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EMISSION AND DISPERSION OF GASEOUS POLLUTION FROM EXHAUST SHAFTS OF COPPER MINE

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The primary objective of the study was to determine the volumes of emission and dispersion of gaseous pollution from 3 exhaust shafts of a copper mine P-VII, SW-3 and SG-2. To calculate the volumes of emission and dispersion of SO_2, NO_2 and CO the KOMIN and RWW computer programs were applied. The conducted analysis of the calculations and computer simulation showed that the extent of the impact of emisson on the rural residential area situated in the nearest vicinity of the shaft site is insignificant. The observed exceedance of reference values occurred on the premises of KGHM Polska Miedź S.A. The computer simulation proved that the nature reserve 'Buczyna Jakubowska' situated 1.6 kms north-west of the nearest emitters belonging to the mine is not exposed to above-standard concentrations of SO_2, NO_2 and CO.

Keywords: exhaust shafts, gaseous pollution, emission, dispersion

1. INTRODUCTION

Business entities conducting mining activity may exert a negative impact on the environment by emitting dust and gaseous pollution and by storing the post-floatation waste [3]. The gaseous pollution is emitted into the atmospheric air are on-ground and underground installations and facilities such as: exhaust shafts, heating installations, dust exhaust and extraction installations for salt transportation, ore and salt loading facilities.The underground exploitation makes it necessary to ventilate this part of the mine. The operating ventilation system is aimed to pump in the fresh air (downcast shafts) from the outside and remove the polluted air (exhaust shafts) [5].

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The environmental impact of such a big mining and minerals processing business entity as a copper mine, built in a densely-populated agricultural area, is unavoidable and includes the following: terrain deformation in the mining area, the discharge of mineralized water from mine drainage into surface water courses, the discharge of mill waste containing heavy metal compounds, the storage of slag, post-floatation and other industrial waste in large-format waste storage facilities, the emission of gaseous and dust pollution (containing heavy metal compounds) and its impact on the neighbouring area[6].

The impact of dust fall emission from mining sources (both current and forecast) is small. The emission does not exceed the standards of air quality outside the mine's premises [12].

The pollution emitted from the ventilation systems includes dust and gases, especially sulphur dioxide, nitrogen oxides and carbon oxides. They have a particularly negative impact on the environment as they undergo numerous transformations in the air and react with water vapour to form acid rain [13].

In compliance with *the Regulation of the Minister of the Environment of 2 July 2010 on the types of installations whose exploitation requires registration (Dz.U.10.130.880)*, business entities utilizing the environment are obliged to prepare documentation on the kinds and volumes of pollution emitted into the environment.

The primary objective of this study was to determine the volumes of emission and dispersion of the gaseous pollution emitted from the exhaust shafts of the copper mine with special regard to its impact on the nature reserve 'Buczyna Jakubowska'.

2. MATERIAL AND METHODS

The installation for minerals exploration ore deposits is an underground copper ore mine.

The following exhaust shafts were evaluated: P-VII, SW-3 and SG-2 located respectively in the communes of Polkowice, Radwanice and at the border of Radwanice and Jerzmanowa communes:

– the P-VII shaft: located in the P-VII region, has an on-ground ventilation station equipped with 4 radial fans WPK-3.9. The air is removed from the ventilators by means of individual diffusers with the outlet dimensions of 3.9 m x 6.0 m (the equivalent diameter dz = 5.46 m) and the height of 12 m above ground level. During normal operation 3 of the 4 ventilators are in operation and the fourth one is on standby as required by the law. - the SW-3 shaft: located in the SW-3 region, with an on-ground ventilation station equipped with 6 radial fans WPG-278/1.8 with the rated output of 850 m3/s each. The ventilators are connected in pairs to three diffusers with the height of 23.2 m AGL and the outlet dimensions of 11.5 m x 6.5 m (dz = 9.76 m). During normal operation 4 ventilators are in operation and the remaining two are on standby as required by the law. - the SG-2 shaft: located in the region of Sieroszowice Główne (SG), with an on-ground ventilation station equipped with 4 axial fans GAF38/24-1W with the rated output of 400 m3/s each. The ventilators are connected to individual diffusers with the outlet at the height of 36.3 m and the effective cross section of S = 46.6 m2 (dz = 7.7 m) (there are ceramic-coated silencers installed inside the diffusers). During normal operation 3 ventilators are in operation and the fourth one is on standby as required by the law. The volumes of the gaseous pollution emitted into the air was determined on the basis of measurements taken with automatic measuring systems.

The calculations of the volumes of emission from the ventilation shafts and the modelling of SO_2, NO_2 i CO dispersion in the atmospheric air was done in compliance with the referential methodology specified in the Regulation of the Minister of the Environment of 26 January 2010 on the reference values for certain substances in the air [11].

The reference values for

SO_2 350 μg/m^3 for one hour and 20 μg/m3 for a calendar year,
NO_2 200 μg/m^3 for one hour and 40 μg/m3 for a calendar year,
CO 30000 μg/m^3 for one hour.

The following assumptions were used for calculations:

– the aerodynamic terrain roughness – z 0 [m]

P-VII	SW-3	SG-2
0.53	0.63	1.09

– height of emitters

P-VII	SW-3	SG-2
12.0	23.3	36.3

– ambient temperature

The average annual temperature in Poland ranges between 7 and 9 °C.
For the calculations 8 °C (281 K) was assumed.

– temperature of exhaust gases

As temperature of exhaust gases 25 °C (298 K) was assumed.

– parameters of exhaust shafts

Table 1. collates the calculation results obtained with the Komin program

Emission sources	Emitter symbol	Height of emitter [m]	Equivalent diameter [m]	Gas temperature [K]	Average annual ambient temp [K]
Exhaust shaft P-VII	P-VII/E1	12.0	5.46	298	281
	P-VII/E2	12.0	5.46	298	281
	P-VII/E3	12.0	5.46	298	281
	P-VII/E4	12.0	5.46	298	281
Exhaust shaft SW-3	SW-3/E1	23.3	9.76	298	281
	SW-3/E2	23.3	9.76	298	281
	SW-3/E3	23.3	9.76	298	281
Exhaust shaft SG-2	SG-2/E1	36.3	7.7	298	281
	SG-2/E2	36.3	7.7	298	281
	SG-2/E3	36.3	7.7	298	281
	SG-2/E4	36.3	7.7	298	281

The calculations of the volumes of emission of gaseous pollution into the air were done in 2012 on the basis of measurements of concentrations taken with automatic measuring systems in the collector ducts situated before the ventilation stations for each of the exhaust shafts.

The calculations of the volumes of emission from the ventilation shafts and the modelling of SO_2, NO_2 i CO dispersion in the atmospheric air was done in compliance with the referential methodology specified in the Regulation of the Minister of the Environment of 26 January 2010 on the reference values for certain substances in the air [11].

3. RESULTS AND DISCUSSION

Table 1. Emissions of SO2, NO2, CO from exhaust shaft.

Shaft name	Pollution type	Smm [µg/m3]	Maximum of average annual concentrations [µg/m3]	Maximum of 1-hour concentrations [µg/m3]	Maximum of percentile S99.8 [µg/m3]	Maximum of percentile S99.726 [µg/m3]
P	SO_2	0.225	0.045	1.125	-	0.784

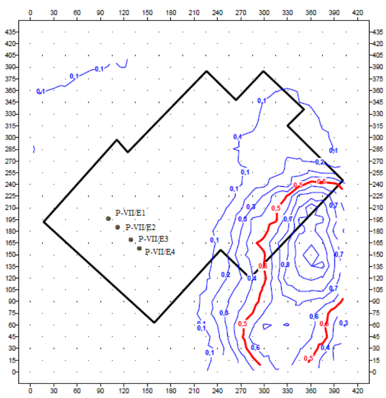
	NO_2	13.507	2.701	67.511	47.053	-
	CO	16.884	3.376	84.388	58.817	-
SW-3	SO_2	1.668	0.089	8.383	-	4.153
	NO_2	24.602	1.309	123.644	61.250	-
	CO	14.178	0.755	71.253	35.296	-
SG-2	SO_2	2.111	1.656	323.029	-	45.925
	NO_2	40.820	32.010	6 245.229	887.889	-
	CO	17.595	17.595	2 691.909	382.711	-

The analysis of the above data shows that the lowest values of SO_2 concentrations calculated for Smm, of maximum average annual and 1-hour concentrations were for the shaft P-VII. The highest values of SO_2 concentrations calculated for Smm, of maximum average annual and 1-hour concentrations were for the shaft SG-2. The lowest values of NO_2 emission calculated for Smm, of maximum average annual and 1-hour concentrations were also for the shaft P-VII, and the highest for the shaft SG-2. The Smm values of maximum average annual and 1-hour concentrations of emitted CO were the lowest for the shaft SW-3, and the highest for the shaft SG-2.

3.1. The distribution of contour lines for the shaft P-VII

Figures 1-5 present the distribution of the contour lines illustrating the dispersion of the analyzed pollution from the ventilation shafts only when the reference values were exceeded.

The only pollution exceeding the threshold values within the area of the shaft P-VII is nitrogen dioxide.



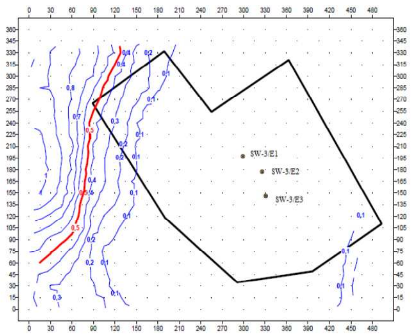
Source: author's calculations

Fig. 1. The incidence of reference value exceedance for NO_2 for a calendar year [%]

The distribution of the contour lines of NO_2 emittions into the atmospheric air shows that it disperses eastward of the four emitters P-VII/E1, P-VII/E2, P-VII/E3 and P-VII/E4. The contour lines cover the area of the shaft P-VII and go beyond that area. The red contour line represents the exceeded value. The threshold value is exceeded in the east part of the P-VII region and that exceedance disperses beyond its boundary in a southward direction (Fig.1). The exceeded levels of NO_2 pollution do not have a negative impact on the nearest residential area as it is situated approx. 400 metres north-west of the region.

The shaft SW-3

The only pollution exceeding the threshold values within the area of the shaft SW-3 is nitrogen dioxide.



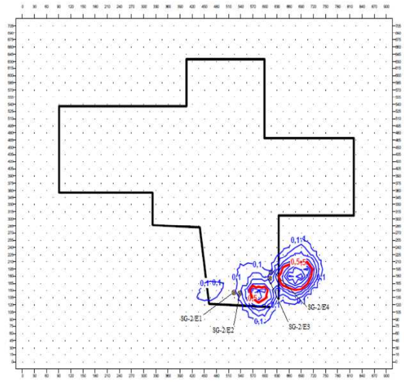
Source: author's calculations

Fig. 2. The incidence of reference value exceedance for NO_2 for a calendar year [%]

The distribution of the contour lines of NO_2 emissions into the atmospheric air shows that it disperses westward of the three emitters SW-3/E1, SW-3/E2 and SW-3/E3. The contour lines cover the area of the shaft SW-3 and go beyond it. The red contour line represents the exceeded value. The permissible value is exceeded in the west part of the region and has a minor impact on the shaft region (Fig. 2). However, it disperses over the whole of the west part, from north to south. The reference values are exceeded in the west part of the region and go 50 metres beyond that area, to which the copper mine holds a legal title. The nearest residential area is the village of Sieroszowice, situated 1.5 km south-west of the shaft site, so the excessive NO2 pollution will not have a negative impact on it.

The shaft SG-2

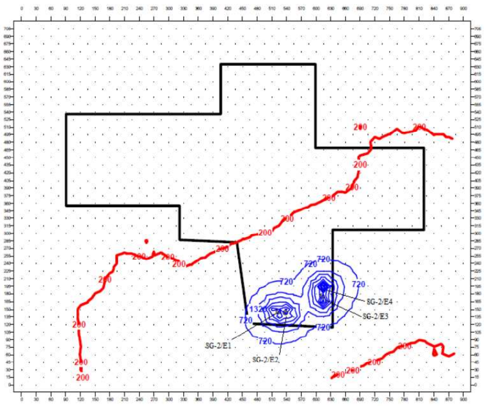
Within the area of the shaft SG-2 the threshold values of SO_2 and NO_2 pollution were exceeded.



Source: author's calculations

Fig. 3. The incidence of reference value exceedance for SO_2 for a calendar year [%]

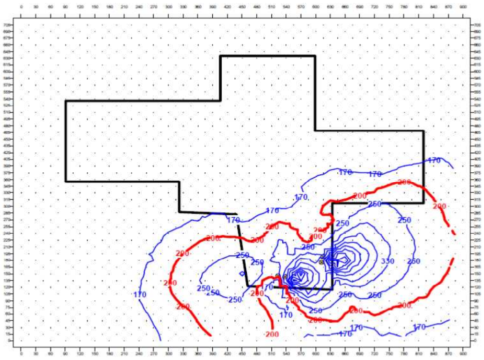
The distribution of the contour lines of sulphur dioxide emissions into the atmospheric air from the emitters SG-2/E1 and SG-2/E2, situated in the south of the SG region, disperses over a short distance in an eastward direction. The contour lines above the emitters SG-2/E3 and SG-2/E4, situated in the south-east of the region, show the same direction. The plumes cumulate tightly in the south-east. The reference values for SO_2 concentrations are exceeded in the south of the SG region and about 100 metres beyond its area (Fig. 3). North and north-east of the shaft site, beyond a belt of cultivated land, at a distance of approx. 1.5 km, lies a compact residential area of the villages Jakubów and Maniów Górny.



Source: author's calculations

Fig. 4. The distribution of the contour lines of NO2 dispersion
for a maximum 1-hour concentration

The distribution of the contour lines of nitrogen dioxide emissions into the atmospheric air shows that it cumulates in the south of the region, reaching about 60 metres beyond it. The red contour lines represent the exceeded maximum 1-hour concentrations of NO2. The exceedance occurred south-east of the SG area, where there is a large forest complex. The contour line representing the exceeded reference values shows that the plume disperses from south-west up to north-east. It covers part of the SG region, the adjacent cultivated land and the forest area in the south. The exceeded levels of the maximum 1-hour concentration should not have a negative impact on the rural residential area as it is situated 1.5 km north-east of the SG region.



Source: author's calculations

Fig. 5. The maximum of percentile S99.8 for NO2

Fig. 5 presents the dispersion of the plume of the emitted nitrogen dioxide for the maximum of percentile S99.8. The red contour lines represent high incidence of the reference value exceedance. The pollution disperses in a southward and eastward direction. It covers the south part of the SG area so it may have a negative impact on the nearby forest complex.

4. SUMMARY AND CONCLUSIONS

The applied computer program KOMIN allowed for a precise and reliable calculations of the volumes of emission of gaseous pollution (sulphur dioxide, nitrogen dioxide and carbon monoxide) from the exhaust shafts of a copper mine. The extent of the impact of the analyzed pollution was determined with the sue of the Rww program, which generated readable and clear images of pollution dispersion. The conducted analysis of calculation results and computer simulations that mining complexes emit gaseous pollution that may be an environmental hazard.

The exhaust shafts are the source of organized emission of gaseous pollution (sulphur dioxides, nitrogen dioxides and carbon oxides) into the air, which then react with other compounds present in the atmosphere. The products of these transformations may have a negative impact on the environment intensifying the acid rain effect or increasing the effect of ozonesphere destruction.

The few sources of unorganized emission present on the mining complex make a minor contribution to the environment pollution. The result analysis showed that the reference values were exceeded at the shaft SG-2, and the exceedance concerned the maximum 1-hour concentrations of NO2. For other analyzed pollutions (SO2 and CO) the permissible values were not exceeded.

The extent of dispersion of the emitted pollution is relatively small with the exception of the shaft SG-2, which exerts a limited impact on an area to which the mine does not holds a legal title. The emission of sulphur dioxide, nitrogen dioxide and carbon monoxide pollution is unavoidable resulting from the continuous operations of the mine. By implementing environmental measures the emission can be reduced, thus minimizing its negative impact on the natural environment.

The following conclusions can be drawn from the conducted analysis:

1. Every business entity that generates pollution should prepare an environmental impact assessment, a reliable document allowing one to determine the level of noxiousness.
2. The use of the computer programs KOMIN i Rww allowed for a precise determination of the volumes of the emitted gaseous pollution (SO2, NO2 and CO) and accurate imaging of the impact area.
3. The impact of the emission of sulphur dioxide, nitrogen dioxide and carbon monoxide pollution on the residential area situated in the nearest vicinity of the shaft site is insignificant. Whenever the standards of air quality are violated, it is only in an area being the property of the mine and in a limited bordering area.
4. The computer simulation proved that the nature reserve 'Buczyna Jakubowska' is not exposed to above-standard concentrations of SO_2, NO_2 and CO.

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9. Rozporządzenie Ministra Środowiska z dnia 2 lipca 2010 w sprawie przypadków, w których wprowadzanie gazów lub pyłów do powietrza z instalacji nie wymaga pozwolenia (Dz.U.10.130.881).
10. Rozporządzenie Ministra Środowiska z dnia 2 lipca 2010 r. w sprawie rodzajów instalacji, których eksploatacja wymaga zgłoszenia (Dz.U.10.130.880).
11. Rozporządzenie Ministra Środowiska z dnia 26 stycznia 2010 r. w sprawie wartości odniesienia dla niektórych substancji w powietrzu (Dz.U. Nr 16/2010, poz. 87).
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EMISJA I DYSPERSJA ZANIECZYSZCZEŃ GAZOWYCH Z SZYBÓW WYDECHOWYCH KOPALNI MIEDZI

S t r e s z c z e n i e

Podstawowym celem pracy jest określenie wielkości emisji i dyspersji zanieczyszczeń gazowych z 3. szybów wydechowych kopalni miedzi P-VII, SW-3 i SG-2. Do obliczeń wielkości emisji i dyspersji SO_2, NO_2 i CO wykorzystano program komputerowy KOMIN oraz Rww. Analiza wyników obliczeń i symulacji komputerowej pokazała, że zasięg oddziaływania emisji na zabudowę wiejską znajdującą się w najbliższych odległościach od rejonów szybów jest znikomy. Stwierdzone przekroczenia wartości dopuszczalnych znajdowały się na terenie należącym do KGHM Polska Miedź S.A. Symulacja komputerowa wykazała, że Rezerwat przyrody ,,Buczyna Jakubowska'' leżący 1,6 km na północny-zachód od najbliższych emitorów rejonu kopalni nie jest narażony na ponadnormatywne stężenia SO_2, NO_2 oraz CO.