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Environmental interaction assessment of VOC's emission under emergency work of IPPC installation

Ocena oddziaływania na środowisko pracy emisji LZO w warunkach awaryjnej pracy instalacji IPPC

Abstract

The study evaluated the impact of emissions (VOCs) as a result of the operation of the printing of plant at working positions of those performing their tasks outdoors or in buildings next door to the subject of the printing installation (offset printing). The first part of the paper presents the general characteristics of the process and materials used for printing. The further part shows the results of the modelling of emissions, depending on the operating state of purification (emission in normal conditions and emission conditions, which deviate from normal – failure state of the afterburner).

Keywords: modelling of emissions, printing industry, heat-set rotary offset, working under emergency conditions, failure of afterburner

Streszczenie

W pracy oceniono wpływ emisji zanieczyszczeń organicznych (LZO) w wyniku działalności zakładu poligraficznego na środowisko. W części pierwszej przedstawiono ogólną charakterystykę procesu druku oraz wykorzystywanych farb. W dalszej części przedstawiono wyniki modelowanie emisji zanieczyszczeń w zależności od stanu pracy układu oczyszczającego (emisja w warunkach normalnych oraz emisja w warunkach odbiegających od normalnych – stan awarii dopalacza).

Słowa kluczowe: modelowanie emisji zanieczyszczeń, przemysł poligraficzny, gorący offset rotacyjny (heat-set), praca **w warunkach awaryjnych, awaria dopalacza**

1. Introduction

In this publication, calculations (based on the measurements of emissions of pollutants) of the concentrations of pollutants in ambient air emitted during technological processes were performed:

a) under normal conditions (operation of all equipment is compatible with the assumptions of technological process and the conditions, which are set out in the applicable decision – permission for the introduction of pollutants into the air (i.e. the integrated and sectoral permission),
b) under fault conditions of the thermal afterburner and emission of contaminants by emitters of emergency in accordance with the conditions, which are set out in the applicable decision – permission for the introduction of pollutants into the air (i.e. the integrated permission):
   - in the case of "normal weather conditions";
   - in the case of "very bad weather conditions".

This paper presents a comparison of the calculated concentrations of pollutants in the air to the benchmarks defined in the Regulation of the Minister of the Environment of the 26th of January 2010 on reference values for certain substances in the air [1].

2. The analysis in the context of the gaseous emissions in the various operating conditions of the purifying exhaust fumes system

2.1. Research object

The object of the analysed company is the printing activity. The installation that is classified as an IPPC installation (web offset machines) is covered by an integrated permission defined in the Regulation of the Minister of the Environment of the 27th of August 2014 on the types of installations, which may cause significant pollution of individual elements of nature or the environment as a whole (Journal of Laws of 2014 item 1169), i.e. installation for offset printing, classified as an installation for the surface treatment of substances, objects or products using organic solvents, solvent consumption of 150 kg per hour or more than 200 tonnes per year.

The object of the analysed plant is the printing activity. The installation, classified as an IPPC installation (web offset machines), is covered by an integrated permission.

The plant is located in one of the outlying districts of the city, in an area intended for production and service activities. The immediate surroundings of the plant are the lands used for the purposes of business production and service.

2.2. Printing technology

Offset printing is a relatively cheap and quick way to obtain a large number of prints. Lightweight aluminium matrix formed on the printing drum sends images to an intermediate drum covered with rubber, which in turn transfers the image to paper. Hence, there is the second important definition of this technique – "indirect" printing. This printing unit is capable of rotating at high speed.

In the heat-set web offset printing, the ink is fixed into the paper by soaking and evaporation at high temperatures. The printed paper passes through a drying tunnel, which is heated to a high temperature, in which the evaporation of the solvents contained in the paint occurs, which is a source of contamination of the air extracted from the tunnel.

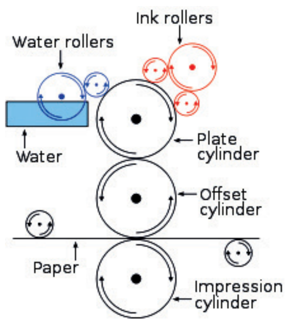

Fig. 1. The principle of offset printing [2]

2.3. Raw materials used in the printing process

Due to the volume of the used raw materials and the characteristics of the fusing mechanisms of printing inks in the process of web offset printing, determination of the characteristics of used inks is essential in order to assess the impact of the installation on atmospheric air. Fusing mechanisms of inks of the *heat-set* type occur due to the influence of delivery of significant amounts of heat (blow heat, drying tunnels, which are heated by gas burning, etc.). Depending on the drying system, the paper has a temperature from 90 to 150°C, which corresponds to a temperature of 200 ÷ 300°C of the drying agent. At these high temperatures, it evaporates the mineral oil, which is a solvent for paints of the *heat-set* type and water (moisture) from paper and wetting agents.

For the production of *heat-set* paints, adhesives containing the composition of phenol-formaldehyde resins and alkyd resins, polymerised linseed oil, mineral oil (fraction with a boiling point of 240–300°C), colorants, tinters and excipients are used. Mineral oils used for the production of paints of the *heat-set* type are special types usually of naphthenic mineral oils. They are refined in such a way that they are almost odourless and colourless. Depending on the distillation, the boiling point is in the range of 240–270°C, 260–290 and 270–300°C. In the *halftone* paints, mineral oils vary in their boiling points because paints of different colours are to be traversed in the printing path of different distances.

2.4. Types of emitted pollutants

The organic contaminants (VOCs) were taken into account for the analysis. They are associated with both the functioning of basic technological processes, as well as the auxiliary processes. The table below lists all the contaminants identified in the measurements of emissions performed by specialised companies dealing with the measurement of emissions, as well as listed in material safety data sheets of used raw materials.

Table 1. The list of pollutants emitted into the atmosphere

No.	Pollution
1	Benzene
2	Methylethylketon
3	Ethylobenzene
4	Xylene
5	Styrene
6	Toluene
7	aliphatic hydrocarbons
8	aromatic hydrocarbons

2.5. Devices for reducing the emission of pollutants

The plant has afterburners, which are installed in systems of offset web machines thermoforming (IPPC installations), in which hydrocarbons and alcohols vapours, cleaning solutions, printing inks are burnt. With these vapours, the exhaust gas used for drying the printed paper strip is transported.

In addition, during the manufacturing process, as a result of cutting the paper to the desired size, scrap and paper dust are formed. They are pneumatically conveyed to the baling machine. Paper dust is retained on the filter bag, and then it is briquetted in a briquetting press and it is added to the compressed *bale* or put into the recipient. Other emitters, due to the type and amount of pollutants, do not have the equipment reducing emissions.

2.5.1. Legal requirements relating to the issue of emerging contaminants

Legal requirements for environmental protection are regulated by the Framework Law of the 27th of April 2001. Environmental Protection Law (Journal of Laws of 2013 item. 1232, as amended.) and implementing acts to the above Law. According to the Regulation of the Minister of the Environment of the 26th of January 2010 on reference values for certain substances in the air [1], a plant that leads pollution in an organised manner to the atmosphere is obliged to use solutions that will not exceed the permissible reference value, i.e. appropriate normative values concerning excess emissions and immissions will be saved.

Moreover, in the case of large printing plants, which consume large quantities of raw materials (this translates into considerable use of VOC), additional requirements apply for the protection of atmospheric air as defined in the Regulation of the Minister of the Environment of the 4^{th} of November 2014 on emission standards for certain types of installations, combustion plants and equipment incineration or co-incineration of waste [3]. The processes carried out in the system used in this printing plant include (in accordance with Annex 7 to the above regulation to hot offset rotary process, which identified the following emission standards (Annex 8 point 1):

For VOC usage > 25 Mg/year
S1 = 20 mg/m^3 VOC
(counted on organic carbon).

Moreover, according to the Environmental Protection Law, in special cases, the competent authority for issuing integrated permission may in this integrated permission allow a derogation from the emission limit values if, in its assessment, their achievement would lead to disproportionately higher costs compared to the environmental benefits, and provided that emission standards are not exceeded, when they are applicable. After the evaluation, referred to above, the competent authority takes into account the geographical location, the local environmental conditions, technical characteristics of the installation or other factors affecting the operation of the installation and the environment as a whole.

2.5.2. Assumptions about the calculations of the spread of contamination

To realise this objective work, three variants (variant I variant IIA and IIB variant) were established, for which the analysis of the spread of pollutants was performed:

- Variant I – normal operation of all installations and equipment reducing emissions. In this variant of pollution, arising printing presses are collected in one conduit and carried to catalytic afterburner where they are burned. The purified exhaust gas is emitted into the atmosphere;
- Variant II – failure of the catalytic afterburner. In this variant of pollution, the arising printing presses are discharged by the individual emergency emitters to the atmosphere. There is no purification of pollutants.

Due to the fact that the aim of the study was to determine the concentrations of pollutants in the grid of receptors and in free points, and as we know, this concentration will be a function of the emission and meteorological conditions, two variants: IIA and IIB variant were separated for the second variant.

- Variant IIA is characterised by normal meteorological conditions;
- Variant IIB is characterised by unfavourable weather.

Thus, the size of the air pollution will vary discretely;

- the lowest contamination to the conditions described in Option I, which will occur approximately 75% of the time during the year,
- high contamination for conditions described in Variant IIA, which will be present to 7.5% of the time during the year,
- very high contamination for conditions described in the variant IIB, which will occur to 2.5% of the time during the year,
- lack of contamination, when the system does not work – about 15% per year.

Normal meteorological conditions mean meteorological data containing meteorological statistics for given area and the different seasons (winter, summer and year).

The nuisance of sources of emissions to the environment depends, to a large extent, on meteorological parameters, of which the most important are: speed and wind direction, the equilibrium of the atmosphere, the air temperature and precipitation. Factors affecting speed and intensity of the spread of contamination are: atmospheric stability conditions characterised by the possibility of atmospheric diffusion and the frequency and speed of the winds. There are 6 classes of atmospheric stability, and 36 found in the atmosphere of a combination of equilibrium states and wind speed.

- Class I – highly unstable,
- Class II – moderately unstable,
- Class III – weak instability,
- Class IV – indifferent balance,
- Class V – poor durability,
- Class VI – constant and firmly fixed equilibrium.

The occurrence of class balance I–III proves favourable dispersion (taking out the emissions outside the region of their emittance). The occurrence of states V and VI proves unfavourable spread of contamination and the possibility of their concentration in the area of emissions.

Class IV is an indifferent class, but its occurrence while large wind speed favours a beneficial spread of contamination.

Due to the fact that computer programs used for modelling the emissions calculate the distribution of contaminants for the annual meteorological values, there was no possibility to introduce in the program the conditions, which occurred in the small amount of time (about several to several tens of hours). For this reason, when trying to grasp the impact of very adverse weather conditions, after a full analysis of the data resulting from our own research and literature data, it was found that it is possible to do this indirectly by increasing the size of the emission with the ratio, which presents the hindered spread of pollutants in the air.

2.6. Tables of distribution of concentrations of selected pollutants around the premises

On the basis of knowledge of the emission of pollutants (developed on the basis of measurements carried out by an accredited laboratory), distribution maps of concentrations of individual pollutants (according to Polish reference methodology for performing the analysis) were made. The results in the following tables allow you to determine where the greatest concentration of major pollutants is in the vicinity of the plant and to compare them with the maximum concentrations of pollutants in the workplace:

Table 2. Maximum concentration in free points

No.	Pollution	Maximum concentration in free points [μg/m³]			Maximum concentrations during normal operation of afterburner compared to reference value [%]
		Normal operation of afterburner	Failure of afterburner– favourable weather conditions	Failure of afterburner – adverse weather conditions	
3	Benzene	1,817	22,951	78,976	6,06
		1,650	16,859	50,401	5,50
4	Styrene	0,871	24,305	84,308	4,36
		0,780	17,868	53,688	3,90
5	Methylethylketon	9,918	9,938	9,952	3,31
		17,021	17,221	17,454	5,67
6	Ethylbenzene	0,919	24,337	84,340	0,18
		0,841	17,911	53,714	0,17
7	Xylene	1,530	40,406	140,024	1,53
		1,412	29,585	89,177	1,41
8	Toluene	1,282	34,174	118,450	1,28
		1,174	25,020	75,438	1,17
9	aliphatic hydrocarbons	24,586	700,524	2430,695	0,82
		21,915	514,828	1547,808	0,73
10	Aromatic hydrocarbons	11,277	321,060	1114,013	1,13
		10,055	235,955	709,378	1,01

The results for office space in the building number 1 are presented by the green colour and italics, while the results for office space in building number 2 are presented by the blue colour.

The map allows you to determine the places of the greatest concentration of major pollutants in the vicinity of the plant.

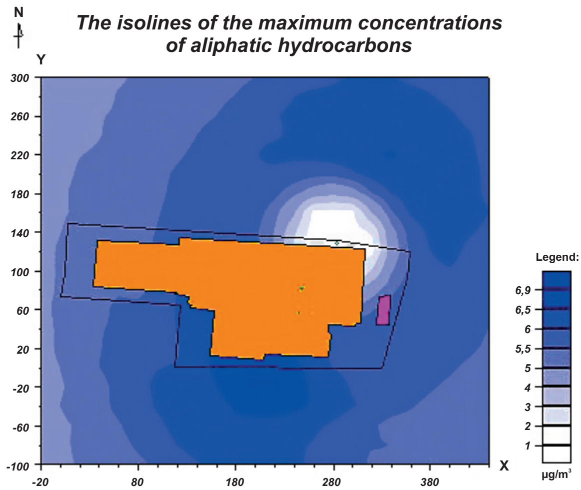

Fig. 2. The drawings present the isolines of the maximum concentrations of selected pollutants

3. Conclusion

1. The size of the concentrations of pollutants in atmospheric air is dependent on the size of the emissions.
2. An increase of the concentrations of pollutants, which are burnt by the afterburner in the event of a failure of the afterburner and adverse weather conditions, is 10 000% (assuming normal operation of afterburner for 100%).
3. The size of the concentrations of free points is the smallest at the normal operation of the afterburner, and the largest in event of the failure of the afterburner and adverse weather conditions.
4. The size of immission in a normal operation of afterburner is consistent with the values given by the Minister of the Environment. There are no reported exceedances of temporary values D1, the frequency of their exceedance and the exceedance of annual average values Da.
5. The size of immission in the event of a failure of the afterburner under normal atmospheric conditions is consistent with the specified current values given by the Minister of the Environment. It is true that there were exceedances of the permissible temporary value D1 for nitrogen oxide and styrene; however, for these concentrations, the frequency of their exceedances of 0.2% and the annual average values Da were not exceed.
6. The size of immission in the event of a failure of the afterburner during adverse weather conditions:
   a) exceeds the instantaneous values of the nitrogen oxide, benzene, xylene, styrene, toluene, and aromatic hydrocarbons, but is does not exceed the frequency

of occurrence for nitrogen oxides, benzene, xylene, toluene and aromatic hydrocarbons;
b) exceeds the permissible temporary values and the frequency of their exceedances for styrene;
c) does not exceed acceptable annual average values for any pollution.

References

[1] Regulation of the Minister of Environment of 26 January 2010 on reference values for certain substances in the air, Journal of Laws 2010, No. 16, item 87.
[2] https://en.wikipedia.org/wiki/Offset_printing#Modern_offset_printing (access: 27.04.2017).
[3] Regulation of the Minister of Environment of 4 November 2014 on emission standards for certain types of installations, combustion plants and equipment incineration or co-incineration of waste, Journal of Laws 2014, No. 0, item 1546.