

“Activities undertaken by Polish manufacturing companies to reduce air emissions”

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ACTIVITIES UNDERTAKEN BY POLISH MANUFACTURING COMPANIES TO REDUCE AIR EMISSIONS

Abstract

The emphasis on the need to balance the relations between the economy and the natural environment has been growing in recent years. For individual enterprises, it means considering the environmental protection issues in their activities and switching to environmentally-friendly business practices. The purpose of this paper is to present the activities undertaken and performed by Polish manufacturing companies participating in the European Union Eco-Management and Audit Scheme (EMAS) to reduce emissions of contaminants to air and an attempt to determine solutions that could serve as good environmental practices in this aspect. The grounds for the assumed research method were the analysis of secondary sources in the form of environmental statements. Environmental statements were downloaded from the EMAS website. The selection of the sample was targeted, the study was complete and included 13 manufacturing companies from Poland participating in EMAS, according to the register as of February 18, 2021. The findings indicate that Polish enterprises most frequently performed activities that involved using or improvement of technologies to reduce air emissions and implementation of monitoring and emissions measurement systems. The implemented or improved technologies mostly focused on limiting hard coal usage and replacing it with other energy sources, e.g., liquid gas, earth gas, or renewable energy sources. Analyzed enterprises also performed activities with the purpose of process containment, improvement of offered products, or reducing transport-related emissions.

Keywords

EMAS, technologies, improvement of technologies, reduction of emission

JEL Classification

F64, Q53, Q54, Q55

INTRODUCTION

The interest in environmental protection issues in the economy has grown in recent years. Continuing deterioration of the natural environment, being the consequence of technical advancement, mass production, and demographic growth, has become a major problem for many governments and international organizations. Currently, identifying solutions to mitigate the impact of businesses on the natural environment is increasingly gaining importance (Górzyński, 2007). In this context, the involvement of enterprises (whose role should mainly consist in searching for effective methods in this area) and public administration (that should mainly perform effective supervision over those enterprises) is essential. It is also extremely important to support individual states that should provide proper instruments and tools, and arrange a system of incentives to implement them in the organization.

In order to achieve measurable environmental effects, a scale effect should be achieved. Therefore, it is very important to develop a sort of internal mechanism to ensure continuous activity towards limit-



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ing the environmental impact of businesses. One of the instruments that could be significant in the context of the development of such a mechanism is the Eco-Management and Audit Scheme (EMAS). It is a voluntary Community instrument aiming at the support of participating organizations in continuous improvements in environmental performance. The Commission Communication as of 16 July 2008 on the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan recognizes that EMAS helps organizations to optimize their production processes by reducing environmental impacts and more effective use of resources (Commission of the European Communities, 2008). The impact of EMAS introduction on more rational use of resources and reduction in emission of contaminants has also been emphasized in the “Living well, within the limits of our planet” program. Additionally, it has been underlined that implementing EMAS in the industry may contribute to stimulating the development of innovative techniques, greening the economy, and reducing costs for industry in the longer term (The European Parliament & The Council of the European Union, 2013).

As has already been mentioned, the primary goal of the Eco-Management and Audit Scheme is supporting organizations in gaining continuous improvements in environmental performance. That requirement forces organizations to search for solutions that can contribute to decreasing the negative or increasing the positive impact on the environment.

This paper aims at eliminating the cognitive gap in the knowledge concerning the activities undertaken by Polish enterprises participating in EMAS to reduce the environmental impact of operations in different environmental areas (e.g., related to emissions). Filling this gap is crucial not only in terms of presenting the solutions allowing to meet EMAS requirements but also in the context of indicating environmental practices that may be implemented in many organizations (not only those participating in EMAS), dealing with various types of activities and seeking solutions to reduce their environmental impact.

1. LITERATURE REVIEW

The Eco-Management and Audit Scheme is currently considered the most credible and transparent environmental management system. It is a result of strict requirements imposed on organizations interested in participation or maintaining participation in the system. One of the prerequisites of the EMAS system is the obligation to achieve continuous improvements in environmental performance. The results achieved in that area are presented and assessed in the form of officially available environmental statements, based on calculated values of environmental performance indicators. The EMAS Regulation defines six major indicators related to key environmental areas, concerning energy, materials, water, waste, land-use with regard to biodiversity, and emissions (European Commission, 2018). Enterprises participating in the Eco-Management and Audit Scheme are obliged to improve their environmental performance in these particular areas (except those not important in terms of the type of activity performed by a given organization). The prereq-

uisite of continuous (year-by-year) improvement in the environmental performance somehow forces organizations participating in EMAS to search for new solutions that enable the reduction of negative or increasing positive environmental impact. Some organizations, despite the lack of a formal requirement, decide to declare in their environmental statements specific activities implemented or performed regularly to improve their environmental performance. These activities, often related to the improvement of products or previous technologies, can be perceived as one of the positive environmental effects of EMAS implementation. It needs to be emphasized that the previous research concerning environmental effects of the Eco-Management and Audit Scheme implementation focused mainly on determining whether and what general environmental benefits were achieved by the companies. Only a few studies regarded specific activities taken to reduce the negative environmental effect. Environmental benefits of the EMAS system implementation most frequently indicated by the analyzed organizations included systematization and arrangement of previous en-

environmental activities (Freimann & Schwaderlapp, 1996; Hillary et al., 1998; Bohne, 2000; Steger, 2000; Umweltbundesamt, 2000; Kössler et al., 2002; Morrow & Rondinelli, 2002; Hyršlová & Hájek, 2005, 2006; Abeliotis, 2006; Ministerio De Medio Ambiente, 2006), limiting the negative environmental impact mainly through the reduction of resources and energy usage (Bültmann & Wätzold, 2000; Schucht, 2000; Umweltbundesamt, 2000; Braun & Grotz, 2002; Wenk, 2004; Hyršlová & Hájek, 2006; Vernon et al., 2009; Merli et al., 2016), and improvement of environmental performance (Hillary et al., 1998; Morrow & Rondinelli, 2002; Hillary, 2004; Iraldo et al., 2005; Daddi et al., 2011; Merli et al., 2014). These studies, however, do not explain how the analyzed companies achieved improvement in terms of particular listed areas. Only a few studies regarding EMAS included an attempt to indicate more specific solutions. One of those studies concerned Polish enterprises participating in EMAS. It presented, among others, the activities implemented by companies from different sectors (except power engineering) in order to improve energy efficiency. They involved improvement of production processes, replacement of lighting with energy-efficient lamps, and introduction of continuous monitoring or additional indexes to measure the consumption of energy, etc. That study also listed activities performed by Polish enterprises in the power engineering sector to reduce the emission of contaminants to the air. They concerned installing atmosphere protective devices on power units, switching to modern technologies, containment of processes, and using a continuous emission measurement system (Nycz-Wróbel, 2020). Another two studies, concerning French and German enterprises participating in EMAS, presented planned or already implemented activities aiming at the improvement of environmental performance. They involved introducing technical improvements in existing facilities or installations, optimizing or implementation of new processes, replacement of problematic materials, introducing environmental improvements in the product area, and optimizing transport activities with reference to environmental aspects (Bültmann & Wätzold, 2000; Schucht, 2000). However, these studies did not indicate examples of more specific undertakings, which could also be helpful for other organizations searching for readily feasible solutions or inspiring the develop-

ment of individual effective methods contributing to the improvement in the area of environmental activities.

It is worth mentioning that organizations participating in the Eco-Management and Audit Scheme in many cases search for more radical solutions (including innovations) to achieve continuous improvement of environmental performance. It was indicated that companies most frequently implemented environmental innovations in the area of offered products (Hoffmann et al., 2003; Salomone, 2008; Nycz-Wróbel, 2016) or technological processes (Braun & Grotz, 2002; Rennings et al., 2006; Nycz-Wróbel, 2016).

2. AIM

As has already been mentioned, there are still only a few studies presenting examples of particular activities implemented by organizations participating in EMAS to improve their environmental performance. This paper is an attempt to fill this gap. It is so important because the results of these studies may serve as a benchmarking basis for organizations from different sectors in terms of solutions that could be adopted to improve environmental performance in particular environmental areas listed in the EMAS Regulation. These areas are related to reducing energy, materials, and water consumption, reducing emissions of air contaminants, biodiversity, or more rational waste management. The purpose of this paper is to present the activities undertaken and performed by Polish manufacturing companies participating in EMAS in order to reduce emissions of contaminants to air and an attempt to determine solutions that could serve as good environmental practices in this aspect.

3. METHOD

The theoretical part of the paper presents the results of analysis (desk research) of studies concerning environmental effects achieved by enterprises as a result of EMAS implementation, determining the cognitive gap in the knowledge concerning particular activities undertaken to improve their environmental performance. One of the key prerequisites of the system has also been emphasized,

namely continuous improvement of effects of performed environmental activities, essential in the context of stimulating organizations to search for effective solutions in this area.

The empirical part contains the results of individual research conducted in Polish enterprises participating in EMAS. The grounds for the assumed research method were the analysis of secondary sources in the form of environmental statements. Environmental statements are reports that enterprises participating in EMAS are obliged to publish and update annually. In the EMAS Regulation, they are defined as comprehensive information made available to the public and other interested parties, regarding the type of activity performed, planned or ongoing environmental programs, objectives, and tasks, as well as the results achieved in the course of conducted environmental activity (The European Parliament & The Council of the European Union, 2009). Being subject to regular validation, environmental statements are credible data sources. In the process of validation, an independent environmental validator (third party) checks if the information presented in the statement is correct, reliable, credible, and consistent with the requirements specified in the EMAS Regulation (The European Parliament & The Council of the European Union, 2009). It should be noted that the analysis of environmental statements has already been used as a basis for previous research regarding EMAS system. Among others, it was used in the studies concerning the effect of EMAS implementation on the improvement of environmental performance (Daddi et al., 2011; Matuszak-Flejszman et al., 2019; Heras-Saizarbitoria et al., 2020).

Environmental statements were downloaded from the Polish EMAS website. The selection of the sample was targeted, the research was complete and included 13 manufacturing companies from Poland participating in EMAS, according to the register dated February 18, 2021. Considering the size of an organization, the analyzed population consisted of 6 large, 5 medium, 1 small, and 1 micro-enterprise. Considering the type of conducted activities, the analyzed population included manufacturing companies (three of which were specialized in clinker and/or cement production, while the other manufactured power supply devices

and facilities, environmental protection systems and devices; gypsum plaster construction materials, paper, aromatic hydrocarbons, utility vehicles, aerosol products such as cosmetics, medical products, household chemicals, meat products, PVC-coated, varnished and extruded materials, polyester and plastic products).

The study was conducted from February 18, 2021, to April 21, 2021. It involved an in-depth analysis of complete environmental statements filed by individual enterprises participating in the study. The analysis allowed identifying all activities performed to reduce emission to air, specified in the environmental statements published by the companies (only implemented or ongoing activities were listed, except planned ones). Next, all identified activities were divided into several groups, based on the type of a given activity. That allowed distinguishing the types of activities most frequently undertaken by the analyzed companies to reduce emissions. The results are presented in Table 1. Specific activities distinguished based on the analysis of environmental statements and the division into particular groups are presented in Tables 2–5.

4. RESULTS

Table 1 presents activities most frequently undertaken by the analyzed enterprises to reduce the emission of air contaminants.

Table 1. Types of activities most frequently undertaken by Polish manufacturing companies registered with EMAS in order to reduce the emission of air contaminants

Source: Author's elaboration.

Type of activity	Number of organizations
Using state-of-the-art technology	7
Improvement of technology	8
Implementing emissions monitoring and measurement system	5
Other activities	7

Based on the analysis of environmental statements it has been found that the most frequent activities undertaken by Polish manufacturing companies to reduce emissions included: using (7) or improvement of existing technologies (8) and imple-

Table 2. Technologies used by Polish companies registered with EMAS to reduce the emission of air contaminants

Source: Author's elaboration.

Technologies to reduce emissions	Production of	Size of organizations	Number of organizations
Using renewable sources of energy	paper/utility vehicles/ meat products	large/medium	3
Flue gas treatment systems	cement/clinker and cement	large	2
Steam-heated calciners for gypsum processing	gypsum plaster construction materials	medium	1
Modern calcination plant			
Modern mixing plant and storage hall			
Boiler plant fueled with liquid gas instead of hard coal			
Direct feeding of raw material using an enclosed belt conveyor	aromatic hydrocarbons	medium	1
Process discharge gas post-combustion technology, Extractive Distillation Plant, Sulphuric Acid Recovery Plant, Steam Production Plant			
Use of forerunnings as a charge material for the sulphuric acid recovery plant and using an acid recovery technology allowing reduction of SO ₂ emission			
Feeding oxygen to the clinker furnace to improve combustion efficiency	clinker and cement	large	1

mentation of emissions monitoring and measurement systems (5). A group of other activities has also been distinguished, including all other activities reported by the analyzed companies (7).

One of the most frequent types of activities was using technologies aiming at the reduction of emissions (Table 2).

Seven enterprises declared the use of technologies to reduce emissions. They were only large and medium enterprises dealing with the production of paper, utility vehicles, meat products, cement, clinker and cement, gypsum plaster construction materials, and aromatic hydrocarbons. Based on the conducted analysis, it has been found that technologies to reduce the emission of air contaminants were mainly oriented on limiting hard coal usage and replacing it with other energy sources, e.g., liquid gas, earth gas, or renewable energy sources. The analyzed manufacturing companies used wind energy, photovoltaic energy, solar energy, biomass, geothermal energy (utility vehicles), and hydroelectric energy sources (paper). The most common solutions in this area also included using flue gas treatment technologies or plants (electrostatic precipitators, fabric jet filters, bag filters), directly oriented on reduction of selected types of emissions. These solutions were introduced in two large enterprises producing clinker and cement.

The analyzed companies also performed activities aimed at the improvement of existing technologies (Table 3).

Eight enterprises declared improvement activities. Two of them dealt with the production of clinker and cement, while the other produced: PVC-coated, varnished, and extruded materials; power supply devices and facilities, environmental protection systems and devices; aromatic hydrocarbons; polyester; cement and gypsum plaster construction materials. Considering the size, they were mostly large or medium enterprises, with one micro-enterprise. Based on the conducted investigation, it has been found that the activities to improve existing technologies were mainly focused on extending, rebuilding, or replacement of particular elements of plants and systems. Besides, solutions consisted in replacement or optimization of material or fuel management (clinker and cement) and improvement of existing flue gas treatment systems have been identified (clinker and cement; PVC-coated, varnished, and extruded materials). In the latter area, electrostatic filters have been replaced with highly effective fabric filters and a bio-filter plant has been introduced, allowing reducing the concentration of volatile organic compounds (VOCs) in the off-gas. The analysis of environmental statements indicates that the majority of modernization activities aimed at reaching effects by means of replacement of hard

Table 3. Solutions implemented by Polish companies registered with EMAS to improve technologies to reduce emissions

Source: Author's elaboration.

Improvement of used technologies	Production of	Size of organizations	Number of organizations
Modernization of flue gas treatment plant	clinker and cement/ PVC-coated, varnished, and extruded materials	large/small	2
Modernization of the boiler plant deslagging system and modernization of boiler plant	power supply devices and facilities, environmental protection systems and devices	large	1
Providing welders with portable welding fume extraction units			
Modernization of air protection system with a benzol plant gas flare	aromatic hydrocarbons	medium	1
Modernization of clinker hall dust removal system	clinker and cement	large	1
Replacement of loading bellows at the cement trailers loading station			
Installing a central dust removal system inside the building where clinker milling is performed			
Optimized material and fuel batching			
Rebuilding the railway clinker unloading station and construction of a clinker charging hopper with a dust removal system			
Modernization of gas furnace consisted in burner adjustment	polyester	medium	1
Launching a dry process rotary kiln for clinker burning	cement	large	1
Change of gypsum roasting technology	gypsum plaster construction materials	medium	1
Construction of a vehicle unloading system allowing to transfer clinker to a storage site	clinker and cement	large	1
Increasing the volume of alternative fuels used in the clinker burning process			

coal with liquid gas, earth gas, or alternative fuels, which in turn contributed to the reduction of particular types of air contaminants.

Activities in the area of monitoring and measurement of emissions have also been identified (Table 4).

Five enterprises indicated additional monitoring or measurement of emissions. These were only large or medium enterprises dealing with the production of gypsum plaster construction materials, cement, clinker and cement, polyester, and aromatic hydrocarbons. The analysis has shown that the activities performed by the Polish manufacturing companies in the field of monitoring and measurement of emissions were mainly oriented on maintaining continuous monitoring or measurement in specific areas of operation. The objective was to prevent exceeding the levels of emissions specified in the permits and enable quick response in emergencies or when any irregularities occur in this area. The analyzed organizations were also involved in initiatives related to introducing additional monitoring or measurement

elements, which in the case of cement producers resulted from the obligation to adjust to restrictive changes in relevant legal regulations.

Polish manufacturing companies also implemented other activities to reduce emissions (Table 5).

Seven enterprises declared other activities undertaken to reduce emissions. They were large and medium enterprises, with one micro-enterprise. Two of them dealt with the production of clinker and cement, while the other produced aromatic hydrocarbons; power supply devices and facilities, environmental protection systems and devices; utility vehicles; plastic products, and meat products.

Other activities to reduce emissions to air included e.g. solutions in process containment (aromatic hydrocarbons; clinker and cement). They involved purchase and installation of hermetic pumps and probes, insulation and replacement of vacuum relief valves on particular benzene tanks, installation of exhaust gas piping, and re-

Table 4. Activities in the area of monitoring and measurement of emissions undertaken by Polish companies registered with EMAS

Source: Author's elaboration.

Activities in the area of monitoring and measurement of emissions	Production of	Size of organizations	Number of organizations
Monitoring of emissions with permanent supervision of production process parameters stability	gypsum plaster construction materials	medium	1
Fitting all process systems with emissions control and measurement devices	cement	large	1
Installation of a permanent emission monitoring system on cement kilns at selected dry processing lines			
Permanent ammonia emission monitoring			
Additional periodic measurement of contaminants emission from the process of waste co-incineration			
Installation of NH ₃ monitoring analyzer	clinker and cement	large	1
Monitoring of emissions from individual emitters, regular control of process parameters, and using a computer control system integrated with plant devices	polyester	medium	1
Monitoring of CO ₂ carbon footprint	aromatic hydrocarbons	medium	1
Change in the monitoring methodology of CO ₂ emission from the post-refining mixture stream			

Table 5. Other activities undertaken by Polish companies registered with EMAS to reduce the emission of air contaminants

Source: Author's elaboration.

Other activities	Production of	Size of organizations	Number of organizations
Containment of processes	aromatic hydrocarbons/clinker and cement	medium/large	3
Sale of products facilitating the reduction of emissions	power supply devices and facilities, environmental protection systems and devices/utility vehicles	large	2
Replacement of fleet	utility vehicles/plastic products	large/micro	2
Activities in order to reduce unorganized dust emission caused by unloading raw materials and intralogistics	clinker and cement	large	1
Regular technical inspection and continuous control of cement trailer loading stations			
Activities to reduce emissions caused by suppliers' transport or transport of empty containers	utility vehicles	large	1
Installing special sprinkler systems	clinker and cement	large	1
Planting trees – as part of the "Plant Three Trees" campaign	meat products	medium	1

duction of storage area or shifting from open and half-open storages to contained and closed warehouses. These solutions were mainly oriented on the elimination of the issue of unorganized emission of dust and gas.

This group of activities also included initiatives related to engineering, production and sale of products allowing reducing emissions, namely state-of-the-art technologies for the energy sector and electric vehicles (municipal buses, transporters, and lorries).

Among other activities were undertakings aimed at reduction of unorganized emission of dust, caused by the unloading of materials and intralogistics (clinker and cement). This group included a regular sprinkling of the site, limiting the speed of vehicles at the plant, sweeper cleaning of paved yards and roads, cleaning of pavements and areas with restricted access using an engine powered sweeper, and use of an industrial vacuum cleaner with flexible hoses at the cement milling plant.

Activities performed to reduce transport-related emissions have also been identified (utility vehicles). In terms of suppliers' transport, these included continuous analysis, visualization, and optimizing transport structures and processes, including more suppliers in the Supply Cockpit 2.0 program to allow systemic arrangement of complete loading procedures and to avoid additional shipments in the process of materials supply, as well as the implementation of an empty container management software. In the area of internal transport of empty containers, activities have been performed to increase the efficiency of loading space usage, including stacking unification in transport between plants and replacement of non-foldable containers or pallets with foldable ones.

As far as fleet replacement is concerned, companies have switched to vehicles with higher Euro standards, and E-Truck test vehicles have been introduced in intralogistics. This solution has been introduced by two enterprises dealing with the production of utility vehicles and plastic products.

5. DISCUSSION

The presented analysis lead to a conclusion that solutions contributing to the reduction of emissions were mostly undertaken by Polish manufacturing enterprises performing activities that entail emission of a high volume of air contaminants (production of clinker and cement; polyester; aromatic hydrocarbons; paper; meat products; plastic products; PVC-coated, varnished and extruded materials; gypsum plaster construction materials), as well as those in which modification in the offered products may contribute to the reduction of emissions to air (utility vehicles; power supply devices and facilities, environmental protection systems and devices). Solutions presented in this paper were implemented mostly by large and medium enterprises, which was mainly determined by the population structure (11 of 13 analyzed organizations were large and medium enterprises).

The study described herein has indicated that Polish enterprises performed a variety of activities to reduce the emission of air contaminants, including the use of modern technologies, improve-

ment of previous technologies (mainly consisted in the modernization of existing facilities and plants), and considering environmental aspects in the offered products or transport operations. It is consistent with the results of previous research concerning activities planned or implemented by French and German enterprises to improve their environmental performance. Comparison of the current and previous analysis results obtained among Polish companies also indicates that there are no significant differences between activities undertaken to reduce emissions in particular sectors represented by the analyzed organizations. The same type of solutions adopted by manufacturing and power engineering enterprises can be specified. They involved using modern technologies to reduce emissions, introducing flue gas treatment plants, process containment, and using continuous emission monitoring or measurement systems. This leads to the conclusion that solutions presented in this paper can be applied not only in manufacturing enterprises.

It should also be stressed that some solutions introduced by the analyzed companies were process or product innovations (e.g. green technologies in power engineering or steam-heated calciners for gypsum processing, which were novelties on a world scale). This also confirms the conclusions from the previous studies that environmental innovations introduced as a result of EMAS implementation mainly concern products and technological processes.

The study conducted among Polish manufacturing companies allows formulating recommendations that could be taken into account by managers while determining and planning specific solutions to be introduced in an organization to reduce the emission of air contaminants:

- 1) when using or improving technologies to reduce emissions to air, companies should mainly focus on:
 - replacement of hard coal charge with gas (liquid, earth gas) or renewable sources of energy, which may result in a reduction of CO₂ emission – using RDF (Refuse Derived Fuel) may additionally benefit in improved waste management;

- optimizing raw material input employing elimination or limiting main CO₂ carriers from the so-called process emission; eliminating empty runs in transport or using vehicles that meet higher categories of Euro standards).
 - using flue gas treatment technology or systems, which should mainly result in limiting unorganized emission of dust.
- 2) All enterprises obliged to have environmental permits concerning achievable levels of emission might consider the introduction of continuous emission monitoring or measurement. As it has already been mentioned, it might help to maintain legal conformity and to identify possible failures or irregularities that could result in exceeding allowable levels of emission.
 - 3) A valuable suggestion for enterprises resulting from the analysis in the field of transport is that they can improve environmental performance both in their transport operations (including intralogistics) and in transport services provided by third parties with whom they cooperate (specific solutions that can be implemented in this area have been indicated based on the conducted study, e.g.
- It should be noted that the implementation of many solutions contributing to the reduction in emission to air presented herein may be expensive and time-consuming. On the other hand, the described analysis also indicated less radical solutions that could be adopted in many organizations. They include, e.g. sprinkling yards where dust emission may occur, cleaning with the use of special brushes, or planting trees.
- As already stated above, the results may supplement and detail the results of previous research concerning the environmental effects achieved in enterprises as a result of EMAS implementation. A certain limitation of the paper is the fact that information provided by individual companies in environmental reports is not uniform, which makes it difficult to analyze. Not every organization includes data on specific implemented activities in their environmental reports. However, solutions contributing to the reduction of air contaminants presented herein can be implemented also in other manufacturing enterprises or companies from different sectors.

CONCLUSION

The purpose of this paper is to present the activities undertaken and performed by Polish manufacturing companies participating in EMAS in order to reduce emissions of contaminants to air and an attempt to determine solutions that could serve as good environmental practices in this aspect. The investigation conducted among Polish manufacturing companies registered with EMAS allowed determining the types of activities most frequently undertaken in order to reduce the emission of air contaminants. They included using appropriate technologies to reduce emissions (the main focus in this area was on the replacement of raw material or fuel charge), improvement of previously used technologies (which mainly consisted in the modernization of existing facilities or plants), introducing continuous monitoring or measurement of emissions and improvement of offered products or transport activities considering the environmental aspects. This paper shows that enterprises interested in reducing emissions to air should search for more specific and feasible solutions in this particular area. The key input determined in the course of this study are examples of specific activities that can be implemented or considered good practices in the field of reducing emissions of airborne contaminants. As has been shown, presented solutions could also be implemented by enterprises from other sectors. The comparison of research results has proved that there were no significant differences between activities undertaken to reduce emissions to air in power engineering and manufacturing companies. This implies that similar activities could be introduced by enterprises in other branches of industry. This paper also supplements previous studies regarding the EMAS system with more specific information, indicating specific environmental solutions used by the described enterprises.

It must be noted that the analysis should be continued to fill the cognitive gap in the knowledge concerning the activities undertaken by Polish enterprises participating in EMAS to reduce the environmental impact of operations in different environmental areas. Further research in this field could be conducted in the following areas:

- activities undertaken by organizations registered with EMAS from sectors other than manufacturing in terms of reduction of air emissions,
- undertakings fulfilled by organizations from different sectors registered with EMAS in environmental areas other than emissions (e.g. in waste management).

AUTHOR CONTRIBUTIONS

Conceptualization: Jadwiga Nycz-Wróbel.

Data curation: Jadwiga Nycz-Wróbel.

Formal analysis: Jadwiga Nycz-Wróbel.

Investigation: Jadwiga Nycz-Wróbel.

Methodology: Jadwiga Nycz-Wróbel.

Project administration: Jadwiga Nycz-Wróbel.

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Visualization: Jadwiga Nycz-Wróbel.

Writing – original draft: Jadwiga Nycz-Wróbel.

Writing – review & editing: Jadwiga Nycz-Wróbel.

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