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Letter to Editor

Evaluation of Atmospheric Dust Pollution in the Lublin Area

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Abstract

In this paper some of the more important properties of aerosols and their influence on the human organism are described. Sample results of measurements of the pollution with airborne particulate matter, conducted in Lublin (March and April 1999) and Kozlowka (June 1999) are presented. Measurements of the imission of airborne particulate matter were carried out with a GRIMM 1.105 apparatus for two chosen fractions of solid phase dispersion, i.e. PMio (solid phase radius is smaller or equal to 10 μ^i) and AP (radius of solid phase particles which are easily deposited in alveoli. See Figure 1).

Keywords: airborne particulate matter, PM-10, dust pollution, GRIMM 1.105

Introduction

A system of small particles or liquid droplets suspended in a gaseous phase is called an aerosol. In spite of the microscopic size of aerosols, their presence in the air is discernible because they give a hazy appearance to distant objects. The fact that aerosols are easily perceived means that dust and smoke have been written about since classical times. Early writers leave us in no doubt that they regarded them as undesirable. They were considered detrimental to health and annoying because they discoloured buildings and lowered visibility.

There are two main sources of fine particles in the atmosphere: primary particulate material, which is directly derived from the dispersal of materials from the Earth's surface, and secondary particulate material, which forms as a result of chemical reactions in the atmosphere.

The chemical composition of an aerosol at any given time and location is a product of its sources and the kind of chemical changes it has undergone. The water-insoluble components of the aerosol, although not immune to change, are more resistant than the soluble component. Maritime aerosols are dominated by the presence of sea salt but they can be modified. Continental aerosols are more likely to be dominated by dust (predominantly silica, aluminum and iron compounds). Organic compounds are also found as atmospheric aerosols. The ether-soluble compounds detected include organic acid and bases, phenols and aliphatic and aromatic hydrocarbons.

An important source of particles is the suspension of dust from relatively dry rural areas, where concentrations of almost one milligram of solid per cubic meter of air may sometimes be found. This is roughly an order of magnitude higher than those found in city air.

The influence of aerosols on human organisms depends on their chemical composition, size of particulate matter and on the kind of substances adsorbed on their surfaces. Three destructive ways of an aerosol action on humans may be distinguished, namely: through the skin, alimentary canal and respiratory system [1, 2]. Since the human respiratory system has a large surface of the order of 100 m^2, through which about 20 m^3 of air pass per day, this system is the most exposed to a negative action of air

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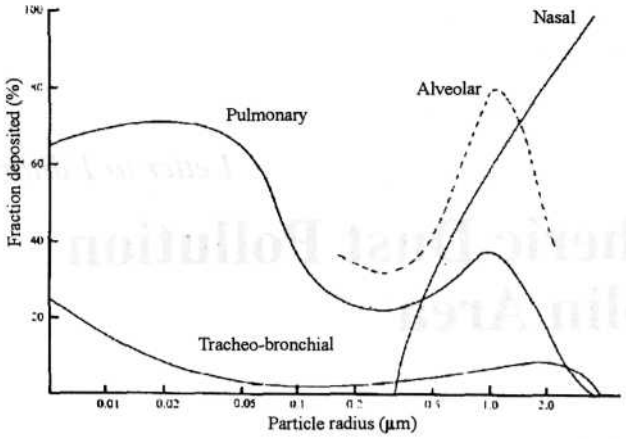

Fig. 1. Fractional amounts of particles of various sizes deposited in the various areas of the respiratory tract.

aerosols, and especially of their respirable fraction that has essentially dimensions smaller than 10 μm. The degree of aerosol deposition depends on the dimension of the particles and on the site of the respiratory tract, and thus: the fraction of the size 5.8-30 μm deposits mainly in the nasal mucosa, in the pharynx 5.0-5.8 μm, trachea 3.3-5.0 μm, bronchi 2.1-3.3 μm, bronchial remifications 1.1-2.1 *pm,* and alveoli less than 1 μm. Particulates of less than 0.2 μm are essentially exhaled unless they penetrate through small areas (0.8-1.0 μm) in the epithelium of alveoli to the lymphatic system [3]. The fractions of deposited and exhaled particles depend very clearly both on the size of aerosol particles and the site of the respiratory tract, and these relationships are shown in Figure 1 [4]. As seen in Figure 1, the high probability for the deposition exists for the small diameter of particles; therefore, in this study, it was decided to deal with measurements of the imission of the so-called particulate matter-10 (PMio) and alveolic part (AP) fractions. It is worth mentioning that the former fraction is controlled by the Polish standard [5] presented in Table 1.

Table 1. Polish standards to control PMio concentration in the atmospheric air.

Mode of measurements	Concentration of PM_{10}, μg/m³
30-minute	280
daily	125 (but 50 from 2005 year)
annual	50 (but 30 from 2005 year, and 20 from 2010 year)

Experimental

The imission of the PM_{10} and alveolic part fractions of the atmospheric aerosol was determined in Kozlowka and Lublin, with the GRIMM 1.105 apparatus. During measurements the air was sampled at a height of about 1.5 m, through the isokinetic tube.

The sample results obtained are presented in Tables 2 and 3.

Since presenting the day-by-day and day-around records of the readings of measurements is out of the scope of this paper, only a few selected and representative readings of measurements are presented here to give the reader some idea about the level of atmospheric dust pollution over chosen measurement sites in the city of Lublin and over one rural locality - Kozlowka, about 30 km north-west of Lublin. The Lublin locality with two measurement sites, i.e. Krakowskie Przedmiescie (promenade) and Aleja Solidarnosci was selected to be the first for the sample studies of the level of PM_{10}concentration

Table 2. Results of determination of instantaneous PMio imission.

Locality	Site	Date	PM_{10} concentration (μg/m³) in the atmospheric air				
			Time of measurement	PM_{10} concentration, μg/m³			
				$x_{av.}$	$x_{min.}$	$x_{max.}$	n
Kozłówka	(a)	16.06.1999	$13^{48} - 14^{15}$	25	20	28	14
Lublin	(b)	29.04.1999	$10^{35} - 10^{55}$	94	68	167	15
			$14^{35} - 14^{55}$	153	128	168	15
			$17^{10} - 17^{25}$	33	27	37	12
Lublin	(c)	29.04.1999	$9^{52} - 10^{19}$	155	102	282	15
			$14^{02} - 14^{22}$	118	76	278	15
			$16^{32} - 16^{45}$	49	39	60	11
Lublin	(b)	30.04.1999	$10^{13} - 10^{32}$	48	24	107	15
			$12^{15} - 12^{35}$	69	37	146	15
			$16^{18} - 16^{38}$	102	41	148	15
Lublin	(c)	30.04.1999	$9^{35} - 9^{55}$	53	21	117	15
			$11^{32} - 11^{52}$	54	14	186	15
			$16^{53} - 17^{13}$	33	17	62	15

(a) - near coffee bar, (b) - Krakowskie Przedmiescie (promenade), (c) - Aleja Solidarnosci, n - number of readings, Xa_V. - arithmetic mean, x_{min}. - smallest value, x_{max}. - highest value.

in atmospheric air. Two consecutive days to conduct the measurements were chosen: 29 and 30 April 1999. Within each day three time-intervals were distinguished. Unfortunately, the duration of measurements and the number of readings were not exactly the same each day, and ranged from 11 to 15, as far as the latter is concerned. However, this had no major influence on the obtained results and then on the general conclusions drawn, since the readings were taken every 90 seconds on average. These readings were regarded as the so-called instantaneous PM_{10} concentration. Based on the results obtained for the Lublin locality, we decided to

Table 3. Results of determination of instantaneous AP imission conducted on 23 March 1999.

AP concentration (μg/m³) in the atmospheric air							
	Time of measurement				Time of measurement		
	$9^{16} - 10^{00}$	$15^{05} - 15^{35}$	$16^{35} - 17^{01}$		$10^{15} - 11^{00}$	$14^{12} - 14^{47}$	$15^{55} - 16^{16}$
Krakowskie Przedmieście (promenade)	27	43	45	Aleja Solidarności	35	20	47
	34	51	35		28	56	61
	29	45	44		25	58	32
	22	31	46		20	47	19
	25	45	30		17	51	39
	24	40	40		29	45	67
	30	41	58		32	34	36
	20	35	52		27	35	41
	25	40	47		26	41	28
	32	34	52		26	20	48
	29	36	47		31	17	46
	28	39	40		55	23	33
	38	45	51		31	62	51
	27	44	54		19	39	25
	23	37	56		35	52	30
	28	45	49		31	124	23
	35	44	58		30	35	–
	28	58	80		28	53	–
	27	38	55		34	63	–
	30	40	–		24	37	–
	31	36	–		25	33	–
	32	43	–		45	34	–
	32	–	–		19	40	–
	28	–	–		16	54	–
	34	–	–		16	–	–
	32	–	–		28	–	–
	32	–	–		32	–	–
	31	–	–		29	–	–
	37	–	–		32	–	–
	33	–	–		23	–	–
$x_{av.}$	**29.4**	**41.4**	**49.4**		**28.3**	**44.7**	**39.1**
standard deviation	0.78	1.3	2.4		1.5	4.4	3.4
temperature	10°C	9°C	9°C		10°C	8°C	8°C
relative humidity	90%	100%	100%		90%	100%	100%
atmospheric pressure	990.0 hPa				990.0 hPa		
wind direction	west				west		

conduct similar determinations of the atmospheric PMio concentration over a rural area and Kozlowka was chosen as the second locality for our studies. The measurements of the PM_{10} concentration in the Kozlowka atmospheric air was conducted once in the afternoon, on 16 June 1999. The purpose of this determination was to find out if the PM_{10} concentration in the atmospheric air over the rural area would differ markedly or not in respect to the city air. The dates of the measurements conducted in Lublin and Kozlowka were selected at random, although the availability of the GRIMM 1.105 apparatus and weather conditions were also taken into account.

The imission of the AP aerosol fraction was conducted in March, i.e. during the heating period, and the purpose of the measurements was to get some knowledge about the level of the imission of that fraction. Two measurement sites were selected. At each site three series of measurements were carried out, one in the morning and two on the afternoon. As there was only one apparatus available for that kind of measurement, the measurement could not be performed simultaneously at two sites and at the same time. The number of readings was not the same at each site but the readings of the AP concentrations were taken every 90 seconds on average.

The Krakowskie Przedmiescie site was characterized by the lack of car traffic, but it was the center of Lublin. In contrast, the Aleja Solidarnosci measurement site was characterized by heavy car traffic. The measurement point was situated on pavement about lm from the street.

Each data set collected was processed statistically. In addition air temperature, relative humidity, atmospheric pressure, and wind direction were also specified in Table 3. The relative humidity was high enough, and it was nearly raining, and had moderately rained the night before.

Conclusions

The results obtained show that the instantaneous PM_{10} concentrations in the atmospheric air over the Kozlowka and Lublin sites vary markedly, especially as far as the Lublin sites are concerned. It is very characteristic that the spread of readings obtained at each site, and regardless of the date and time of the measurements, is relatively broad. On one occasion, i.e. on 30 April 1999 at the Lublin site, the highest value x_{max}. was twelve fold the smallest value (x_{min}). The most narrow spread was observed in the case of Kozlowka, when x_{max}. was equal to 28 $\mu g/m^3$ and x_{min}. to 20 $\mu g/m^3$. The reason why the spread of PM_{10} readings obtained for the rural air is narrow can be attributed to the much more stable dynamic equilibrium of particulate matter in the air, resulting from the small number of stationary and mobile emitters there. In contrast, the urban sites (especially with vast number of mobile sources of PM particles, i. e. cars and/or pedestrians) will exhibit wide spreads of readings, and this rule was confirmed by our preliminary studies, the results of which are presented in Table 2. In addition, however, it is necessary to emphasize the fact that the numerical values of concentrations of particulate matter suspended in atmospheric air may vary widely within a fraction of a second, even when the number of identified emission points and their emission intensities are constant. The above would not be true for other air impurities such as SO2, NO_X, etc. The concentrations of the latter are not changed as quickly as the PM concentration because the PM concentration also depends strongly on wind velocity and weather conditions, whereas others do not to such an extent. In the case of PM concentration, any change in wind velocity and wind direction may give rise to significant changes in the PM concentration, especially in areas where surfaces have been covered with deposited dust that may then be quickly resuspended in air due to any movement of air, especially to a gust or even breeze.

When the average PM_{10} concentrations (x_{av}.) in atmospheric air are compared with the Polish standard for the 30-minute mode of measurements, the reader can find that none of the results exceeded the standard which, in this case, is 280 $\mu g/m^3$. The highest x_{av}. values amounted to 153 $\mu g/m^3$ and 155 $\mu g/m^3$ obtained on 29 April 1999 at the Krakowskie Przedmiescie site (between 14.35 and 14.45) and the Aleja Solidarnosci site (between 14.02 and 14.22), respectively. These two highest x_{av}. values constitute 55 per cent of the 30-minute Polish standard.

The smallest x_{av}. values were found to be 25 $\mu g/m^3$ and 33 $\mu g/m^3$. The former represented the measurements conducted on 16 June 1999 at Kozlowka (between 13.48 and 14.15). The latter refers to two Lublin sites, and the dates of measurements were 29 April 1999 (between 17.10 and 17.25) and 30 April 1999 (between 16.53 and 17.13), respectively. The smallest x_{av}. values constitute 8.9% and 11.8% of the standard in question.

The smallest x_{min}. readings were 14 $\mu g/m^3$ and 17 $\mu g/m^3$, and they were obtained on 30 April 1999 at the Aleja Solidarnosci site, for two measurement time intervals: 11.32-11.52 and 16.53-17.13. Those values constitute only 5.0% and 6.1% of the 30-minute standard.

As far as x_{max}. is concerned, it can be seen that the 30-minute Polish standard was slightly exceeded once at the Aleja Solidarnosci site on 29 April 1999 at 9.52-10.19. The value of 278 $\mu g/m^3$ against 280 $\mu g/m^3$ was recorded at the same site and on the same day but for the measurement time interval 14.02-14.22. The smallest values of Xmax. were recorded for the Kozlowka site and the Krakowskie Przedmiescie site in Lublin. These values were 28 $\mu g/m^3$ and 37 $\mu g/m^3$. They constitute 10% and 13.2% of the Polish standard to control the PM_{10} concentration for the 30- minute mode of measurement. When similar comparisons between X_{aV}., x_{min}., x_{max}. and the daily Polish standard (125 $\mu g/m^3$) are performed, the following conclusions can be drawn:

1. This standard was exceeded twice, out of 13 x_{av}. values found for 3 sites. These values amounted to 153 $\mu g/m^3$, and 155 $\mu g/m^3$, and the sites and measurement time intervals are the same as mentioned earlier when the highest x_{aV}. values were discussed.

2. The daily standard was slightly exceeded only once in respect to x_{min}.. The exceeding was 128 $\mu g/m^3$ against 125 $\mu g/m^3$. This took place on 29 April 1999 at 14.35 - 14.55 at the Krakowskie Przedmiescie site. This high value of x_{min} as well as high values of X_{aV}. and x_{max}. can be the result of a busy period of the day when people are

going on foot, which creates an increased PMw concentration in atmospheric air.

3. The daily standard was exceeded 6 times, out of 13 x_{max}. values. None of the exceedings concerns the rural area. The most pronounced exceedings are 282 μg/m^3 and 278 μg/m^3, both obtained at the Aleja Solidarnosci site on 29 April 1999, at 9.52 - 10.19 and 14.02 - 14.22, respectively. The smallest x_{max}. values were found, as usual, for the rural area - Kozlowka and also for the Krakowskie Przedmiescie site on 16 June 1999 and 29 April 1999, respectively.

When the annual Polish standard to control the PM_{10} concentration is applied (50 μg/m^3) to x_{av}., x_{min}. and x_{max}. the following general conclusions can be drawn:

1. Only 5 out of 13 X_{av}. values could keep the standard. In two cases the standard was exceeded by 200% (153 μg/m^3 and 155 μg/m^3 against 50 μg/m^3).

2. The values of x_{min}. exceeded the standard 4 times out of 13. They were 68, 128, 102, and 76 μg/m^3. These took place in two sites in Lublin.

3. The x_{max}. value was not exceeded only twice out of 13. Of course, Kozlowka was one of these cases. Out of the 11, two were significant (282 μg/m^3 and 278 μg/m^3, both in Lublin at the Aleja Solidarnosci site on 29 April 1999).

It is worth noting that the above findings will be markedly different from previous ones when the new annual Polish PM_{10} concentration standards are in force from 2005 (30 ug/m^3) and from 2010 (20 μg/m^3). For example, if we consider the standard of 20 μg/m^3, the following will be noticed:

1. None of 13 x_{av}. and none of 13 x_{max}. values could keep the standard.

2. In the case of x_{min}. values, only 2 of them would keep the standard.

This observation clearly indicates that the quality of air over the studied localities is bad, and a lot has to be done in the near future to make some reasonable improvement to limit and eliminate drastically both the intensity and the number of stationary and mobile dust emitters.

The readings of the determination of the instantaneous alveolic part imission presented in Table 3 were obtained on 23 March 1999. We have decided to present these readings to the reader in order to give him the opportunity to see how drastically the AP imission changes within a relatively short period of time.

When examining the data, we can find out that the air is cleaner in the morning, regardless of the measurement site. The average AP imissions do not exceed 30 μg/m^3. In the afternoon these imissions are 35-70% higher.

Based on 6 time-interval measurements, each lasting 35-45 minutes and conducted within one day, we can get the preliminary information about the level of the AP pollution of air. Nonetheless, when the annual Polish standard to control the PM_{10} concentration (20 μg/m^3 after 2010 year) is applied, we can find out that only one reading obtained at 9.31 a.m. at the Krakowskie Przedmiescie does not exceed the standard. There are only 10 readings (out of 70) obtained at the Aleja Solidarnosci site that do not exceed the standard. At this site, one reading amounted even to 124 μg/m^3, meaning that the annual Polish standard is exceeded by at least 500%.

It can also be found out that the spreads of readings are broad, and the most wide spread (17 μg/m^3 - 124 μg/m^3) was observed for the set of data obtained at the Aleja Solidarnosci site at 14.12 - 14.47.

The highest x_{av}. value amounting to 49.4 μg/m^3 was obtained for the Krakowskie Przedmiescie measurement site at 16.35 - 17.01. When this value is compared to the prospective annual Polish standard of 20 μg/m^3, the latter x_{av}. value exceeds this standard by nearly 150%. All of the above-mentioned findings show again that the quality of air in Lublin is bad.

More data on measurements of the PM_{10} and AP concentrations at several sites in Lublin, results and discussions of the results can be found elsewhere [6].

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