Environment Protection Engineering

Vol. 46 2020 No. 4

DOI:10.37190/epe200409

ŁUKASZ SZAŁATA[1], JERZY ZWOŹDZIAK[2], MAKSYM BYELYAYEV[3]

METHOD OF DETERMINING TECHNIQUES FOR THE LIMITATION OF A WASTE MANAGEMENT PLANT'S ENVIRONMENTAL IMPACT WITH THE USE OF DYNAMIC CRITICAL VALUES BASED ON THE CASE STUDY

This article presents the results of the work conducted on the development of a method for the determination of techniques limiting the environmental impact of a selected waste management plant according to the best available technology (BAT) and BAT-specified compatible techniques based on critical values. A case study was based on the existing municipal waste mechanical-biological processing plant in the Mazovian district. The method of determining impact-limiting techniques (MOTOD) has been developed in terms of reducing the impact of odor emissions in the waste management sector. The applied method is used to select the optimal variant for the implementation of the technology limiting environmental impact for the appropriate technological system. The criteria for the implementation of techniques, related to the limitation of the environmental impact in existing or planned projects, require adequate planning, element cooperation algorithms as well as balancing their intended effects.

1. INTRODUCTION

The interrelation of the environmental management system in the enterprises and the principle of the best available technologies have been shown. The effective use of one of these management tools is impossible without the establishment of the other [1]. So far, in the local and global areas within the EU, techniques have been selected based on BAT standards, but no specific mechanism has been established for the management, implementation, or selection of the appropriate BAT techniques, nor compatible techniques that reduce the environmental impact. In the context of the IPPC (Integrated Pollution Prevention and Control) directive, which has become increasingly strict, some

[1]Department of Environmental Engineering, Wrocław University of Science and Technology, pl. Grunwaldzki 9, 50-377 Wrocław, Poland, corresponding author, email address: lukasz.szalata@pwr.edu.pl

[2]State Higher Vocational School in Nowy Sącz, ul. Staszica 1, 33-300 Nowy Sącz, Poland.

[3]Eko-Biegły Association, ul. Purkyniego 1, 50-155 Wrocław, Poland.

methodologies have been developed for a deeper and better understanding of the selection procedure of the BAT concept for operators at the plant level and national policy-makers [2, 3]. Taking into account practical aspects, the result of these procedures leads to an inflexible model for the management, assessment, and design of planned and existing investments. It is crucial to develop environmental performance assessment methodologies in the IPPC context which will help operators to compare them to validate their existing techniques as BAT [4]. The current methods of determination are based on the status of relevant legislation and directives describing a certain concept, the direction of standardization of elements of a specific sector, which often leads to negative results, caused by the violation of the technological system, redundant investment and operating costs, and ineffective environmental values. Life cycle assessment (LCA) is nowadays the only method that quantifies a set of environmental impacts and that highlights cross-media effects [5]. The LCA plays an important role in understanding the whole idea of assessing potential environmental risks and achieving potential effects, while it is a superficial one-level assessment in the context of taking into account all the aspects of sustainable development related to the process of determining the optimal mitigation technique. Some tools are based on the aggregation of indicators or propose environmental performances from one single sort of indicators, such as the carbon balance or ecological footprint. Then, industrial operators have difficulties in assessing their environmental impact through an integrated approach in terms of management procedures and technologies [4]. The Flemish Institute for Technological Research (VITO) proposed a methodology for BAT assessment for some industrial sectors (vehicle refinishing and manure processing) to be defined in the BAT reference documents (BREFs) [6]. Nowadays, the BAT assessment is mainly based on the emission and consumption levels achieved by the techniques applied [7]. Following the analysis of the above, it was decided to define and select an appropriate method to determine the techniques for limiting the environmental impact for a specific sector in terms of limiting a specific negative impact.

2. MATERIAL AND METHODS

The main idea, on which MOTOD was developed, consists of a comprehensive analysis of interdependent technological elements, the impact of the technology on the environment, and the changes taking place concerning the implementation of mitigation techniques. Besides, the method assumes the use of the currently available techniques to the extent that they meet the intended needs, thereby eliminating the stage of determining the compatibility of the technique according to the above-mentioned methods. Preferences, for example, can be estimated through methods such as discrete choice experiments [8]. The MOTOD definition format presented in this article has been used, taking into account a parallel case study showing sense and acceptability in the analytical space.

Analyzing the legal and technical framework applicable at the international level, the BAT concept can be defined, analyzed, and assessed through two different but complementary approaches: (1) the emission and consumption levels are defined in the BREFs which establish emission limit value (ELV) for national regulation at the sectoral level, and (2) the screening of the environmental aspects of each technique [4]. Nevertheless, these two aspects should be taken into account as interdependent variables, as the reduction of the impact caused by over-emission often results in changes in the technological parameters and economic indicators. Empirical research conducted on environmental values generally seeks to represent particular aspects of human-environmental relationships in ways that can inform environmental decision-making [9–11]. This method is based on the main environmental aspects, taking into account the technological and economic aspects, because a single confined principle (ELV) to evaluate the environmental impact cannot give a clear and complete vision [4].

When analyzing the current range of choice of methodologies used to assess the compatible BAT, it should be noted that many methodologies exist, e.g., MIOW via model BEAsT, PNUE/PAM, VITO, and LCA methodology [12–15]. Estimating the scale, type of environmental impact of techniques, and changes occurring in connection with the implementation or modernization of technologies including the environmental and economic effects can be done using the following tools: Sustainable Value Added, LCA, Environmental Evaluation Matrix, Carbon Footprint/Carbon Performance Indicators, and Epstein Roy Framework. Sustainable Value Added considers the economic, environmental, and social aspects simultaneously and is inspired by the concept of strong sustainability, when all forms of capital are kept constant [16]. LCA analysis is a methodological tool focused on quantitatively evaluating environmental damages [17]. Environmental Evaluation Matrix is a tool used to assimilate environmental information to appraise projects [18]. Carbon Footprint/Carbon Performance Indicators are a subset of the ecological, or environmental footprints, and the life cycle analysis method [19]. The Epstein Roy Framework is a comprehensive approach used to examine corporate sustainability drivers [20]. All these methods are applicable in the estimation of the possible environmental, economic and social effects, while the transposition of these effects does not allow one to determine the potential impact on technological processes, and does not allow you to select the optimal variant of the technique limiting the impact. The tools and methods presented hereinabove have been considered in the development of this MOTOD, but only as part of the structure.

To develop the MOTOD method, the key components have been identified, i.e., its components, and their interrelations. These interrelations are defined as the MOTOD algorithm which consists of elements of the MOTOD structure and functional steps – the progress of a specific result in terms of obtaining the appropriate technique for the selected case. This algorithm takes into account the variability of the values of all the elements to obtain an optimal solution. The scope of the MOTOD has been determined for the actual case, which is the negative impact of odor compounds, shown based on a research and analytical case study conducted in the selected sector and type of technology (Fig. 1).

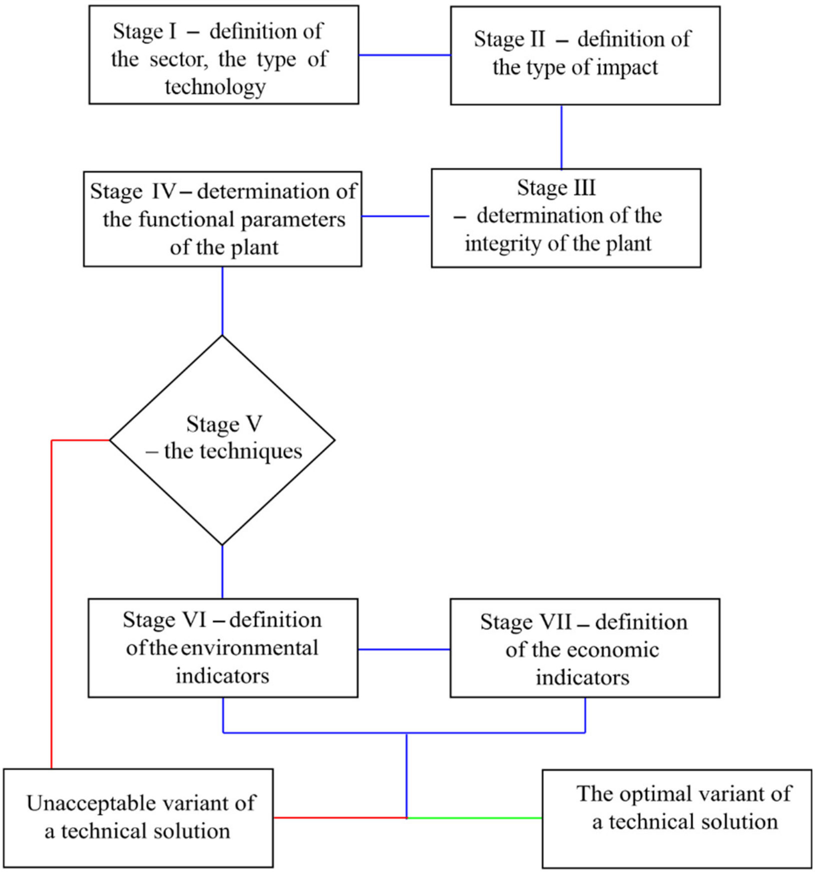

Fig. 1. MOTOD functional diagram

There are 7 functional steps for the MOTOD algorithm which generally consist of defining the scope of the relevant element, as shown below:

1. Stage I – definition of the sector, the type of technology.
2. Stage II – definition of the type of impact.
3. Stage III – determination of the integrity of the plant.
4. Stage IV – determination of the functional parameters of the plant.
5. Stage V – determination of the techniques.
6. Stage VI – definition of the environmental indicators.
7. Stage VII – definition of the economic indicators.

Method elements stand for the basic part of the defined method, which is characterized by variability in the project period. The elements that have been selected for MOTOD include sector, technological type, type of impact, plant, plant's integrity, functional parameters of the plant, economic indicators, environmental indicators and techniques, and are defined as follows:

- Sector – a specific typological economic and industrial area characterized by burdensome activity in terms of the environmental impact; for the MOTOD, the method in the waste management sector was chosen. The selection of a sector is an important element in determining the range of techniques that can be implemented for the given sector and the emission standards applicable to that sector [21].
- Technological type – a technological system applied for a given sector, constituting some mechanisms and technical elements together with the technical infrastructure operating interdependently, characterized by the appropriate unit processes. The technological type for the given sector is mechanical-biological waste treatment, for example.
- Type of impact – possible potentially negative impact (including the extent and coverage) on the surrounding environment caused by pollutant emissions. The types of influence for the selected MOTOD sector include the influence caused by the emission of compounds into the air, emission of sewage, emission of noise as well as the sanitary condition of the air caused by exceeding the microbiological standards. The range and coverage of emissions are calculated based on critical values selected for the appropriate technological type [22, 23]. The type of impact should identify the potentially sensitive elements which may occur as well as shape the impact to be defined as a reference point for determining the environmental effect. The estimation of the type and scale of the potential impact should be carried out using reference methods or reference-compatible methods. There are several tools for estimating the potential impact in terms of measuring the negative impact caused by a single subject. Known tools can be used for the analysis at this stage. As a method of determining the potential impact in this article, the method of analysis of measurement studies regarding critical values has been used, which is the most precise assessment of the level of impact in a given case study. The critical values for this case are defined on the critical level based on the difference between the permitted concentration values of the individual substances (emissions) at the border of the sensitive area and based on the actual concentration levels of the substance. The critical level means the level of a substance in the air established based on scientific knowledge, above which there may occur direct adverse effects on certain receptors, such as trees, other plants, or natural ecosystems, but not on humans [24]. ELV means the mass, expressed in terms of certain specific parameters, concentration, or level of emission, which must not be exceeded during one or more periods [25]. The limit value means the level of a substance in the air established based on scientific knowledge to avoid, prevent, or reduce the harmful effects on human health or the environment as a whole, which should be attained within a given period and should not be exceeded after that date. There is now a huge array of approaches to documenting and analyzing

human and ecological values, and these approaches come with their concepts, assumptions, and limitations, and it is not yet clear which concepts of value should do the governing one [26]. Sensitive areas were defined as special protection areas defined based on local plans, where exceeding the normative values is not allowed. Local comprehensive planning is a decision-making strategy which many communities have used in steering development away from fragile lands or environmentally sensitive areas. The identification of sensitive areas is important because they are a reference value based on which the critical values and the required environmental effect are measured.

• Plant – a stationary technical unit where one or more activities listed in Annex I or Part 1 of Annex VII of the IPPC Directive are carried out, and all other directly associated activities on the same site which are technically connected with the activities listed in those annexes and which could have an effect on emissions and pollution [25].

• Plant's integrity – the level of integrity of the processing system after considering the proportion of unorganized emissions or the relative level of integrity of each part of the processing system, together with the level of their interaction. This element is decisive for the accuracy of the determination of the technique. The determination of the plant's integrity consists in the determination of the "tightness" of the entire technological system, where a possible method of determination is to estimate the share of unorganized emissions concerning the organized emissions for the plant in question or the relative level of integrity of each part of the technological system together with the level of their interaction estimated based on expert knowledge. The precise determination of each technological element is important from the point of view of analyzing the potential leaks of the technological system and evaluating possible retrofit solutions.

• Functional parameters of the plant – variables of the selected technological type which influence the functioning of the plant, where the number of these values and their range depends on standardized values for this relevant technological type. An important factor that determines the purposefulness/effectiveness of the implemented impact-limiting techniques is a specific functional parameter, the determination of which results in the estimation of anticipated environmental and economic effects in terms of positive or negative values. Selected functional parameters are characterized by variability and are independent. This article only considers the basic parameters showing the change of the whole technological system and allowing to show the target of the solution selected in the MOTOD. To clarify the outcome of the MOTOD, more parameters can be adopted, including those for individual unit processes affecting the overall process.

• Economic indicators – variables showing the expected economic effect, including investment and operating costs, as well as the profits related to the implementation of the relevant technique [27]. Economic indicators expressed in the potential investment and operating costs incurred or profits obtained because of the implementation of impact reduction techniques proposed following MOTOD. Economic indicators are characterized by high variability depending on the expected, planned environmental effects to be achieved. Economic indicators are one of the most important elements in the implementation of techniques according to the MOTOD. Economic indicators should be adopted for the relevant technique and case study to the extent that they define the possible investment and operating costs incurred and the benefits in terms of profits.

- Environmental indicators – variables showing the predicted environmental effect taking into account the change, including the reduction of the negative impacts associated with the implementation of the relevant technique [27]. Environmental indicators are determined based on the predicted environmental effect expressed based on the positive values obtained after the implementation of techniques following the MOTOD. For the plant in question, the positive values obtained as a result of the implementation of the techniques are connected with the planned, intended reduction of the environmental impact of foul-smelling compounds, expressed based on the reduction of the frequency of exceeding one-hour concentrations at the border of sensitive areas, taking into account the dispersion of compounds in the atmosphere.
- Techniques – techniques that correspond to the planned effects with such levels of development that allow implementation in the sector concerned, under economically and technically viable conditions, taking into account the costs and advantages, even if the techniques are not used or have not been developed, as long as they are reasonably accessible to the operator and are the most effective in achieving a high general level of protection of the environment as a whole. They cover the technologies used and how the plant is designed, built, and maintained as well as operated and decommissioned. The techniques described in the present paper concern the reduction of odor-active compounds. The selection of the appropriate technique or combination of techniques (variants) is the result of the MOTOD method. To obtain the most precise technological solution, a comparison of the technique variants should be made. The selection of variants consists of compiling all the calculated variants for the selected mitigation techniques and comparing the achieved environmental, economic, and process impacts. The optimal variant is the technical solution that is the most effective in terms of obtaining environmental and economic effects with the least impact on technological processes. An unacceptable variant of a technical solution – this is a variant which, concerning other listed variants, has relatively lower values of the environmental and economic effects achieved and/or significantly affects the technological process. An appropriate technique takes into account all the elements of the MOTOD algorithm, where the values of individual elements determine the correctness of the selected technique. Following the principle of sustainable development, each decisive element and its sequence should lead to an optimal environmental, economic, and technological effect [1]. The techniques implemented and analyzed only concern the appropriate type of impact and technological type. The analyzed techniques relate to the characteristics of the case in question. Where the techniques are compared and selected for another type of impact or for another sector, techniques with an effect adapted to the planned achievable environmental and economic effects should be adopted.

3. RESULTS. CASE STUDY BY THE MOTOD ANALYSIS

3.1. STAGE I

Based on the analytically derived methodology, a selected example was analyzed, showing the individual stages of the MOTOD method.

Selected sector – waste management, type of technology – mechanical-biological waste treatment, technique selection – techniques concerning the reduction of odor-active compounds. The plant (hereinafter referred to as the mechanical-biological waste treatment plant or MBT plant) facility consists of the following parts:

- The mechanical part – with a total capacity (three-shift operation) of 75 000 Mg/year and allowing the following processes: mechanical-biological treatment of mixed municipal waste, code 20 03 01 (variant I) up to 60 000 Mg/year; mechanical treatment of separately collected waste, code 15 01 and 2001 (variant II) up to 15 000 Mg/year.
- Biological part – with a total capacity of 26 000 Mg/year, in which the biological processing of the mixed municipal waste fraction 0–80 mm (variant I) is carried out up to 26 000 Mg/year.
- Screens with a mesh size of 20 mm and a total capacity of 8 Mg/h, in which the mechanical processing of the produced stabilizer is carried out up to 20 800 Mg/year.

The mechanical-biological treatment plant is used for the biological treatment or a combination of treatment and disposal of non-hazardous waste and its capacity total over 75 tons per day. The facility has a hardened, sealed and reinforced concrete floor with an abrasion-resistant, anti-slip resin coating, including a concrete surface with a thickness of 0.2 m, tar paper waterproof insulation, geotextile, drainage layer with a thickness of 0.02 m, and HDPE film insulation with a thickness of 1.5 mm. The building is equipped with a mechanical ventilation system. The facility has no sewage system. The mechanical part of the plant is a technological line intended for processing mixed municipal waste and raw materials from selective waste collection. In addition to the equipment included in the process line, the sorting facility has a section for the temporary storage of waste before sorting, with an area of about 700 m^2, and a stand for bulk waste stripping. The technological line of the mechanical part of the plant includes:

- Waste preparation and loading system: channel conveyor, bag opener, incline conveyor.
- Sorting booth No. 1 (initial segregation booth) designed for initial waste segregation (4-station booth) with a set of containers for separated raw materials.
- Three-fraction drum screen for the separation of waste into fractions of 0–80 mm, 80–300 mm, and over 300 mm.
- Sorting booth No. 2 (8-station booth) for the segregation of 20–300 mm fractions of waste from the selective collection, together with a system of storage boxes.
- Sorting booth No. 3 (8-station booth) for the segregation of over 300 mm fractions of waste from the selective collection, together with a system of storage boxes.

- Ferrous metal separator No. 1, located in the transport system of 0–80 mm fraction (so-called undersized fraction).
- Ferrous metal separator No. 2, located in the system for transporting residues from waste sorting in booth No. 2.
- Ferrous metal separator No. 3, located in the system for transporting residues from waste sorting in booth No. 3.
- Sorting booth No. 4 (1-station booth) for cleaning metals separated on magnetic separators Nos. 2 and 3.
- Optoelectronic separator No. 1 for the separation of the high energy fraction from the combined stream, fractions of 80–300 and over 300 mm waste from the selective collection.
- Optoelectronic separator No. 2 for the separation of the high energy fraction from the combined stream of fractions of 80–300 and over 300 mm waste from the selective collection.
- Sorting booth No. 5 (2-station booth) for cleaning paper separated on the optoelectronic separator No. 2.
- A baler.
- A system of belt conveyors transporting individual waste streams between elements of the mechanical part of the plant.

The biological part of the plant includes:

- Ten undersized fraction stabilization reactors, each with an internal width of 8.0 m, an internal length of 36.0 m, and a wall 1.5 m high. Each of the reactors has three side-walls made of concrete blocks that are placed on the concrete base. The roofing and covering of the reactor entrance are made of a semi-permeable geomembrane which is attached to each outer wall of the reactor using a steel rail with snap hooks located at the ground and a rubber fastening cord. From the entrance side, the membrane is pressed against the ground using flexible hoses filled with sand.
- The waste aeration system in the reactor consists of fans (one for each reactor) located on the reactor rear retaining walls and aeration channels (four channels for each reactor) located on the floor of each reactor.
- A system for capturing leachate from the reactors consists of channels for collecting the leachate (a common element with the aeration system) placed on the floor of each reactor (four channels for each reactor), leachate piping, wells, and two leachate tanks with a capacity of 6 m^3 each. Besides, from the side of the entrance to the reactors, leachate will be collected in a 0.2 m wide profiled trough which will discharge into the sewage drains and further to the above-mentioned contained containers. To prevent the entry of pollutants into the water and groundwater environment, the entrance-side floor of each reactor was raised by ca. 5 cm, thereby creating a threshold to prevent leachate from escaping outside the reactor.

• A process control system consisting of hardware, software for process control and data storage, ten temperature measurement probes, ten control cabinets.

• Diaphragm winding/reeling device.

3.2. STAGE II

The negative impact was shown based on the research conducted in the sorting facility, in the green waste reception zone, at bioreactors in the initial phase of the process and its final phase, at the waste canopy outside the site, and an additional reference point located on the south-western side outside the site at a distance of 153 m from the plant boundary. As a result of the research, the most important places were identified where increased emissions of foul-smelling compounds may occur (Fig. 2).

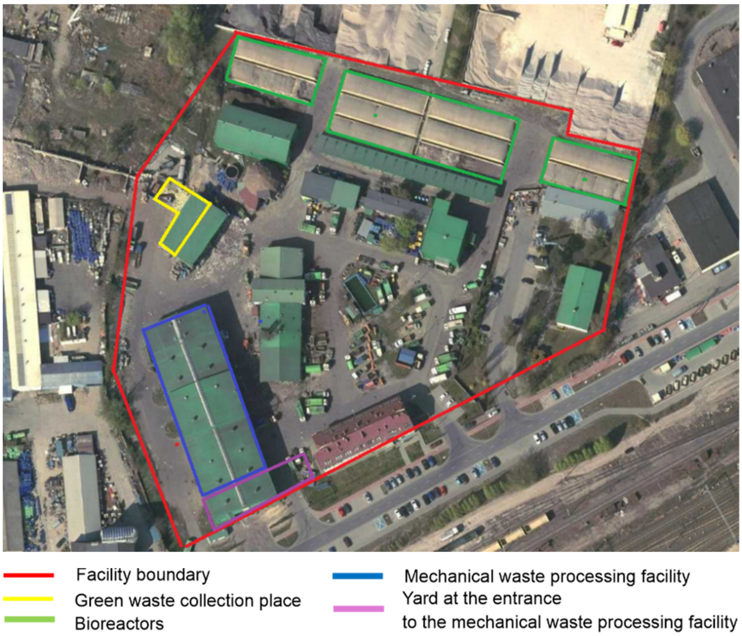

Fig. 2. Identified places where increased emission of foul-smelling compounds may occur

• Mechanical waste processing facility – the facility is used for the storage of mixed municipal and selectively collected waste. In the facility, waste is also screened to prepare it for biological processing. The places of potential odor emission are storage boxes for mixed municipal waste. Foul-smelling compounds and bioaerosol may gather there. This, however, is not related to the fact of collecting waste in this part of the facility itself, but rather to the operations related to the unloading and handling of waste for mechanical treatment. When waste is transferred with loaders, there is increased emission of foul-smelling compounds and bioaerosol as well as a significant emission of dust.

• Green waste collection place – this is where green waste from the city is collected. The emission problem is primarily due to systemic issues. Quite a rare period associated with the collection of green waste from generators affects the accumulation of green waste on-site in excessive quantities in storage boxes. This results in waste rotting processes. Another issue is the collection of waste in plastic bags, which directly intensifies the rotting effect. Under such conditions, excessive amounts of hydrogen sulfide and mercaptans are produced but above all ammonia, which is characteristic of these processes in green waste.

• Bioreactors – in bioreactors the biological transformation of waste takes place during the composting process. Appropriate selection of the process parameters (primarily aeration) enables the effective reduction of odor nuisance associated with the process itself. Nevertheless, increased emissions of foul-smelling compounds may occur during the loading of waste into bioreactors and possibly during the removal of waste from reactors.

• The yard at the entrance to the mechanical waste processing facility – during the on-site visit, an additional site of increased odor emission was identified. Quite intensive, the perceptible concentration of foul-smelling compounds was detected at the entrance to the mechanical waste processing facility. This was mainly related to the transport of waste by trucks. The odor emission resulted from the accumulation of vehicles transporting waste in one place, and in the opinion of the authors of the study, the reason for this was the leachate from waste, directly infiltrating the maneuvering yard. In periods directly after rainfall, the leachate may mix with the rainwater gathering at the entrance area, which in unfavorable weather conditions (strong sunlight and high temperature) may cause the intensification of the emission of foul-smelling compounds into the atmosphere [22].

Table 1

Summary of the obtained measurement results

Point No.	Measuring point	Odor concentration [OU_E/m^3]
1	bioreactors	410.5
2	green waste	330.5
3	sorting facility	1,224

For the range of the critical values in question selected for the analyzed case, it is the odor concentration [22]. The actual concentration levels were determined based on the analyzed values obtained during the olfactometric tests performed in 2017 in the plant (Table 1). The evaluation of odor concentration in air samples utilizing dynamic olfactometry was carried out on samples of the delivered test material with the use of olfactometer T08 in accordance with PN-EN 13725:2007. Sampling was performed with an automatic CSD 30 sampler (LBTBR-P-93), and the automatic filling time of the sample bag is 5 minutes. The concentration was evaluated after 20–24 hours from sampling according to EN 13725:2007. Various approaches and techniques can be used for measuring odors in the environment.

In general, different types of models can be used to simulate the dispersion of pollutants into the atmosphere. The model used (i.e., Pasquill's equation), which is consistent with the reference methodology described in the Regulation of the Minister of Environment of 26 January 2010 on the reference values for certain substances in the air, is based on calculations for the Gaussian "plume" model, shaped by wind and diffusion processes.

Due to the insignificant share of cultivated fields located south of the plant, the 1.799 aerodynamic roughness coefficient was assumed. Knowing the airborne concentrations of foul-smelling compounds determined for individual sources and the airflow rate in the applied passive surface source sampler, the specific emissions were calculated based on the specific odor emission rate (SOER) formula as well as the emissions for individual surface sources (Table 2).

Table 2

Calculated emissions

Point No.	Measuring point	SOER [$OU_E/(s \cdot m^3)$]	Emitter's surface [m^2]	Odor emissions [MOU_E/h]
1	bioreactors	74.0	2,046.0	545.01
2	green waste	59.6	75.0	16.08
3	sorting facility	220.6	1658.5	1317.30

Therefore, based on modeling calculations using the reference method described in the Regulation of the Minister of Environment of 26 January 2010 on the reference values for certain substances in the air, the 16% (E) concentration of odor compounds in sensitive areas was determined (Fig. 2). Figure 3 presents the frequency of exceeding one-hour concentrations 5 OU_E/m^3. A 2% exceedance rate was adopted based on the UK Environmental Agency guidelines.

The modeling was performed on a 1:4000 scale map which covered the plant site and all areas potentially affected by the plant, in particular the buildings located to the north-east of the plant. Figure 3 shows the modeled maximum odor concentrations together with the concentrations determined during field tests at the measuring points. The odor concentration limit values for the sensitive areas concerned are 2% (*ELV*). Critical values were determined using the following formula:

$$WKR = E - ELV \tag{1}$$

The critical value (*WKR*) indicates the necessary reduction of odor-active compounds 16 – 2 = 14%.

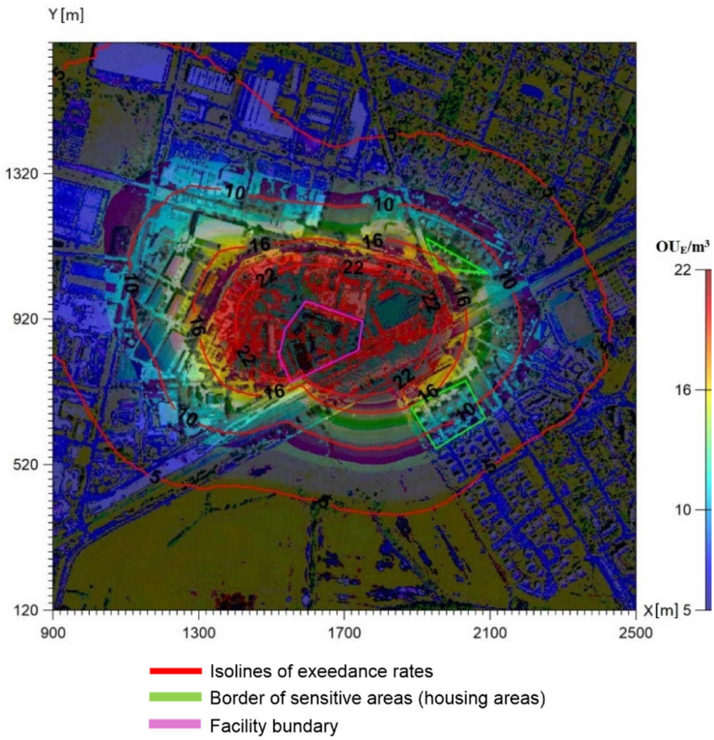

Fig. 3. Frequency of exceeding one-hour concentrations of the 5 OU_E/m^3 actual state

Sensitive areas were defined as protected areas, i.e. the nearest residential development, which is located 450 m in a straight line to the south-east and north-east. The frequency of exceedances of one-hour concentrations at the border of sensitive areas oscillated around 16%.

3.3. STAGE III

Due to the lack of information on the proportion of unorganized emissions to organized emissions, it was decided to estimate the level of integrity based on the relative integrity of each part of the technological system together with the level of their interaction. A relatively leaky part of that system is the "green waste collection place". Therefore, when determining techniques with the MOTOD method, the possible deviation of the effects obtained should be considered.

3.4. STAGE IV

As the point of reference, the following technological parameters of the plant have been adopted to define the technique using the MOTOD algorithm – plant performance:

- Mechanical part with a total capacity (three-shift operation) of 75 000 Mg/year.
- Biological part with a total capacity of 26 000 Mg/year.

3.5. STAGE V

Due to the selection of the appropriate type of impact, i.e., the negative impact of the odor compounds, the techniques in question only concern the below-mentioned techniques causing the reduction of the odor impact:

- appropriately configured deodorization system (spot, surface, and linear fogging with anti-odor preparation, anti-odor membranes),
- collection and directing emissions to an appropriate emission reduction system employing an air extraction system or air intake systems located close to the emission sources,
- rainwater drainage system with a separator,
- frequency of green waste disposal,
- exhaust gas recirculation,
- limiting the waste material dumping height,
- using wind barriers,
- selection and use of equipment with a high level of integrity (valves with double gland seal or equally effective equipment, high integrity seals (such as spiral wound seals, ring seals) for critical applications, pumps/compressors/mixers with mechanical seals instead of gland seals),
- maintaining adequate pressure in enclosed equipment or buildings,
- the efficiency of the bag opener at the waste reception point,
- minimizing storage time,
- green buffers in the form of isolating green belts,
- washing and disinfecting technical vehicles,
- maintenance of compost fields and infrastructure,
- hermitization of emission sources,
- installation of a biological filter,
- leak detection and repair (LDAR) program,
- a system for responding to identified excess odor emissions,
- odor management plan,
- sewage segregation,
- water/wastewater recirculation.

The above techniques selected for the comparison have been distinguished concerning the selected sector and technology, as well as the type of impact. Some of them are selected according to the BAT reference documents for the waste management sector, compatible techniques not mentioned in the reference documents but with appropriate mitigation, characteristics have been selected based on literature with a high degree of scientific confidence.

3.6. STAGE VI

The reduction of the impact of foul-smelling compounds in a given case was calculated as the difference in the value of the frequency of exceeding one-hour concentrations before the implementation of the technique and after the implementation of the analyzed technique based on the literature data (Fig. 4). The determination of the environmental effect was carried out in the scope of critical values defined for the relevant industry, i.e., waste management [8] (Stage II).

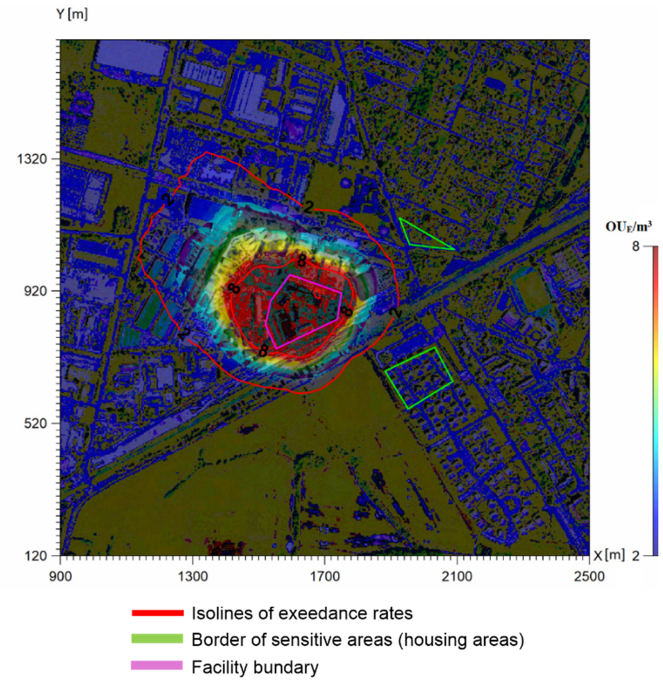

Fig. 4. Frequency of exceedance of one-hour concentrations 5 OU_E/m^3 with the planned implementation of appropriately configured deodorization system (Stage V)

Based on the modeling of odor dispersion, a possible/necessary emission reduction was found by using Technique 1 – deodorization system of the appropriate configuration, at a level of 90.21% (value calculated based on emission reductions). The planned environmental effect has been achieved – the calculated *WKR* was reduced by more than 14%.

3.7. STAGE VII

The following economic indicators were estimated for this plant:

- investment cost expressed in one-off financial expenses related to the implementation of techniques (e.g., cost of construction, assembly, materials),

- operating cost expressed in periodic financial expenditure relating to the operation of the implemented techniques (e.g., cost of maintaining the technique, cost of purchasing the parts of the technique used),
- operating profit caused by a potential change/modernization of the processing line (e.g., greater capacity of the system which results in a higher process efficiency).

3.8. VISUALISATION OF THE MOTOD METHOD – CASE STUDY

All components of this method have been linked according to the theoretical concept, where each relevant element is an integral part of the process sequence. A modular functional diagram was created to visualize the overall concept of the method, showing the interdependence of each stage and data processing with the individual result obtained in the form of the "optimum solution variant" (Fig. 5). The choice of variants consists of compiling all the calculated variants for the selected techniques to reduce the impact and concerning obtaining environmental and economic effects and the impact on the technological process. The appropriate technique considers all elements of the MOTOD, where the values of individual elements determine the correctness of the selected technique.

The diagram shows the visualization of the functional sequence of the individual stages of the MOTOD method. The presented values were obtained from the plant operator and based on environmental and model tests. The presented result in the form of the optimum solution variant defines Technique 1 as the most effective in terms of economic and environmental effects. Defining the effects has been done separately for each technique, while the diagram above shows only data from Technique 1. According to the principle of sustainable development, each decisive element and its sequence should lead to an optimal environmental, economic, and technological effect. The application of this method in the presented system resulted in the selection of the optimal technique to reduce the impact at the required level considering environmental and economic aspects.

4. DISCUSSION AND CONCLUSIONS

The MOTOD method is a new approach in the implementation of the decision-making process in the selection and determination of techniques to reduce the impact based on the technological, economic and environmental aspects while taking into account the idea of sustainable development. When stating that a technical solution is sustainable should understand the compliance with aspects of the principles of sustainable development. The extent of the deviation of the planned effects should be estimated by an empirical method, taking into account the margin of tolerance, all the techniques analyzed, and compiled on a case-by-case basis estimated based on practical experience and literature

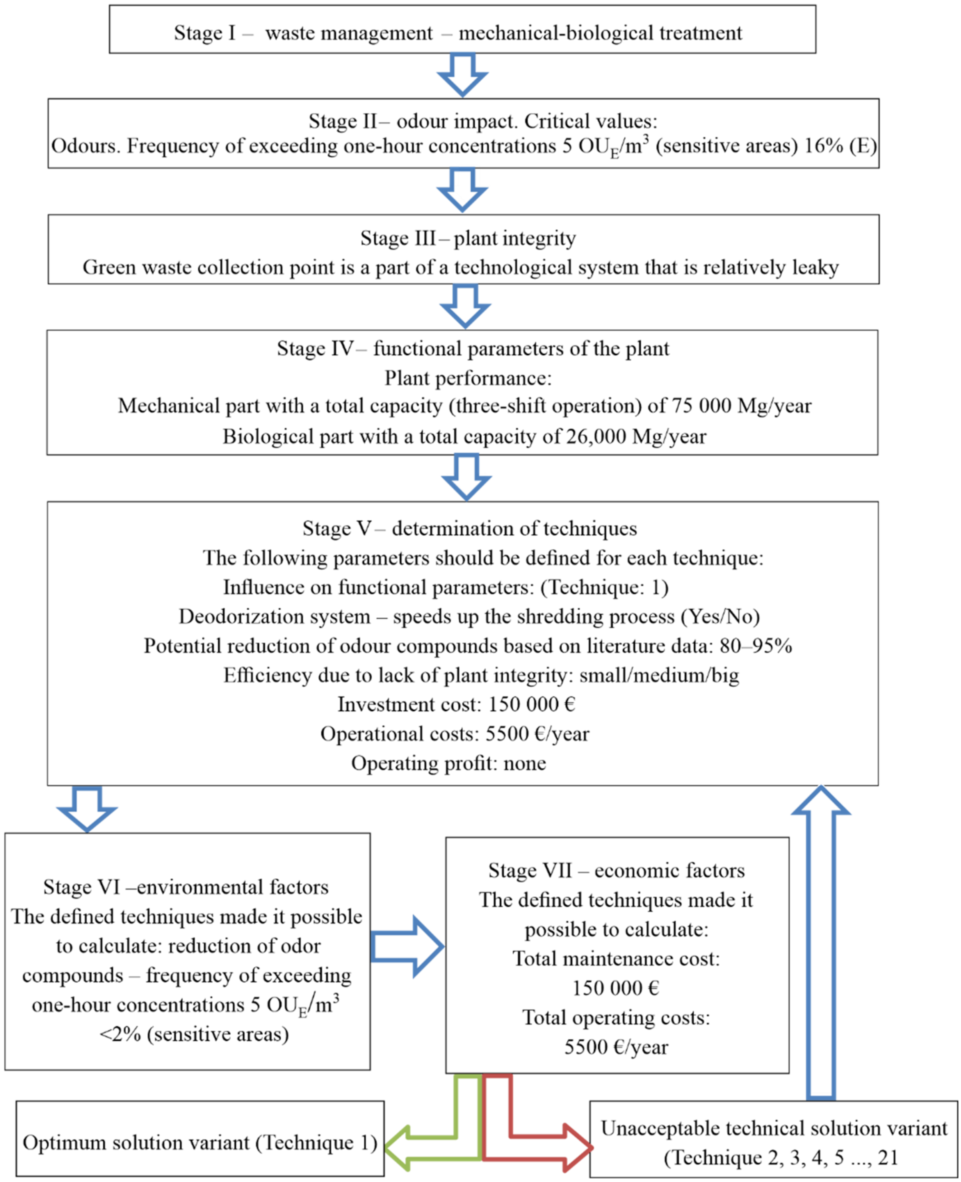

Fig. 5. MOTOD function diagram based on case study

data. In this article, some of the most essential functional parameters have been selected. The indicated functional parameters only show an exemplary sequence of elements of the selected method which explains the main idea of the relationship between the elements and the expected effects. Depending on the case, an appropriate functional parameter should be selected to influence the technological process. The optimal solution variant is selected based on a list and analysis of the individual techniques selected for a specific case. The analysis of the individual items according to the MOTOD method was carried out based on the environmental, economic, and technological effects obtained. The techniques selected following the MOTOD form an appropriate list of variants proposed for implementation. The optimal choice of techniques using the MOTOD method is to achieve the most economically optimal variant in terms of implementation and operation, considering the achievement of the intended environmental effect and not significantly influencing the course of technological processes.

The method introduces a structured mechanism of project management, is a state of the art approach in the implementation of the decision-making process and a practical tool for many decision-makers in charge of optimal design and implementation of techniques to reduce the impact, thus resulting in the appropriate, sustainable development of projects with a significant impact on the environment and local space. The application of the presented method is a practical application in the management of technological processes to test the economically and environmentally effective use of the environment.

The terminology introduced defines the necessary elements concerning technological design processes, spatial management, and shaping the aspects of sustainable development. The MOTOD method can be used for all the burdensome industrial and environmental sectors as a basic tool to determine impact-mitigation techniques. The structure of the method enables flexible adaptation to the reference environmental requirements of the decision-making and strategic area. From the perspective of the development of the method, it is planned to supplement the database of technical solutions in the field of environmental and economic effects for each sector of industry characterized by nuisance as well as their technological characteristics required for the MOTOD analysis. Currently, the presented state of development of the MOTOD method is the first, albeit key stage, allowing to define the main outline of the concept for the selection of techniques limiting the impact for the waste management sector. The method has been developed based on the technological possibilities of its implementation in all sectors and considering the key characteristic types of impact as well as for various technological systems. Besides, the entire method is currently subject to automation in terms of database optimization, data calculation at the individual stages for selected techniques, sectors, and technological systems as well as the determination of the environmental and economic effect.

REFERENCES

[1] MAZHITOV D., ERMILOVA M., ALTUKHOVA E., MAKSIMOVA T., ZHDANOVA O., *Development of technologies and processes in environmental management*, E3S Web of Conferences, 2019, 135, 8.

[2] GELDERMANN J., RENTZ O., *The reference installation approach for the technoeconomic assessment of emission abatement options and the determination of BAT according to the IPPC-directive*, J. Cleaner Prod., 2004, 389–402.

[3] SAMARAKOON S.M.K., GUDMESTAD O.T., *The IPPC directive and technique qualification at offshore oil and gas installations*, J. Cleaner Prod., 2011, 19, 13–20.
[4] CIKANKOWITZ A., LAFOREST V., *Using BAT performance as an evaluation method of techniques*, J. Cleaner Prod., 2013, 42, 141–158.
[5] AFNOR, *ISO 14040 Standard Environmental Management – Life Cycle Assessment – Principles and Framework*, AFNOR, Paris 2006.
[6] DIJKMANS R., *Methodology for selection of Best Available Techniques (BAT) at the sector level*, J. Cleaner Prod., 2000, 8, 11–21.
[7] SILVO K., *Implications of regulation based on the IPPC directive a review on the Finnish pulp and paper industry*, J. Cleaner Prod., 2009, 17, 713–723 .
[8] FREEMAN M., HERRIGES J.A., KLING C.L., *The measurement of environmental and resource values: theory and methods*, Res. Pol., 1994, 20 (4), 281–289.
[9] IVES C.D., KENDAL D., *The role of social values in the management of ecological systems*, J. Environ. Manage., 2014, 144, 67–72.
[10] JONES N.A., SHAW S., ROSS H., WITT K., PINNER B., *The study of human values in understanding and managing social-ecological systems*, Ecol. Soc., 2016, 21 (1), 15.
[11] WALLACE K.J., WAGNER C., SMITH M.J., *Eliciting human values for conservation planning and decisions: a global issue*, J. Environ. Manage., 2016, 170, 160–168.
[12] DERDEN A., VERCAEMST P., DIJKMANS R., *Best available techniques (BAT) for the fruit and vegetable processing industry*, Res. Cons. Rec., 2002, 34, 261–271.
[13] GEORGOPOULOU E., HONTOU V., GAKIS N., SARAFIDIS Y., LALAS D., LOUKATOS A., GARGOULAS N., MENTIS A., ECONOMIDIS D., TRIANTAFILOPOULOS T., KORIZI K., *BEAsT: a decision-support tool for assessing the environmental benefits and the economic attractiveness of best available techniques in industry*, J. Cleaner Prod., 2008, 16, 359–373.
[14] PNUE/PAM, *Guidelines for the application of best available techniques (BATs), best environmental practices (BEPs) and cleaner technologies (CTs) in industry in 146 of the Mediterranean countries*, [In:] *Clean Technologies and Best Environmental Practices for the Mediterranean Region*, BAT, Athens 2004, 15–22 (in French).
[15] DIJKMANS R., *Methodology for selection of best available techniques (BAT) at the sector level*, J. Cleaner Prod., 2000, 8, 11–21.
[16] FRANK F., TOBIAS H., *Sustainable value-added measuring corporate contributions to sustainability beyond eco-efficiency*, Ecol. Econ., 2004, 48, 173–187.
[17] AUMONIER S., *Life cycle assessment in industry and business*, Int. J. Life Cycle Assess., 2001, 6 (3), 773–776.
[18] GRAEDEL T., ALLENBY B., *Industrial Ecology*, Pearson, AT&T, 2002.
[19] WIEDMANN T., MINX J., *A Definition of "Carbon Footprint". Ecological Economics Research Trends*, Ch. 1, Nova Science Publishers, New York 2008.
[20] EPSTEIN J.M., ROY M., *Sustainability in action. Identifying and measuring the key performance drivers*, Long Range Plan., 2001, 34, 585–604.
[21] *Communication from the Commission. Establishment of the working plan setting out an indicative list of sectors for the adoption of sectoral and cross-sectoral reference documents (2011/C 358/02), under Regulation (EC) No. 1221/2009*, Official Journal of the European Union, 2011, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2011:358:0002:0005:EN:PDF, accessed 25.10.2020.
[22] BELGIORNO V., NADDEO V., ZARRA T., *Odour impact assessment handbook*, Wiley, 2013.
[23] KONOVALOV A., BATUROVA G., *Determination of environmental indicators critical values depending on their impact on various types of infrastructure in harsh climate*, IOP Conf. Ser.: Earth Environ. Sci., 2019, 345.

[24] *Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe*, Official Journal of the European Union, 21 May 2008, https://eur-lex.europa.eu/legal-content/PL/TXT/?uri=CELEX%3A32008L0050, accessed 25.10.2020.
[25] *Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control)*, Official Journal of the European Union, 24 November 2010, https://eur lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=PL, accessed 25.10.2020.
[26] TADAKI M., SINNER J., CHAN K.M.A., *Making sense of environmental values: a typology of concepts*, Ecol. Soc., 2017, 22 (1), 7.
[27] SHEREMET A., *A complex analysis of sustainable development indicators*, Econ. Anal., Theory Pract., 2014, 45 (396), 1–9.