

## Epidemiology of Selected Diseases Related to Air Pollution in Krakow

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### ABSTRACT

Excessive concentrations of smog toxicants constitute a critical factor influencing the health quality of inhabitants of urban agglomerations. The exposure to elevated concentrations of suspended particulate matter, sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>) and carbon monoxide (CO) is associated with an increase of adverse health effects. Prolonged exposure to air pollution, especially from low emission, may be linked not only to a greater risk of developing cancer of the respiratory system, or cardiovascular morbidity but also to the increased frequency of admissions to hospitals and emergency units as well as medical consultations in surgeries and outpatient clinics. The issue was investigated using the city of Cracow as an example. Attempts were made to find the connection between air pollution in the city of Cracow and the frequency of hospitalization and medical consultations of patients (registered in the city) due to lung and bronchial malignancy and cardiac dysrhythmia taking into account the data from the years 2010–2016 submitted by the Malopolska Regional Branch of the National Health Fund.

**Keywords:** air pollution, smog, low emission, morbidity

### INTRODUCTION

Air pollutants monitoring, conducted in terms of assessing their harmfulness to human health in accordance with the EU and national regulations, includes the emission of 11 substances [Holnicki et al. 2014]. The study analyzes four selected substances which are especially prevalent in the Cracow agglomeration: suspended particulate matter (PM<sub>10</sub>, PM<sub>2.5</sub>), sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>) and carbon monoxide (CO). Particular attention is paid to the threats arising from the emission of suspended particulate matter due to the fact that its concentration levels show the highest values among the four aforementioned toxicants and for this reason they arise public interest. For the conducted analyses, the basic thesis is that air polluted with low emission products poses a potential threat to the health of users and city dwellers. The low-emission sources such as urban transport and other transport pollution, the heating system of detached houses based on the combustion of coal and municipal waste, or lo-

cal boiler rooms, rather than cogeneration plants, steel plants or other industrial plants, are the main source of air pollution in urban agglomerations [Bagieński and Jaskulska 2016; Report 2010; Petryk 2017a; Petryk 2017b]. This is related to the fact that the emission of pollutants from large industrial, heating, energy and transport sources is subject to numerous legal acts and to strict control, contrary to the uncontrolled practice of burning fuels and waste in household furnaces, which, however, is gradually normalizing [Juda-Rezler 2016]. For this reason, the emission of pollutants from low sources (so-called low emission) has a greater influence on air quality at the ground level of the atmosphere where fuels of low quality are often burnt, rather than from high sources (steel plants, cogeneration plants, etc.) where the quality of fuels used is incomparably higher, and in addition they are obligatorily equipped with high efficiency dust collectors [Juda-Rezler 2016]. In Poland, the most commonly used device for heating detached houses “is a boiler or coal furnace, less often a fireplace or a boiler fu-

elled with wood or pallets or other types of biomass, whereas gas, oil boilers or electric heating are the rarest" [Degórska 2016]. The sources of low emission show multiple variations, depending on the chemical composition of pollutants and their emission intensity as well as the technical conditions of the emitter (height, diameter, etc.) [Juda-Rezler 2000].

## SOURCES AND IMPACT OF AIR POLLUTANTS ON HUMAN HEALTH

The analysis of the related literature does not cast any doubt that the occurrence of some diseases is directly or at least indirectly associated with the pathogenic exposure to air pollution, especially in urban agglomerations. The relationship between the air pollutants and their impact on the health of inhabitants of urban agglomerations, especially metropolitan cities, concerns not only the morbidity of respiratory and immune system diseases or neurological symptoms, but also the prevalence of prematurity, spontaneous abortion, low birth weight and birth defects of newborns that lower their intellectual and immunological potential in subsequent developmental stages [Report on the state of health 2011].

Low emission of suspended particulate matter from the sources of municipal and household sector as well as from the so-called secondary emission related to the negligence of city cleanliness and the growing intensity of car transport is a real problem in Polish cities [Wnuka 2010]. Suspended particulate matter has its toxic impact on significant areas due to its cross-border nature caused by meteorological factors that may stimulate the spread of pollutants by air or restrict air ventilation in rural and urbanized areas [Kozłowska et al. 2011; Wnuka 2010]. Primary particulate matter emission comes from natural and anthropogenic sources, while the particulate matter generated as a result of chemical reactions becomes a secondary toxicant in the atmospheric air [Degórska 2016].

The number of research projects in which confirmation or exclusion of dependence between high concentrations of suspended particulate matter and the higher number diagnoses of specific diseases in people susceptible to short or long-term exposure to these toxicants is increasing. Among the effects of short-term exposure to the

absorption of higher concentrations of suspended particulate matter by the body, acute responses of the respiratory system were found in individual age categories. Long-term exposure, even to relatively low concentrations of particulate matter, over many years leads to the development of chronic diseases, including cancer, especially lung cancer, as confirmed by the International Agency for Research on Cancer (IARC) [Skotak 2016].

The prenatal and perinatal exposure to toxic effects of suspended particulate matter may lead to fetal development disorders and cause perinatal complications; it also poses a higher risk of developing allergies, diabetes, asthma, nervous system diseases, etc. in a child's adult life [Skotak 2016]. The risk of recurrent pneumonia is even three times higher in the children whose mothers were exposed to high levels of PM<sub>2.5</sub> during pregnancy [Warczyński 2016]. In etiopathogenesis of diseases, both the finest particulate matter fractions and the concentration of its individual constituent substances can be critical. It is believed that it is the content of hydrocarbons or transition metals exert more influence on the development of asthma than the total concentration of particulate matter [Jędrak, Badyda and Konduracka 2016]. Physical activity, which intensifies lung ventilation, exposes the people doing sport under the conditions of higher particulate matter concentration to the inhalation of higher content of the toxicant [Malec and Borowski 2016]. There is no safe level of concentration below which there are no adverse health effects of exposure to this toxicant [Skotak 2016].

The number of medical consultations as well as absenteeism in schools and workplaces rises when the concentration of suspended particulate is relatively low. Higher concentrations may determine the increase in the number of people being hospitalized as well as in the number of deaths [Skotak 2016]. Every year in Poland, more than fifteen times more people die from the diseases related to air pollution than from road accidents. This is estimated at forty-five thousand people a year [Warczyński 2016].

Black smog occurring in industrial areas in the winter is particularly dangerous for human health [Juda-Rezler 2000] due to the high concentrations of sulphur dioxide. Sulphur dioxide (SO<sub>2</sub>) of anthropogenic origin is emitted from municipal and household sources, and above all from the energy and industrial sources associated with

the extraction, processing and combustion of fossil fuels, in particular, hard coal in Poland [Kordylewski 2008]. Exposure to high concentrations of the colourless gas characterized by a choking odour is fraught with a high risk of airway damage [Kostrz and Satora 2017].

In the case of nitrogen dioxide ( $\text{NO}_2$ ), there is an upward trend in its anthropogenic emission from urban transport sources, with a noticeable reduction in the production of nitrogen oxides in the energy industry [Juda-Rezler 2000]. On the one hand, this is due to the increasing share of cars in urban transport, on the other, it results from the use of modern technologies in the power industry [Juda-Rezler 2000]. Exhaust fumes constitute the main source of carbon monoxide (CO) emission although combustion of fuels in the municipal and household sector, accounting for nearly 50% of its national emissions plays also a significant role [Zakrzewski 1995; Juda-Rezler 2000; Hławiczka 2008].

## AIR POLLUTION IN CRACOW

Road transport is a critical source of particulate matter emission. Not only is the dust caused by the combustion of fuels in car engines, but also by the wear of brake pads and the abrasion of tires and road surfaces, including re-suspension, i.e. re-lifting of road dust during road traffic [Degórska 2016]. According to the data of the Department of Municipal Economy and Environmental Protection of the Municipal Office of Cracow, collected on the basis of vehicular traffic measurements, approximately 40,000 vehicles pass through Cracow through transit traffic every day, and the total number of people entering the city daily amounts to 246 thousand. The most traffic-laden are: Kościuszko barrage, the Dębnicki

Bridge, as well as ul. Wielicka and Zakopiańska [“Gazeta Krakowska” 2017].

It was estimated that several hundred people die due to air pollution in Cracow per year. “The average number of avoidable deaths per year was estimated for 2001 in relation to the level of pollution reduction (average annual  $\text{PM}_{2.5}$ ). The reduction to the level of  $25 \mu\text{g}/\text{m}^3$  would decrease the number of deaths on average by 232, to the level of  $20 \mu\text{g}/\text{m}^3$  by 362, to the level of  $15 \mu\text{g}/\text{m}^3$  by 492, and to the level of  $10 \mu\text{g}/\text{m}^3$  (WHO recommendation) by 612. In addition, it was estimated that a statistical resident of Cracow would live one year longer, on average, if the mean annual concentration of particulate matter  $\text{PM}_{2.5}$  could be reduced to  $15 \mu\text{g}/\text{m}^3$ ” [bip.malopolska.pl 2017].

The data from the Krakow Smog Alert indicated that the daily dose of benzo[*a*]pyrene absorbed by residents of Krakow during the year 2011 corresponded to the smoking an average of seven cigarettes [Pankowska, Gorczyca 2015].

The measurements carried out in the air quality control stations at the main communication routes in Cracow showed that the permissible level of  $\text{PM}_{10}$  particulate matter concentration had been exceeded in the years 2010–2015 (Table 1). Despite the exceedance of standards, a decrease in the concentration of average annual  $\text{PM}_{10}$  in the analyzed five-year period was observed at all measuring points.

In the same period, the values of average annual  $\text{PM}_{2.5}$  concentration also exceeded the permissible standards (Table 2). As in the case of  $\text{PM}_{10}$ , a downward trend of  $\text{PM}_{2.5}$  concentrations was noticeable in the years 2011–2015. In 2016, in the Cracow agglomeration, more than 35 exceedances of the permissible standard of  $\text{PM}_{10}$  concentrations were observed at all monitoring stations within 24-hour period (Table 3).

**Table 1.** The concentration of average annual  $\text{PM}_{10}$  at air quality monitoring stations in Cracow in the years 2011–2015

Location of the measuring station	Concentration of average annual $\text{PM}_{10}$ [ $\mu\text{g}/\text{m}^3$ ]				
	Permissible level (since 2005) $40 \mu\text{g}/\text{m}^3$				
	2011	2012	2013	2014	2015
Ul. Bujakowa	54	53	44	46	45
Ul. Bulwarowa	77	66	60	64	68
Al. Krasińskiego	63	51	49	49	52

Source: Prepared on the basis of: Annex No. 1 to Resolution No. XXXII / 451/17 of the Regional Assembly of the Malopolska Region of 23 January 2017.

**Table 2.** The concentration of average annual PM 2.5 at air quality monitoring stations in Cracow in the years 2011–2015

Location of the measuring station	Concentration of average annual PM 2.5 [ $\mu\text{g}/\text{m}^3$ ]				
	Permissible level (since 2005): $25 \mu\text{g}/\text{m}^3$ , (since 2020): $25 \mu\text{g}/\text{m}^3$				
	2011	2012	2013	2014	2015
Ul. Bujakowa	37	41	33	33	34
Ul. Bulwarowa	42	38	35	32	33
Al. Krasińskiego	55	47	44	45	44

Source: Prepared on the basis of: Annex No. 1 to Resolution No. XXXII / 451/17 of the Regional Assembly of the Malopolska Region of 23 January 2017.

**Table 3.** List of stations in the area of the Agglomeration of Cracow in 2016 in which there were more than 35 exceedances of levels of permissible concentrations of PM10 – an average of 24 hours (D24) and the number of cases of exceedances at individual stations (health protection)

Zone name	Station code	Number of exceedances D24	The maximum daily concentration value * $\mu\text{g}/\text{m}^3$
The Agglomeration of Cracow	Aleje Krasickiego	165	329
	Ul. Bujaka	78	295
	Ul. Bulwarowa	74	275
	Ul. Dietla	118	314
	Os. Piastów	69	203
	Złoty Róg	85	231

\* The number of stations from which the results were used in the assessment for 2016

Source: own study based on the Air quality assessment in zones in Poland for 2016

## AIR POLLUTION AND INCIDENCES OF THE RESPIRATORY SYSTEM CANCERS, BRONCHI AND LUNGS CANCERS AS WELL AS CARDIAC DYSRHYTHMIA IN CRACOW

Malignancies caused by environmental pollution, mainly air pollution, constitute nearly 2% of the diagnosed malignancies, although this index is even higher in the populations of the Małopolskie and Silesia region [Kapka et al. 2009]. In the urban population, lung cancer is diagnosed more often than in the rural population [Gładka and Zatoński 2016]. In the population of Cracow, this risk increases by 4.5% in the male group and 10.5% in the female group [Kapka et al. 2009]. Air pollution is a critical factor in the development of lung cancer, which is second only to smoking [Gładka and Zatoński 2016, Gładysz et al. 2010]. It is believed that the abnormal concentration of nitrogen dioxide has the largest pathogenic impact on the occurrence of lung cancer [Gładka and Zatoński 2016]. People exposed to prolonged exposure of suspended particulate matter in the air are also highly susceptible due to the fact that the period of lung cancer development under the conditions of intense particulate matter exposure is by four

years shorter than in the case of other carcinogenic substances that pollute the air [Cembrzyńska and in 2012]. Household stoves, in which plastic wastes are burnt, are one of the main emitters of toxicants with a mutagenic and cytotoxic effect [Jędrak et al. 2016].

In the years 2010–2016, men comprised the largest group of the patients treated for malignancy in Cracow; in hospital wards, inpatient emergency departments and admission rooms, the share of men accounted for 62% of the total number of patients treated, while in outpatient clinics it amounted to 60% of the total number of consulted patients (Table 4). Analyzing the diversity of the age structure, it should be stated that men dominated in all age categories. In the years 2011, 2012, 2015 and 2016, no female in the age range of 0–34 applied for treatment in hospital wards, inpatient emergency departments and admission rooms, whereas in outpatient clinics such a situation occurred in 2016. In the male group, the patients in the age range of 0–34 were not treated in hospital wards and in admission rooms in the years 2014 and 2016. There was a noticeable disproportion, both in the female and male group between the number of people in the age range of 0–34 and the total number of people ben-

**Table 4.** List of patients by sex and age living Cracow treated in the years 2010–2016 for the respiratory system cancers, bronchial and lung malignancy

Name of the disease entity	Year	Total number of medical services	Hospital departments with the inpatient emergency departments and the admission room								Outpatient specialist care clinics contracted by Krakow's hospitals							
			age 0–34		age 35–64		age 65+		age O+		age 0–34		age 35–64		age 65+		age O+	
			M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
C-34 (Bronchial and lung malignancy)	2010	4684	2	1	127	67	209	94	338	162	2	2	234	165	352	174	588	341
	2011	4704	1	0	135	69	193	105	329	174	1	2	218	162	353	188	572	352
	2012	5495	2	0	124	67	210	115	336	182	4	2	229	163	366	215	599	380
	2013	5232	1	2	100	80	190	120	291	202	1	2	219	181	371	228	591	411
	2014	5443	0	1	96	74	230	144	326	219	2	3	200	157	402	266	604	426
	2015	5246	2	0	96	70	202	127	300	197	2	1	194	157	406	271	602	429
	2016	5697	0	0	92	65	217	161	309	226	1	0	177	137	430	322	608	459

Source: Own study based on data from the *Malopolska* Provincial Branch of the *National Health Fund* in Krakow obtained applying the public information act (correspondence of 6 July 2017).

efiting from medical services from the other two age ranges of 35–64 and 65+. The morbidity of bronchial and lung malignancies then mainly affected the people over 35 years of age, with a significant predominance of male patients; however, the highest morbidity rate was revealed in people over 65 years of age. In the years 2010–2016, the percentage share of male patients in the age range of 0–34 in the group of all male patients treated for malignant lung cancer and bronchial carcinoma in hospital wards and admission rooms amounted to 0.36%, whereas in outpatient clinics to 0.31%. On the other hand, the percentage share of men in the age range of 65+ treated in the analyzed six-year period in hospital wards and admission rooms accounted for 65%, and in outpatient clinics 64%.

Analyzing the number of medical services provided to patients with bronchial and lung cancer in the reporting period, it should be noted that in comparison to 2010, by 2016 the number of benefits had increased by 1013. In the years 2010–2012, there was an upward trend, which in the next three years was at constant level. Since 2015, there has been a visible, dynamic increase in the number of medical services (Table 4).

The research confirmed that even a short-term exposure to suspended particulate matter may cause electrophysiological changes in the heart that result in cardiac dysrhythmia and intensify susceptibility to this type of heart anomalies [Kowalska and Kocot 2016]. In addition to cardiac dysrhythmia, the consequences of being exposed to air pollution in various time ranges, especially to suspended particulate matter and carbon dioxide, are also indicated by cardiac insufficiency and ischemic heart disease [Kowalska

and Krzych 2007; Malec and Borowski 2016]. Obese and older people (over 65 years of age), patients treated for obstructive pulmonary disease or diabetes, and those with chronic respiratory and cardiovascular diseases are listed in the high-risk group [Jędrak et al. 2016 Kowalska and Kocot 2016]. A long-term exposure to low-emission toxicants is also a pathogenic factor of the inflammatory system in young healthy people [Annex No. 1 to Resolution No. XXXII/451/17 of the Regional Assembly of the *Malopolska* Region of 23 January 2017]. Excessive concentrations of smog toxicants may be responsible for a larger number of urgent hospitalizations caused by the onset or exacerbation of cardiovascular disease symptoms [Kowalska and Krzych 2007]. “It was also proven that the increase in the concentration of PM<sub>2.5</sub> by only 10 $\mu$ g/m<sup>3</sup> in a short time (<24 hours) r the relative risk of cardiovascular deaths from 0.4% to 1.0%” [Jędrak, Badyda and Konduracka 2016].

In the period from 2010 to 2016 (Table 5), women constituted the largest group of patients treated in Cracow due to dysrhythmias in both hospital wards, inpatient emergency departments and admission rooms (65% of total patients), as well as in outpatient clinics (69%). In the distribution of the age structure, there was a strong dominance of women in all age ranges. In the group of men treated in hospital wards, inpatient emergency departments and in admission rooms, patients over 65 comprised the largest group (37%). In turn, in the group of men treated in outpatient clinics, the majority of patients were in the age range of 0–34 (48%). A small number of men aged 65+ who had medical consultations due to heart rhythm disorders in outpatient clinics (15%) was evident.

**Table 5.** List of patients by sex and age living Cracow treated in the years 2010–2016 for cardiac dysrhythmia

Name of the disease entity	Year	Total number of medical services	Hospital departments with the inpatient emergency departments and the admission room								Outpatient specialist care clinics contracted by Krakow's hospitals							
			age 0-34		age 35-64		age 65+		age O+		age 0-34		age 35-64		age 65+		age O+	
			M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
R00 (cardiac arrhythmia)	2010	414	18	19	14	35	13	32	45	86	25	54	21	60	2	17	48	131
	2011	388	20	32	18	42	16	37	54	111	25	33	10	56	7	14	42	103
	2012	457	17	33	23	42	30	54	70	129	32	39	16	52	5	15	53	106
	2013	587	37	48	34	84	37	58	108	190	27	38	14	61	9	22	50	121
	2014	590	35	50	42	70	45	69	122	189	32	47	26	65	11	15	69	127
	2015	683	35	53	43	116	44	87	122	256	22	43	28	76	9	22	59	141
	2016	611	37	67	30	70	53	76	120	213	24	31	28	71	17	32	69	134

Source: Own study based on data from the *Malopolska* Provincial Branch of the *National Health Fund* in Krakow obtained applying the public information act (correspondence of 6 July 2017).

Among the women subject to treatment in hospital wards and admission rooms, female patients in the age range of 35–64 comprised the largest group (39%); a similar trend was in outpatient clinics (51%). In the analyzed six-year period, a relatively constant upward tendency in the number of medical services provided to the patients with arrhythmias was noticed. In 2016, the number increased by 197 services compared to 2010.

## CONCLUSIONS

1. In the years 2010–2016, men constituted the largest group of patients treated for malignancy in Cracow. The morbidity of lung and bronchial malignancy mainly concerned the people over 35 years of age, with a significant majority of male patients. The highest morbidity was found in people over 65 years of age.
2. In the period from 2010 to 2016, women constituted the largest group of patients treated for dysrhythmias. In the distribution of the age structure, strong dominance of women in all age ranges was visible at that time.
3. The latest literature data show that the human exposure to suspended particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>), sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>) and carbon monoxide (CO) is associated with an increased risk of cardiac arrhythmia, lung and bronchial malignancy as well as asthma.
4. The analysis of the state of air pollution: PM<sub>10</sub> and PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, CO showed that there were unfavorable weather conditions in the city of Cracow, resulting in long-term excessive concentrations of low-emission toxicants.

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