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WORK SAFETY 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. 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 in 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 (LZO) przez zakład poligraficzny na stanowiskach pracy usytuowanych na wolnym powietrzu lub w budynkach sąsiadujących. Część pierwsza prezentuje charakterystykę procesu oraz materiałów wykorzystywanych do druku. W dalszej części przedstawiono wyniki modelowania emisji zanieczyszczeń w zależności od stanu pracy układu oczyszczającego (normalna praca oraz awaria dopalacza).

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

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1. Introduction

As part of this work, concentrations of pollutants in ambient air emitted during technological processes were calculated (based on the measurements of emissions of pollutants):

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) during fault conditions of the thermal afterburner and emissions of 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 unfavourable weather conditions".

The publication presents a comparison of the calculated concentrations of pollutants in the air to the limit values for specific workplaces by the applicable Ordinance of the Minister of Labour and Social Policy with the maximum concentrations of pollutants.

2. The analysis in the context of emissions of dust and gas in various operating conditions of the flue gas purification

2.1. Research object

The object of the analysed company is 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 plant area has an approximately rectangular shape with dimensions of 340×120 m. Other industrial plants outweigh in the vicinity of the plant. Wastelands, fields, meadows, groves, etc. prevail from the northern side. The nearest residential buildings (low, dispersed buildings) are located approximately 500 meters from the plant.

2.2. Emission of contaminants

Emission is the act of an operation, which involves the transfer of any element to its surroundings. Emission of contaminants to the environment involves the introduction of pollution (the products of human activity) to the environment, and in particular:

- substances (e.g. solid contaminants, liquid or gaseous contaminants),
- energy (e.g. noise, vibration, electromagnetic fields) to the air, water, soil or earth.

The definition of emission in ecological importance is given in the Act of the 27th of April 2001 on Environmental Protection Law. By emissions, legislator determines the introduction, directly or indirectly, of substances or energy, such as heat, noise, vibration and electromagnetic fields to the air, water, soil or earth as a result of human activity. Importantly, substances are chemical elements and their compounds, mixtures or solutions appearing in the environment or elements, which are the results of human activity. A hazardous substance is one or more substances or mixtures of substances, which, because of their chemical, biological or radioactive characteristics, in the event of improper handling, cause risk to the life or health of humans or the environment; a hazardous substance may be a raw material, product, intermediate waste, as well as a substance, which arises as a result of a failure.

The type and quantity of the introduced substances or energy at a given time and the concentration or levels of substances or energy, in particular in waste gases, sewage and waste generated, is defined as the amount of emissions.

In this paper, we analysed the emissions of solid, liquid and gas contaminants into the air. Emission unit is kg/h (or their derivatives – mg/s, Mg/year).

As a result of the emission of pollutants, the concentration of the pollutant increases in the air. This concentration is dependent on the amount of emissions, characteristics of the emitted gases, the emission process and mainly on the meteorological conditions. Distribution of concentrations of the contaminants in the air is called immission pollution, and the area under study – immission field. The unit of immission is $\mu g/m^3$, determined for the following conditions (temperature 293 K, pressure 101.3 kPa).

Table 1

The list of pollutants emitted into the atmosphere

No	Pollution
1	Benzene
2	Methylethylketon
3	Nitrogen dioxide
4	Sulphur dioxide
5	Ethylbenzene
6	Xylene
7	Sulphuric acid
8	entire dust
9	PM10 dust
10	PM2.5 dust
11	Styrene
12	Carbon monoxide
13	Toluene
14	aliphatic hydrocarbons
15	aromatic hydrocarbons

2.3. Types of emitted pollutants

All the pollution associated with both the functioning of the basic technological processes, as well as the auxiliary processes, were taken into account. 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.

2.4. Legal requirements relating to the issue of emerging contaminants

The permissible concentrations of pollutants on the health requirements defined in the Regulation of the Minister of Labour and Social Policy of the 6th of June 2014 on the maximum permissible concentration and intensity of harmful factors in the work environment (Journal of Laws 2014/817 of the 23rd of June 2014) according to the above Regulation pursuant to Art. 228 § 3 of the Act of the 26th of June 1974 – Labour Code (Journal of Laws of 1998. No. 21, item 94, as amended):

§ 1.1. The values of maximum concentrations of chemicals and dust of harmful factors in the work environment are specified in the list attached as Annex 1 to the Regulation.

§ 2. The values referred to in § 1.1, determine the maximum permissible concentrations of harmful factors, determined as:

1) The maximum allowable concentration (MAC) – the value weighted average concentration, the impact on the employee during an 8-hour daily and average weekly working time, as defined in the Act of the 26th of June 1974 – the Labour Code, the period of its activity should not cause negative changes in the state of health and the health of the future generations;

2) The maximum instantaneous concentration (MIC) – average value of concentration, which should not cause negative changes in the health of the worker, whether in the workplace no longer than 15 minutes and not more than 2 times during a work shift, at an interval of less than 1 hour;

3) maximum threshold concentration (MTC) – the concentration that due to the risk of health or life of the employee cannot be exceeded in the work environment at any time.

Note the differences in the definition of pollution in the environmental protection legislation and the regulations on permitted values of contamination at workplaces.

2.5. 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 impurities.

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 very bad 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 emission 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

Distribution maps of concentrations of individual pollutants (according to Polish reference methodology for performing the analysis) were made on the basis of knowledge of the emission of pollutants (developed on the basis of measurements carried out by an accredited laboratory). 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:

Working conditions in offices

Table 2

Working conditions – normal operation of afterburner

No	No*	Pollution	MAC µg/m^3	STEL µg/m^3	Maximum concentration µg/m^3	The ratio of maximum concentration to MAC
1.	1	The dust containing free silica >50 % inhalable fraction	**2 000**	---	***8,175*** **11,443**	***0,0041*** **0,0057**
2	1	The dust containing free silica >50 % respirable fraction	**300**	---	***8,175*** **11,443**	***0,0272*** **0,0381**
3	37	Benzene	**1600**	---	***1,817*** **1,650**	0,0011 **0,0010**
4	448	Styrene	**50 000**	**100 000**	***0,871*** **0,780**	***0,0001*** **0,0001**
5	67	Methylethylketon	**450 000**	**900 000**	***9,918*** **17,021**	***0,0001*** **0,0001**
6	220	Ethylbenzene	**200 000**	**400 000**	***0,919*** **0,841**	***0,0001*** **0,0001**
7	301	Xylene	**100 000**	---	***1,530*** **1,412**	***0,0001*** **0,0001**
8	479	Toluene	**100 000**	**200 000**	***1,282*** **1,174**	***0,0001*** **0,0001**
9	188	Nitrogen dioxide	**700**	**1500**	***68,840*** **157,177**	***0,0983*** **0,2245**
10	190	Sulphur dioxide	**1300**	**2700**	***8,925*** **6,902**	***0,0069*** **0,0053**
11	320	Sulphuric acid	**50**	---	***0,110*** **0,074**	***0,0022*** **0,0015**
12	475	Carbon monoxide	**23 000**	**117 000**	***202,712*** **172,499**	***0,0088*** **0,0075**
13	---	aliphatic hydrocarbons	---	---	***24,586*** **21,915**	---
14	---	aromatic hydrocarbons	---	---	***11,277*** **10,055**	---

Table 3

Operating conditions: failure of afterburner – favourable weather conditions

No	No*	Pollution	MAC µg/m^3	STEL µg/m^3	Maximum concentration µg/m^3	The ratio of maximum concentration to MAC
1.	1	The dust containing free silica >50 % inhalable fraction	**2 000**	---	***8,194*** **9,706**	***0,0041*** **0,0048**
2	1	The dust containing free silica >50 % respirable fraction	**300**	---	***8,194*** **9,706**	***0,0273*** **0,0323**
3	37	Benzene	**1600**	---	***22,951*** **16,859**	***0,0143*** **0,0105**
4	448	Styrene	**50 000**	**100 000**	***24,305*** **17,868**	***0,0005*** **0,0004**
5	67	Methylethylketon	**450 000**	**900 000**	***9,938*** **17,221**	***0,0001*** **0,0001**
6	220	Ethylobenzene	**200 000**	**400 000**	***24,337*** **17,911**	***0,0001*** **0,0001**
7	301	Xylene	**100 000**	---	***40,406*** **29,585**	***0,0004*** **0,0003**
8	479	Toluene	**100 000**	**200 000**	***34,174*** **25,020**	***0,0004*** **0,0003**
9	188	Nitrogen dioxide	**700**	**1500**	***146,415*** **236,042**	***0,2092*** **0,3372**
10	190	Sulphur dioxide	**1300**	**2700**	***10,987*** **8,799**	***0,0084*** **0,0068**
11	320	Sulphuric acid	**50**	---	***0,110*** **0,074**	***0,0022*** **0,0015**
12	475	Carbon monoxide	**23 000**	**117 000**	***210,548*** **180,460**	***0,0091*** **0,0078**
13	---	aliphatic hydrocarbons	---	---	***700,524*** **514,828**	---
14	---	aromatic hydrocarbons	---	---	***321,060*** **235,955**	---

Table 4

Operating conditions: failure of afterburner – adverse weather conditions

No	No*	Pollution	MAC µg/m^3	STEL µg/m^3	Maximum concentration µg/m^3	The ratio of maximum concentration to MAC
1.	1	The dust containing free silica >50 % inhalable fraction	**2 000**	---	*8,220* **9,709**	*0,0041* **0,0048**
2	1	The dust containing free silica >50 % respirable fraction	**300**	---	*8,220* **9,709**	*0,0274* **0,0323**
3	37	Benzene	**1600**	---	*78,976* **50,401**	*0,0494* **0,0315**
4	448	Styrene	**50 000**	**100 000**	*84,308* **53,688**	*0,0017* **0,0011**
5	67	Methylethylketon	**450 000**	**900 000**	*9,952* **17,454**	*0,0001* **0,0001**
6	220	Ethylobenzene	**200 000**	**400 000**	*84,340* **53,714**	*0,0001* **0,0001**
7	301	Xylene	**100 000**	---	*140,024* **89,177**	*0,0014* **0,0009**
8	479	Toluene	**100 000**	**200 000**	*118,450* **75,438**	*0,0012* **0,0007**
9	188	Nitrogen dioxide	**700**	**1500**	*429,360* **361,463**	*0,6134* **0,5164**
10	190	Sulphur dioxide	**1300**	**2700**	*17,298* **11,643**	*0,0133* **0,0090**
11	320	Sulphuric acid	**50**	---	*0,124* **0,086**	*0,0025* **0,0017**
12	475	Carbon monoxide	**23 000**	**117 000**	*218,732* **189,409**	*0,0095* **0,0082**
13	---	aliphatic hydrocarbons	---	---	*2430,695* **1547,808**	---
14	---	aromatic hydrocarbons	---	---	*1114,013* **709,378**	---

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

3. Conclusion

1. The amount of pollutant concentrations at workplaces (points free) is dependent on the emission of pollutants.
2. An increase in 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 the afterburner for 100%).
3. The size of the concentrations in free points is the smallest at the normal operation of the afterburner and the largest in the failure of afterburner and adverse weather conditions,
4. The volume of concentrations in free points is the lowest for the level of an area ($Z = 0$) and increases with the increasing Z and reaches maximum values at $Z = 11$ m.
5. The analysed work of the plant does not pose a threat to life and health of office workers; however during the failure of the afterburner, temporarily onerous conditions may occur, but they are not harmful.
6. It should be noted that the exposure limits for the workplace environment are about 1,000 times higher than those resulting from environmental regulations. For this reason, the STEL and TWA are expressed in mg/m^3, while the reference values are set out in the environmental protection legislation in $\mu g/m^3$.