                           |
| Sediment densificator              | A                                                                      | A                                                           |
| Sediment densification stations    | C                                                                      | A                                                           |
| Fermentation tanks                 | A                                                                      | A                                                           |
| Gas generator station              | C                                                                      | A                                                           |
| Sewage dewatering station          | C                                                                      | A                                                           |
| Thermal sewage sludge drying plant | B                                                                      | A                                                           |
| Accompanying buildings             | C                                                                      | A                                                           |

The qualities being assessed included technological identifiability in shaping the massing of the structure or installation element, with said “technological identifiability” understood as the impact that the technology of a given structure exerts on its visual reception. Depending on technological conditions, the following were indicated: structures whose massing is determined by technological installation solutions to a significant degree (A), medium degree (B), as well as structures in the case of which technology was not observed to have a significant impact on their form. In addition, the impact of the structure (or installation element) on the surroundings was assessed as well (high, medium, low) without listing the type of impact (positive or negative). In this case a three-grade rating system was used as well (A—as the highest impact, B—medium, C—lowest impact).

5. Results and discussion

Based on the analysis of the structures of the Central Wastewater Treatment Plant in Koziegłowy as an example of good practice (in technical, technological and developmental terms) on the scale of Poland, it can be observed that close to a half of the structures located on the plant's grounds was classified as having a low technological identifiability, however, of note is the fact that accompanying structures were classified as a single group, thus significantly lowering the numerical value of the structures of this type. It should also be noted that the vast majority of structures that were given a "C" rating in this group are typical architectural structures, in the case of which a change in their form is possible and any installations (if present) are sort of "hidden" inside the building. At the same time, the structures that were rated as having high technological identifiability are most often large fragments of
a wastewater treatment plant (e.g. fermentation tanks), or structures that are spatially extensive (grit removal tanks, settling tanks, etc.).

Table 2 also features an assessment of the impact of structures or individual installation elements on the surroundings in visual terms. Close to 2/3 of all of the assessed elements are structures that exert significant impact on the surrounding space. These are both structures that can be described as architectural, as well as installation elements that fulfil solely industrial functions, built without care for the visual aspect. The remaining structures were classified as having medium impact on the surrounding space. In this rating it was important that such structures—as it has already been mentioned—were not classified in terms of impact type. It is for this reason that a single group includes both structures that exert a high impact when viewed from a greater distance, as well as such fragments of the technological installation that, due to their dimensions, can constitute a sort of visual foreground (low, flat and spatially extensive elements).

6. Conclusions and observations
The significance of new technologies in terms of space is particularly reflected in structures that form the engineering infrastructure of the city. In the case of wastewater treatment plants, technological changes are forced not only by technological development and the drive to search for more effective solutions, but also legal conditions, etc. (in the case of Poland—e.g. by becoming a part of the European Union). Contemporary transformations in the field of wastewater treatment technology have led to a situation in which we can formulate the following conclusions based on the analysis performed in the article:

− When analysing the impact of wastewater treatment plants against the background of other municipal engineering structures, it can be observed that the forms of the former are largely determined by their technological solutions [12]. There is no distinction between technology types and whether they exert a greater or lesser impact on their form. This is so because of two reasons: in each type of installation there are structures with a varying degree of impact on space and in each of them we can speak of elements with a greater or smaller degree of reflecting the adopted technology. At the same time, due to the necessity of adapting technology to legal standards, municipal wastewater treatment plants utilise different treatment installations. It would thus be baseless to search for technological divisions in structures in which their contemporary design tendency opposes this and leans towards combined technological solutions within a single plant.

− In the case of Polish municipal wastewater treatment plants, the structure of technological installation elements most often does not feature visually positive solutions. These elements have a decidedly functional expression in space (good access, satisfying legal standards, order is only associated with maintaining cleanliness and smooth functioning, instead of the aspect of spatial attractiveness).

− At the same time it can be observed that there exists a potential in the elements of technological installations in the visual aspect, one that could be used in the shaping of space (large or vertical objects can constitute dominant elements or landmarks, while spatially extensive structures can fulfil the role of visual foregrounds of sorts). However, it is first necessary to be aware of the possibility of shaping them in this manner. Due to the location of wastewater treatment plants, the awareness of the possibility of using water in the shaping of the space of these types of facilities is also highly essential.
References

[1] J. Barnaś, “Architecture from waste,” *7th International Multidisciplinary Scientific Geoconference SGEM 2017: conference proceedings*. Vol. 17, *Nano, bio and green-technologies for a sustainable future*. Iss. 63, *Micro and nano technologies advances in biotechnology, green buildings technologies and materials, green design and sustainable architecture, animals and society*, pp. 447-454

[2] O. Kania, K. Barnaś, “Urban morphology of Krakow’s districts and its influence on smog”, *The International Journal of the Constructed Environment*, vol.10, iss.2, pp.1-8

[3] „Gospodarka ściekowa w Polsce w latach 2015-2016” opracowanym przez Państwowe Gospodarstwo Wodne „Wody Polskie”, report; prepared by Państwowe Gospodarstwo Wodne „Wody Polskie”, www.wody.gov.pl [retrieved on: 15.03.2019]

[4] Z. Heidrich, A.Witkowski, „Urządzenia do oczyszczania ścieków. Projektowanie, przykłady obliczeń”, Warszawa, 2005

[5] A. Mikelonis, A. Herrera, E.Adams, M. Hodge, Honduran Imhoff Tanks: Potentials and Pitfalls”, *Journal of Wastewater Management Modeling*, 2010

[6] B. Podhalański “Technology through the scales and its impact: from the metropolitan region to the district’s urban form”, *Urban Planning Architecture & Design*, SGEM 2017, Book 5, pp.295-302, 2017

[7] Rozporządzenie Ministra Środowiska z dn. 18 listopada 2014 r. w sprawie warunków, jakie należy spełnić przy prowadzaniu ścieków do wód lub do ziemi, oraz w sprawie substancji szczególnie szkodliwych dla środowiska wodnego”, www.prawo.sejm.gov.pl [retrieved on:15.03.2019]

[8] Rozporządzenie Rady Ministrów z dn. 2 marca 1999r. w sprawie Polskiej Klasyfikacji Statystycznej Dotyczącej Działalności i Urządzeń Związanych z Ochroną Środowiska Dz.U. z 1999 r. nr 25, poz. 218, www.prawo.sejm.gov.pl [retrieved on:15.03.2019]

[9] A. Słoniowa, “Początki infrastruktury nowoczesnej Warszawy”, pp.203, 1978.

[10] A. Wójcik A., A. Gajdek, “Do innovations need greenery? About 10 most influential cities in the world”, *Housing Environment*. vol. 19, pp. 28-35, 2017

[11] A. Wójtowicz-Wróbel, „From technology to a landmark – selected thermal waste processing plants in Europe”, *IOP Conference Series: Materials Science and Engineering*, vol.471, 2019

[12] A. Wójtowicz-Wróbel, “Social reception of thermal waste processing system structures”, *17th International Multidisciplinary Scientific Geoconference SGEM 2017, conference proceedings*, vol.17 Energy nad Clean technologies, iss. 41, pp.209, 2017

[13] A. Wójtowicz-Wróbel, „Beauty in eco-technology – a sewage treatment plant as a spatially attractive structure”, *E3S Web of Conferences*, vol.65, 2018

[14] www.aquanet.pl [retrieved on:15.03.2019]