On The Cusp of the New Spatial Challenges – The Thermal Waste Processing Plant as an Element of Urban Space

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Abstract. The goal of this paper is to answer the question about the current importance of structures associated with the thermal processing of waste within the space of Polish cities and what status can they have in the functional and spatial structure of Polish cities in the future. The construction of thermal waste processing plants in Poland is currently a new and important problem, with numerous structures of this type being built due to increasing care for the natural environment, with the introduction of legal regulations, as well as due to the possibility of obtaining large external funding for the purposes of undertaking pro-environmental spatial initiatives, etc. For this reason, the paper contains research on the increase in the number of thermal waste processing plants in Poland in recent years. The abovementioned data was compared with similar information from other European Union member states. In the group containing Polish thermal waste processing plants, research was performed regarding the stage of the construction of a plant (operating plant, plant under construction, design in a construction phase, etc.). The paper also contains a listing of the functions other than the basic form of use, which is the incineration of waste - similarly to numerous foreign examples - that the environmentally friendly waste incineration plants fulfil in Poland, dividing the additional forms of use into “hard” elements (at the design level, requiring the expansion of a building featuring new elements that are not directly associated with the basic purpose of waste processing) and soft (social, educational, promotional actions, as well as other endeavours that require human involvement, but that do not entail significant design work on the buildings itself, expanding its form of use, etc.) as well as mixed activity, which required design work, but on a relatively small scale. Research was also conducted regarding the placement of thermal waste processing plants within the spatial structures of cities (a city's outer zone, central zone, etc.) and their placement in relation to the more important urban units, in addition to specifying what type of urban structure they are located in. On the basis of the research, we can observe that the construction of environmentally friendly thermal waste processing plants is a valid and new problem in Poland, and the potential that lies in the construction of a new environmentally friendly structure and the possibility of using it to improve the quality of an urban space is often left untapped, bringing the construction of such a structure down to nothing but its technological function. The research can serve as a comparative study for similar experiences in other countries, or for studies related to urban structures and their elements.

1. Introduction
The development of technology, science and industry, as well as the intense transformation of the environment that surrounds us that accompanies said development, cause modern man to live
relatively better, act more efficiently and work more effectively on the one hand, but on the other, the pace of the development that we ourselves adopt places new and new challenges before us. One of the prices that we pay for the rapid development of technology and the intense pace of transformation is the increased necessity to protect the environment - the resources that are at our disposal - for both ourselves and the future generations, in accordance with the principle of sustainable development, when compared to past times. On the other hand, we should also ask ourselves the question regarding how we are going to minimise our negative influence on the environment. One of the challenges that we must face in the context of its protection is the management of waste that we produce. The search for this answer poses numerous challenges. They are not only technological challenges. Actions leading to the protection of the environment and the managing of resources also influence sociological, urban and spatial transformation [5]. One of such challenges is the proper manner of the management of solid municipal waste. With the beginning of the XXI century, we are abandoning the idea of stockpiling waste, searching for other means of its "processing" - pro-environmental and pro-recycling means, much more pro-human than in previous centuries. One of them is the neutralisation of solid municipal waste with the help of its thermal processing. Thermal waste processing plants - it would seem - are not a new element of urban structure, as they have already been known since the XIX century. However, we can currently observe a significant increase in the number of structures of this type. They differ from their XIX-century forebears due to their new, pro-environmental technology, their form, size, as well as due to the fact that they offer a much wider range of services than simply processing solid municipal waste.

Poland, in comparison to other EU countries, is at the beginning of changing its solid municipal waste management system, which is why the thermal waste processing plants that are currently being built or that will be built in the near future, are a new challenge, both in terms of sociology (the protests of inhabitants and attempts at changing their views by increasing ecological awareness), function (additional forms of use that can be included in a thermal waste processing plant apart from its main purpose - examples of good practice from other countries can serve as a role model), but, most importantly, space (the influence of large structures on the surrounding urban tissue, their impact on city panoramas, their skylines, etc.).

2. From history to modernity - research background

We could risk making the statement that the problem of waste management has accompanied humanity since the time that humans started to organise themselves into larger residential groups. In the Middle Ages or in ancient times, the problem was solved in a manner that was not tied to the broader understanding of environmental protection. Waste was most often gathered far away from human residences, which was an insufficient and short-term solution [4]. In urban centres, the serious problems associated with solid municipal waste appeared along with the beginning of the era of "steam and electricity". The development of technology in the XIX century was chiefly tied with a large influx of people into cities, who were a source of cheap labour for newly built industrial plants, etc. At the same time, the lack of - even for those times - a well-developed infrastructure that could support environmental solutions was the main cause of the rising problem of the pollution of cities with solid municipal waste. The rapidly increasing urbanisation processes within XIX century cities, as well as the accompanying pollution of urban centres, had a direct impact on the health of their residents. The ease of the spread of infectious diseases in cities with a low level of sanitation, as well as the lack of solutions that could improve the situation in regards to municipal solid waste management, led to the search for new methods of dealing with the problem of pollution in cities. The main goal was the improvement of the living conditions of citizens. The first waste incineration plant was built in 1874 in Nottingham, Great Britain. The plant, called "Destructor" (patent GB-3125) was designed by the English engineer Albert Fryer, who worked for Manlove Alliott & Co. Ltd., which produced washing machines and dryers. It was an incineration plant featuring sixteen chambers, a fixed grate and a processing power of 4-6 Mg per 24 hours [3]. Up to the end of the XIX century, numerous - for those times - new incineration plants were built in Great Britain, in cities like Leeds,
Manchester, Birmingham, Warrington, Hackmondwike, Blackburn, Bradford, Bury, Hull, Bolton, Ealing, Sadford, as well as in London. Thanks to the development of technology and the modernisation of the original design, it was possible to increase the effectiveness of the machinery more and more. At the same time, the first waste incineration plant to be built explicitly due to poor sanitary conditions leading to the spread of infectious diseases was built in 1895 in Hamburg. The cause of the decision to build the thermal waste processing plant was a cholera epidemic that decimated the city in 1892 [3]. The incineration plant was built due to the necessity of the mass incineration of items and clothes used by persons suffering from cholera. Following Great Britain and Germany (the construction of additional waste incineration plants in Frankfurt and Cologne), additional municipal solid waste neutralisation plants were built in other European countries, such as Sweden, Denmark, Belgium, Switzerland and Czechia, in effect leading to a situation in which around 210 waste incineration plants were built in Europe up to the end of the first decade of the XX century. During subsequent decades, the development of incineration technology had no carryover to actions leading in the direction of limiting the emission of pollution associated with the burning of waste. It was only in the 1960's that air pollution caused by the incineration of waste started to be seen as a problem and the first dust collectors were used to limit the emission of harmful substances. The 1970's brought a further development of science in terms of environmental protection, resulting in the development of new exhaust emission reduction systems (mostly regarding acidic gasses: sulphur dioxide and hydrocarbon). The 1980's and the 1990's, due to discoveries associated with the emission and harmfulness of dioxins, were a period of the limiting of the development of thermal waste processing plants, but at the same time, due to additional discoveries, it was also a period of the beginning of intense academic research aimed at developing incineration processes that would allow the minimising of the production of dioxins, as well as of methods that would limit their emission [3]. Currently built thermal waste processing plants are structures with very high environmental standards, featuring highly specialised technology which is constantly being developed. Furthermore, they are also structures that, apart from their main purpose, can also accommodate other forms of use, both in a social dimension (recreational, educational), directed at increasing the ecological awareness of the residents of cities. Currently, there close to 470 thermal waste processing plants in Europe.

3. Thermal waste processing plants - group analysis in regards to a selection of spatial and social problems

The first thermal waste processing plants in Poland were built in the first half of the XX century. Up to the time of the outbreak of the Second World War, there were three such plants within Poland's borders. The wartime destruction and the period of the People's Republic of Poland that followed led to the halting of the method of thermal waste processing. During the period of a centrally controlled economy, solid municipal waste was stockpiled on landfills, which were the cheapest and easiest method to implement. This course of action, along with a low level of environmental awareness at the time, led to the assumption that this method of waste management was - if not the only proper one - the main one. The political transformation of Poland after the year 1989 was associated with numerous changes and an attempt at catching up in economic and social terms to other developing European countries. However, the raising of environmental standards, the awareness of the importance of environmental protection and activity aimed at reducing humanity's negative impact on the world, in the Polish reality of a country that was defining its identity anew and was reclaiming its economic freedom, were considered an obscure subject.

An intense increase in interest in thermal municipal solid waste processing in Poland was observed in the beginning of the XXI century. The construction of the first thermal waste processing plant in Poland was finished in the year 2000 [6]. For many years, the Solid Municipal Waste Neutralisation Plant in Warsaw was the only structure of its type. Due to the implementation of new, pro-environmental standards of the EU, regulated by the adoption of the Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 in waste and repealing certain Directives, the topic of the construction of municipal solid waste neutralisation plants and the
simultaneous production of energy and the reclamation of various substances, became a more and more valid subject. In 2007, a programme of the construction of waste processing plants was developed - it covered the period between 2007 and 2010. On the so-called indicative list of the Ministry of Regional Development, as a part of the "Infrastructure and the Environment" programme, towards the end of 2009, there were 11 projects featuring the construction of thermal waste processing plants [1], the financing of which was procured, among other sources, from the UE Integrity Fund. Table 1, located below, shows the current state of the construction and functioning of thermal waste processing plants in Poland, including also those projects which were on the indicative list, but that were not carried out.

**Table 1.** Planned thermal waste processing plant construction projects in the years 2007-2017, taking into account both projects from the 2007-2010 indicative list, as well projects that were not included, original work.

| City/area of the location of the thermal waste processing plant | Phase of the project |
|---------------------------------------------------------------|----------------------|
| Białystok                                                    | A                    |
| Bydgoszcz                                                    | A                    |
| Gdańsk                                                       | C                    |
| Konin                                                       | A                    |
| Koszalin                                                     | x                    |
| Kraków                                                      | A                    |
| Łódź                                                         | x                    |
| Olsztyn                                                      | x                    |
| Oświęcim                                                     | C                    |
| Poznań                                                       | A                    |
| Rzeszów                                                      | B                    |
| Szczecin                                                     | B                    |
| The Silesian Conurbation                                    | x                    |
| Warsaw                                                       | A,B                  |

A - construction complete/plant is operating, B - plant under construction, C-planned project, x – abandoned project

The planned construction projects featuring thermal waste processing plants listed above were divided into 4 groups. The projects from group A are plants that were built and that have positively passed the operation initiation stage. Projects from group B include those which are in various stages of construction. Projects from group C are most often those projects that have met some difficulties during the approval stage (problems with finding a suitable location - like in Gdańsk, or technological changes - like in Oświęcim), however, work on them is ongoing and there is a very high probability of the project being completed. The fourth group of projects is group X, which includes projects that did not make it out of the initial planning stages regarding the construction of a thermal waste processing plant. The table contains a listing of 14 planned projects of thermal municipal solid waste processing plants. 11 of them were included on the indicative list towards the end of 2009. These are projects in Białystok, Bydgoszcz (at the time it was a joint project by two cooperating cities - Bydgoszcz and Toruń), Gdańsk, Koszalin, Kraków, Łódź, Olsztyn, Poznań, Szczecin, Warsaw (it was planned to solve the current problems of the existing plant, as well as a so-far undetermined expansion of the
plant), as well as a thermal waste processing plant for the Silesian Conurbation. Three of the structures were not included on the indicative list in 2010. These are: the Thermal Municipal Solid Waste Neutralisation Plant in Konin, which began operating in 2015, the waste incineration plant in Rzeszów, which has been under construction since the first half of 2016, as well as the only private thermal waste processing plant on the list, which is to be built in the area of Oświęcim, and which is to generate electric power for the Synthos production plant. Among the 14 proposed projects, 6 are operational as of the beginning of the year 2017. Among these, 4 were on the indicative list of the Ministry of Regional Development as a part of the "Infrastructure and the Environment" programme in 2009. These are projects in Białystok, Bydgoszcz, Kraków and Poznań (which is now in the final stage of entering continuous operation). Three additional projects are under construction. These are: the nearly finished thermal waste processing plant in Szczecin, which is facing difficulties during the final stage of construction work, the project in Rzeszów, as well as the expansion of the first Polish waste incineration plant - the Municipal Solid Waste Neutralisation Plant in Warsaw. This research made it possible to single out a group of projects for which (in the majority of cases) it was not only possible to perform further analyses of thermal waste processing plants in terms of the occurrence of non-technological forms of use, but also to carry out research regarding the importance of municipal solid waste incineration plants as elements of urban space.

The construction of thermal waste processing plants is still faced with opposition from society in Poland [2]. In comparison, in the most economically well developed countries of the EU, opposition caused by the construction of incineration plants does occur, but it is far less intense. At the same time, thermal waste processing plants in those countries often serve additional purposes, in addition to engaging in intense pro-ecological education efforts. To this end, table 2 contains an analysis of the degree of the occurrence of additional forms of use that feature a social dimension (for instance: recreational, such as in the Copenhagen waste incineration plant designed by BIG [7]) in Polish thermal waste processing plant designs, as well as of the occurrence of carrying out pro-environmental education efforts and its manner. Those structures, the construction of which has not progressed beyond initial plans (group X) that were featured in table 1, were excluded.

**Table 2.** Additional, non-technological forms of use within thermal waste processing plants that are either being designed, are under construction or are operational - original work

| Thermal waste processing plant | Additional hard forms of use | Additional intermediate forms of use | Additional soft forms of use |
|-------------------------------|-----------------------------|----------------------------------------|-----------------------------|
| Białystok                     | ---                         | +                                      | +                           |
| Bydgoszcz                     | ---                         | +                                      | +                           |
| Gdańsk                        | ---                         | n.d.                                   | +                           |
| Konin                         | ---                         | n.d.                                   | +                           |
| Kraków                        | ---                         | +                                      | +                           |
| Oświęcim                      | ---                         | n.d.                                   | n.d.                        |
| Poznań                        | ---                         | n.d.                                   | +                           |
| Rzeszów                       | ---                         | n.d.                                   | n.d.                        |
| Szczecin                      | ---                         | n.d.                                   | +                           |
| Warsaw                        | ---                         | ---                                    | +                           |

+ a given form of use is present within the plant, --- lack of a given form of use, n.d. - no data regarding forms of use of this type
The forms of use that are not directly associated with the technology of the structure were divided into three groups: hard, intermediate and soft forms of use. The so-called hard forms of use include those that require considerable design work that completely differs from the basic purpose of the structure. An example of this is the design of other additional elements (either separate structures or parts thereof), either within the structure or within its immediate vicinity, that are not tied to the incineration of waste. A model example of such an approach in relation to foreign projects is the inclusion of a skiing slope and a climbing wall in the thermal waste processing plant in Copenhagen [7]. The group of intermediate structures includes such activities that - even though they require a certain amount of design work - can be linked to the basic purpose of the incineration plant. An example of this can be the construction of an education trail, which is at the same time a circulation route, or the construction of a conference hall that can be used for educational purposes, which is at the same time available for the plant's board meetings. The third, soft type includes all actions that do not require any additional effort during the design stage of a plant. These are activities most often linked to pro-environmental education (the organisation of "open days" or lectures at schools, the setting up of a website for promoting the environmentally friendly activities of a thermal waste processing plant, promotional materials that increase environmental awareness, etc.).

In Poland, thermal waste processing plants are still a new phenomenon within the space of cities. Due to this fact, analyses regarding placement within urban tissue were carried out on a group of ten structures that are in various stages of construction, or that are already built and are currently operating. Table 3 does not include those structures that did not go past the stage of initial planning. There was no possibility to analyse their planning impact, e.g. due to the lack of a specified location. The table thus contains ten thermal waste processing plants. The plants' placement within the area of their particular cities was listed, with the areas being divided into an inner zone that is typically urban and has compact tissue, an intermediate zone, as well as an outer zone. The table also lists the distance of a thermal waste processing plant from the strict city centre (that is, most often from a historical urban layout). The distance was also determined with the use of a mean travel isochrone. To this end, the travel time by car was measured numerous times per day, taking into account the period of the largest traffic load during the morning and evening hours (the morning and evening commute). The measurements were performed only for automobiles, as in the case of some plants the measurement of travel time using public transport was not possible (the lack of access using this mode of transport).

The final element under analysis in the context of thermal waste processing plants as elements of urban space is the development of the area around the plant. Larger, more typologically dense units that fulfil various spatial functions were outlined. The units that were outlined did not have smaller forms of use of a different type considered (for instance individual small-scale retail or other services that are located in large single or multi-family residential buildings). A detailed list of urban centres surrounding a given thermal waste processing plant was presented in table 3.

4. Results and discussion

As a part of the research on thermal waste processing plants as elements of urban space, all of the projects planned during the years 2007-2017 have been analysed. A group of 14 structures was selected, 11 of which were on the indicative list of the Ministry of Regional Development as a part of the "Infrastructure and the Environment" programme. Among all of the construction projects planned during the last decade, 6 have been finalised, 5 of which were on the indicative list. Three additional projects are in the planning stage, while 4 never progressed beyond initial planning. It can thus be assumed that close to 2/3 of the projects have been or will be finalised in the future. The cessation of activities in the case of 4 projects had very diverse causes (a change of financing, the lack of consensus in terms of decisions among the partners involved in the project, a change of plans regarding the size of the plant, its costs, the types of incinerated waste or a change in the manner of municipal solid waste management, which resulted in the lack of the necessity to construct such a plant, etc.). Further research regarding waste incineration plants as elements of urban space both in the context of their placement, as well as their function, has been carried out on a group of 10 cities.
projects that did not progress beyond the initial planning stage were not included in further analyses due to the inability to perform them: either in terms of spatial analyses (the lack of a location) or functional ones (the lack of activity, the lack of a design). As it was previously mentioned, the non-technological forms of use of the plants were divided into three groups: so-called hard, intermediate and soft ones. The hard forms of use, namely those that require the construction of additional structures or parts thereof and which are not directly associated with the main purpose of the incineration plant - are not present in incineration plants in Poland.

**Table 3.** The placement of currently planned, constructed and operating thermal waste processing plants within the structure of cities, original work

| Thermal waste processing plants | Zone of the city | Distance from city centre/accessibility isochrone | The type of surrounding area development |
|--------------------------------|-----------------|-----------------------------------------------|----------------------------------------|
| Białystok                      | Intermediate    | 3 km/ 6 min.                                 | Industrial area - services, dense single and multi-family residential areas, forests |
| Bydgoszcz                      | Outer           | 9,4km/20 min.                                | Industrial and post-industrial areas, forests |
| Gdańsk                         | Outer           | 9 km/17 min.                                 | Big-box stores, logistics services, multi and single family residential areas, forests |
| Konin                          | Outer           | 8,8km/13 min.                                | Industrial areas, forests, agricultural areas, ponds |
| Kraków                         | Outer           | 12 km/ 25 min.                               | Industrial areas, courier services, dense multi and single-family residential areas, riverside green areas, forests |
| Oświęcim                       | Outer           | 4,4 km/11 min.                               | Industrial areas                         |
| Poznań                         | Outer           | 8,1 km/19 min.                               | Industrial areas, courier services, dense multi and single-family residential areas, riverside green areas, forests |
| Rzeszów                        | Outer           | 4,7km/12min.                                 | Industrial and service areas, dense multi and single-family residential areas, riverside green areas, forests |
| Szczecin                       | Outer           | 4,4 km/10 min.                               | Industrial areas with dispersed buildings, open green areas, open waters |
| Warsaw                         | Intermediate    | 9,4 km/18 min.                               | Industrial areas, courier services, green areas, courier services, dense residential areas, mainly multi-family type. |

One can get the impression that Polish property developers - contrary to current global tendencies - are not aware of the unquestionable benefits stemming from the introduction of additional forms of use that can increase the attractiveness of a thermal waste processing plant in the eyes of the inhabitants of a city. Intermediate forms of use are present in three plants. These are mostly educational trails or conference halls which are normally used by the employees of a plant, but that - when the need arises - are made available for use in pro-environmental initiatives. There is a lack of data regarding the existence of intermediate forms of use in the case of over a half of the analysed...
plants. The lack of such information - which is, after all, meant for pro-social and promotional activities - can be treated as proof that such activities - even if they take place at all - are not conducted in an appropriate or sufficient manner. At the same time, so-called soft forms of use are present in 8 thermal municipal solid waste processing plants. These activities are based on the organisation of pro-environmental events, with practically all of the plants that were opened in the last decade hosting so-called "open days". Many plants also take part in pro-environmental activities, which are based on organising lessons for primary school and pre-school children on the topic of waste segregation, etc. Numerous structures also maintain websites on this subject, producing promotional materials, etc. This form of education is particularly important due to the opposition on behalf of the residents of cities to the construction of incineration plants in their areas (which is most often the result of a lack of awareness of the matter). Two plants, in the case of which there is a lack of data regarding the presence of additional soft-type forms of use, are buildings in the initial phase of construction. The aforementioned lack is probably the result of this state of affairs. When analysing the placement of plants within the structures of their respective cities, we can observe that nearly all thermal waste processing plants are located in the outer zones of cities. Only two plants (Warsaw and Białystok) are located in the intermediate zone. Such a placement of incineration plants leads to a far worse accessibility regarding the diversity of modes of transport (most of the plants can only be accessed by individual vehicular transport). We can see a direct correlation between the average transport time and the distance measured in kilometres. At the same time, it can be observed that in terms of distance and travel time, the accessibility of those plants appears to be very good. In terms of spatial placement within urban tissue, it can be observed that 9 plants from among the group are within or in the immediate vicinity of either and industrial or logistics and industrial zone, etc. only a single plant is in the vicinity of a commercial and logistic zone, which, however, is not at all different from an industrial zone in spatial terms. At the same time, a significant number of structures are located in expansive open green areas - meadows, agricultural areas, forests or open waters (rivers, lakes). Such a location seems to be very beneficial for the development of accompanying recreational forms of use, etc.

5. Conclusions and observations

Based on the analyses and research regarding thermal waste processing plants in Poland, the following conclusions and observations were formulated:

- The placement and construction of thermal waste processing plants has become an important and new topic in recent years. Poland, as one of the last countries of the European Union, is expanding its new system of solid municipal waste processing. The decisions that are made regarding the placement of these structures, their massing or additional forms of use are of a significant importance to a city, particularly in terms of its spatial development and the visual reception of a city, as well as in terms of pro-environmental social activities.
- Thermal waste processing plants, due to their size, exert a significant influence on their surrounding space, as well as on the panoramas and skylines of cities, which is why a high aesthetic level of the massing and its placement, while taking into account the wider spatial context, is of particular importance.
- Simultaneously, based on some of the projects featuring the construction of thermal waste processing plants in Poland, we can observe that spatial issues - contrary to foreign examples of good practice - are mostly not taken into account when selecting the location of a plant, and, in some cases, also during the process of designing its form and its later construction.
- In Poland, pro-environmental social activities that are initiated by thermal municipal solid waste processing plants are usually undertaken in the so-called "soft" zone, with a lack of - contrary to foreign examples of good practice - "hard" activities, which are aimed at introducing new and attractive forms of use while building a thermal waste processing plant.

Using examples from those EU countries in which the ecological awareness of residents, the development of technologies associated with the management and processing of solid municipal waste, as well as spatial and sociological experience tied to Waste-to-Energy type buildings is higher,
we can conclude that a properly conducted spatial and social policy creates numerous opportunities for using these types of structures as attractive elements of urban space. At the same time, in relation to Polish examples, it can be observed that we are currently standing at the start of our journey through spatial, social and pro-environmental actions associated with thermal waste processing plants as important spatial elements. On this basis we can conclude that thermal waste processing plants in Poland are a new and viable topic, as well as an important, new and, unfortunately, a spatial and social challenge that is insufficiently taken advantage of.

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