CRACOW CITY REPORT

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Summary of the main findings

Air pollution levels continue to fall in Cracow and it is anticipated that this trend will continue. Annual mean of PM10 concentrations was 32 μg/m^3 in 2000 compared to more than 50 μg/m^3 at the beginning of nineties, but still episodes of high level of PM10 and black smoke occur, especially in wintertime.

In recent years one may notice an increasing activity of local authorities for improving air quality in the city. This in particular includes efforts for modernization of the heating system as well as improving traffic conditions. More attention is also paid to the health effects of air pollution.

The analysis done within Apheis project estimated that reduction of the long-term PM pollution to the levels of PM2.5 of 15 μg/m^3 would reduce mortality in Cracow by 636 deaths in one year, which would save 1.1 years of expected life for starting year of simulation. If the daily means of PM10 would be kept under 20 μg/m^3, 50 deaths could have been avoided in the year 2000.

The concentration of BS gives a slightly greater concern. The annual daily mean level of BS was very close to the level of PM10, but it was characterized by greater daily variability. According to the HIA, if all the days above 20 μg/m^3 of BS were reduced to 20 μg/m^3, it would result in a decrease of 55 annual short-term deaths, including 19 deaths from cardiovascular diseases.

The results of the health impact assessment show the benefits of reducing particulate matter exposure in a local scale. Within the process of the European Integration of Poland the Apheis findings should help improve air quality in the city and should serves as a basis for policy-making in the future.

Background

Cracow, the old historical town in the southern part of Poland, is populated by almost 740 000 inhabitants. It is situated in the Vistula river valley. The topography favours atmospheric inversion with frequent trapping of moisture and fog. As a usual city established in the medieval time it has very dense buildings structure and narrow streets in the city centre. A big metallurgical factory and two power plants located nearby have made it for a long time the most polluted city within the country. In recent years some effort has been made on the local as well as on international level in order to improve the air quality in the city. As the result of international collaboration with the USA Environmental Protection Agency the automatic monitoring system was set up at the beginning of the nineties. A lot of scientific research on air pollution health effects has started since then. One of the aims was to call attention of local authorities to the current situation in this matter. The Apheis program might be one of them.

The different HIA scenarios have been chosen for assessing expected benefits from the reduction of air pollution level. These scenarios were related to limit values for particulate matter that should not be exceeded in 2005 and 2010 as well as a scenario especially useful on a local level: reduction of air pollutants by 5 μg/m^3 was run. As a result, findings from the last year and current analysis support local policy makers that even very small reductions in air-pollution concentration have an impact on public health, and that this impact should justify taking further preventive measures.

Sources

Principal sources of air pollution were described in detail in the previous Apheis city report last year (www.apheis.org). This is an update of the main sources of air pollution.

The Technical Report on the sources of air pollution in Cracow (Report of Environment Status, Cracow, 2001) indicates that 59% of particles and 82% of gases come from industry; the rest is attributed to individual heating as well as to transportation although good estimates of the latter are lacking. Comparing to the previous year a small decrease of particles emission from industrial sources was observed (3%) and at the same level increase of emission of gases (2%) appeared.

Table 1. Main sources of air pollution

Source (year)	Industry (%)	Heating (%)	Road (%)	Other sources (specify)
2000	59	41		

In 2000 mean concentrations of main pollutants (like PM, SO2 and CO) continue to decrease. They rarely went beyond a limits set by the guideline values of year averages and these exceeds were related to low sources of emission. The only exception was at the station located on the main traffic routes of the city where the episodes of high concentrations of pollutants happened very often.

Exposure data

The air pollution indicators are monitored in Cracow by two different networks. Automatic on-line monitoring system consists of five measurement stations collecting data on PM10, SO_2, NO_2, CO and ozone. In three of them VOC and heavy metals components in particulate matter are computed. The second network consists of 11 monitoring stations spread throughout the city. Manual measurements of black smoke, SO_2 and NO_2 provide evidence of spatial differences in concentration of air pollution within the city. For this reason I considered the measurements from all the stations which give different outcome of exposure level in the city (comparing to the previous report).

The exposure data for HIA consist of daily (24-hour) measurements of particulate matter fraction PM10 and BS (black smoke) for the year 2000. The fraction PM2.5 was not available for that year so, for further calculations of HIA, that fraction was converted from PM10 measurements using local factors 0.8.

Apheis guidelines on exposure assessment were fulfilled for all monitoring stations operated in Cracow in 2000 with respect to the completeness criteria. All of them, but one, are located in different residential areas of the city and are not directly influenced by local sources of air pollution. The station measuring pollution from transport sources was excluded.

Measurements of PM10 were obtained from 4 monitoring stations. These stations provide continuous measurements of particulate matter using beta-gauge monitor so local correction factor of 1.25 was used whenever it is appropriate. Measurements of BS were made manually (reflectometric method) in 11 stations.

For year 2000:

- daily mean levels (SD) of PM10 were 32.1 (17.9) µg/m^3.
- the levels of PM10 reached during the 18 days with the lowest (5th percentile) and the highest (95th percentile) levels were respectively 12 µg/m^3 and 70 µg/m^3.

- daily mean levels (SD) of BS were 30.7 (28.5) µg/m^3.
- the levels of BS reached during the 18 days with the lowest (5th percentile) and the highest (95th percentile) levels were respectively 8 µg/m^3 and 94 µg/m^3.

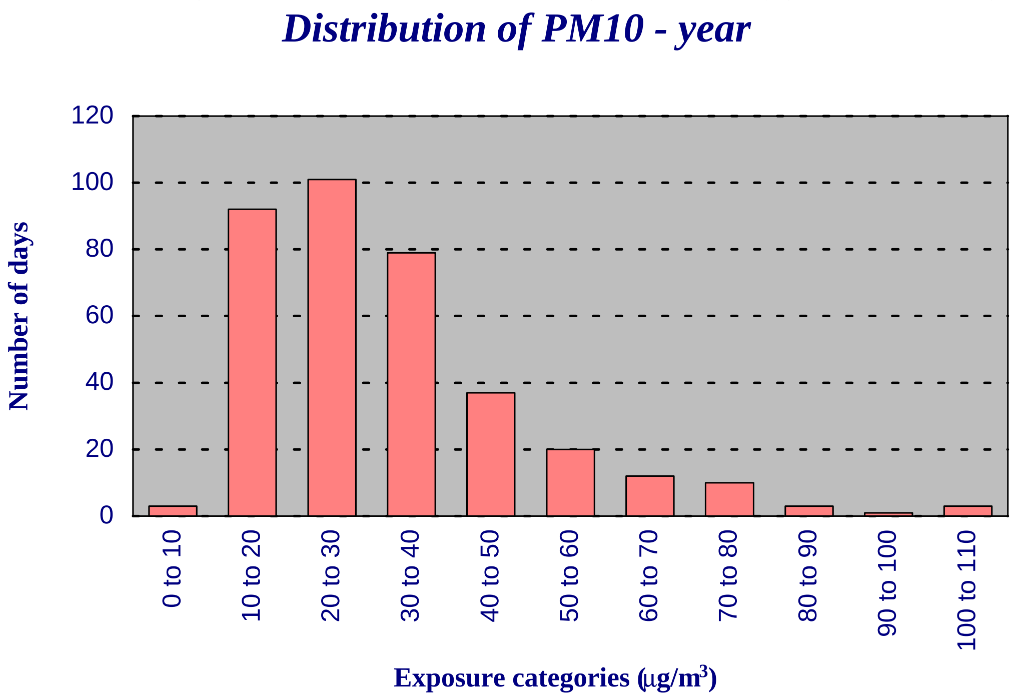
- converted from PM10 measurements daily mean levels (SD) of PM2.5 were 25.7 (14.3) µg/m^3.
- the levels of PM2.5 reached during the 18 days with the lowest (5th percentile) and with the highest (95th percentile) were respectively 10 µg/m^3 and 56 µg/m^3.

  - Number of days when air pollutants exceeded limit levels:

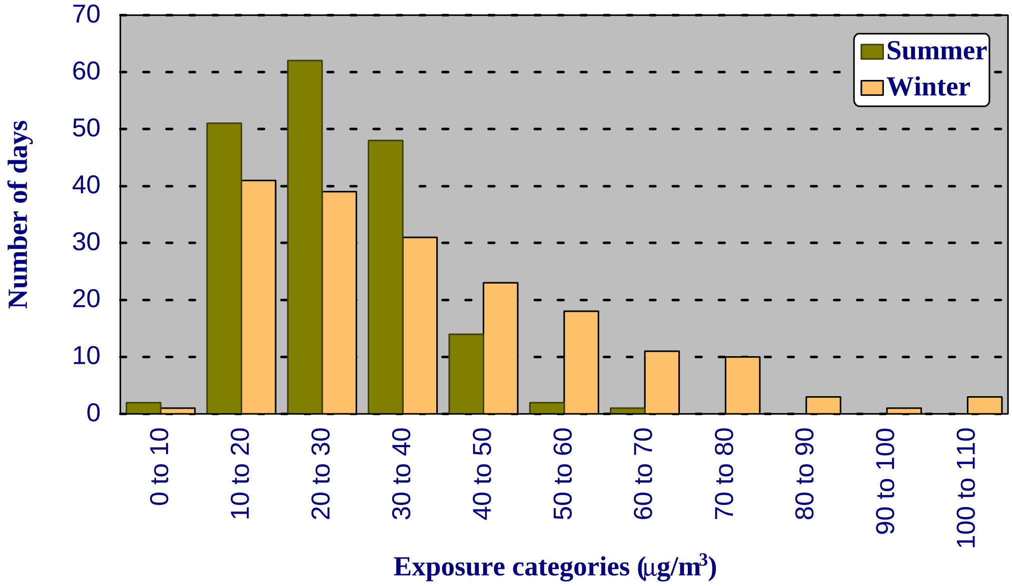
Table 2. Number of days when air pollutants exceeded limit levels

	Short term		
Air pollutant	**PM_{10}**	**BS**	**$PM_{2.5}$**
Number of days above	20 µg/m^3	20 µg/m^3	14 µg/m^3
	265	176	285
Number of days above	50 µg/m^3	50 µg/m^3	35 µg/m^3
	49	65	68

The distribution of daily measurements of PM10 and BS for 2000 including winter and summer seasons are presented in the next few figures. The annual means for both pollutants were very close, however the black smoke measurements were characterised by greater variability. In the range of 10–50 µg/m^3 was 316 PM10 daily values as compared to 271 BS measurements. Seasonal differences in the distribution of both pollutants were significant. The daily values above 50 µg/m^3 were almost exclusively for the winter season with maximum level much higher for BS than PM10 (181 µg/m^3 and 101 µg/m^3 respectively).

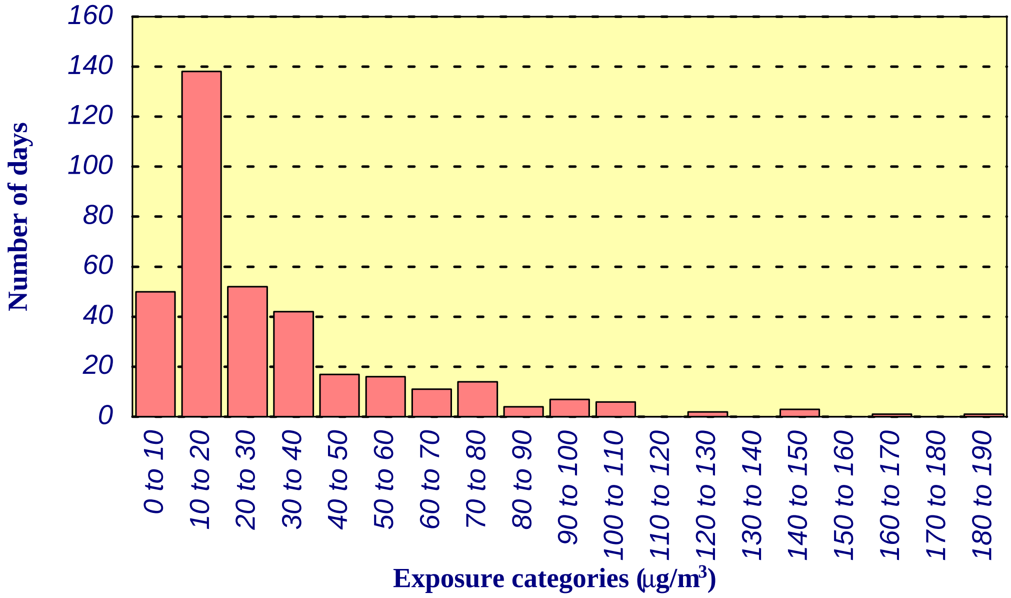


Distribution of PM10 by season

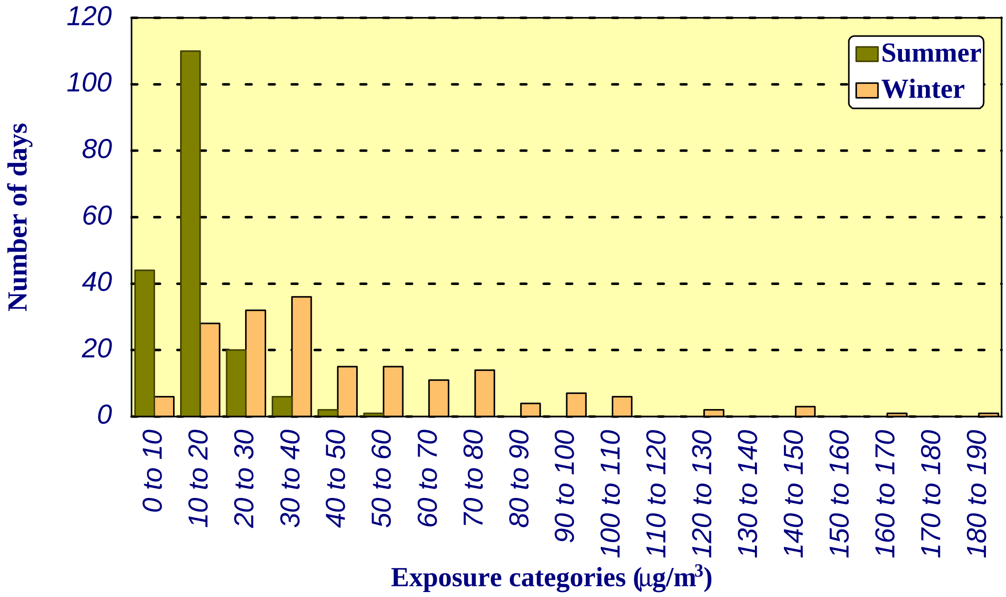


The range of PM10 concentrations encompassed 100 µg/m^3 with a very few days below 10 µg/m^3 and above 90 µg/m^3. A half of daily measurements during the year 2000 were between 20 and 40 µg/m^3. There was a clear seasonal pattern with winter measurements being about 50% higher than summer ones. Almost 90% of daily measurements during summertime were below 40 µg/m^3 comparing to less than 60% of days in winter months.

Distribution of black smoke - year



Distribution of black smoke by season



The distribution of daily measurements of black smoke was much wider than PM10 measurements. Although the median value of PM10 was about 50% higher than BS (28 $\mu g/m^3$ vs. 19 $\mu g/m^3$), the episodes of high concentrations of the latter fraction of particles were much more frequent and reached almost two times higher concentration. This is particularly characteristic phenomena for wintertime as a lot of black particles come from individual coal operated heating in old part of the city. Almost 80% measurements for summertime days were below 20 $\mu g/m^3$ and only 2 days above 40 $\mu g/m^3$.

Health data

The health outcome consists of mortality data only as hospital admission data were not available for the time being. For the year 2000 the mortality data were collected on monthly basis using death certificates from the local Registration Office. This was done in the Chair of Epidemiology and Preventive Medicine of the Jagiellonian University in Cracow.

6576 people died in Cracow in 2000 (49% men). Among them 74% were above 65 years of age. Age-standardised mortality rate for all causes of death (per 100 000 inhabitants, European population [1]) is 1012 for year 2000.

Table 3. Daily mean number and annual rate per 100 000 of deaths and hospital admissions (2000)

Health outcome	ICD9	ICD10	Daily mean number (SD)	Number of cases per 100 000
Short term HIA				
All causes mortality (excluding external causes)*	< 800	A00-R99	17.0 (4.9)	843.7
Cardiovascular mortality	390-459	I00-I99	8.7 (3.2)	429.5
Respiratory mortality	460-519	J00-J99	0.7 (0.9)	35.0
Cardiac hospital admissions	390-429	I00-I52	NA**	NA
Respiratory hospital admissions	460-519	J00-J99	NA	NA
Long term HIA				
All causes mortality	0-999	A00-Y98	18.0 (5.3)	890.5
Cardiopulmonary mortality	401-440 460-519	I10-I70 J00-J99	9.2 (3.4)	454.5
Lung cancer mortality	162	C33-C34	1.1 (1.2)	53.1

* For short and long term scenarios, **NA-not available

The number of births in Cracow in the year 2000 was 5806. The prediction (Main Statistical Office, 2001) for the next 30 years says that the number of births will be increasing till 2013 up to 40% and then will go down assuming the same number in 2030 as in 2000.

Health impact assessment

Different scenarios were used to evaluate short and long-term exposure to particulate pollution. In the city of Cracow these scenarios were built for three indicators of the particulate pollution: BS, PM10 and PM2.5. The estimated health impacts of these indicators may overlap, and caution is recommended in the interpretation of findings.

Different tools and different estimates were used to evaluate the short- and long-term impacts of this particulate pollution on health. (Table 4).

[1] UNITED NATIONS. Population Division Department of Economic and Social Affairs. World Population Prospects: The 2000 Revision.

Table 4. Summary SHORT-TERM Health impact assessment (HIA)					
	Health indicator	**ICD**		**Tool**	**RR (95% IC) For 10 µg/m^3 increase**
Attributable cases		**ICD9**	**ICD10**		
		ST HIA for all cities report			
PM10	All ages, all causes mortality (excluding external causes) All ages, cardiovascular mortality All ages, respiratory mortality All ages, cardiac hospital admissions All ages, respiratory hospital admissions	< 800 390-459 460-519 390-429 460-519	A00-R99 I00-I99 J00-J99 I00-I52 J00-J99	French PSAS-9 Excel spreadsheet	WHO, 2003: 1.006 (1.004 - 1.008) WHO, 2003: 1.009 (1.005 - 1.013) WHO, 2003: 1.013 (1.005 - 1.021) Le Tertre et al. 2002: 1.006 (1.003 - 1.009) Apheis 3: 1.0114 (1.0062 - 1.0167)
BS	All ages, all causes mortality (excluding external causes) All ages, cardiovascular mortality All ages, respiratory mortality All ages, cardiac hospital admissions All ages, respiratory hospital admissions	< 800 390-459 460-519 390-429 460-519	A00-R99 I00-I99 J00-J99 I00-I52 J00-J99	French PSAS-9 Excel spreadsheet	WHO, 2003: 1.006 (1.004 - 1.009) WHO, 2003: 1.004 (1.002 - 1.007) WHO, 2003: 1.006 (0.998 - 1.015) Le Tertre etal. 2002:1.011 (1.004 - 1.019) Apheis 3: 1.0030 (0.9985 -1.0075)
PM10 Distributed lag (40 days)	All ages, all causes mortality (excluding external causes) All ages, cardiovascular mortality All ages, respiratory mortality	< 800 390-459 460-519	A00-R99 I00-I99 J00-J99	French PSAS-9 Excel spreadsheet	Zanobetti et al. 2002: 1.01227 (1.0081 - 1.0164) Zanobetti et al. 2003: 1.01969 (1.0139 - 1.0255) Zanobetti et al. 2003: 1.04206 (1.0109 - 1.0742)
		Complementary ST HIA for some cities reports			
PM10 with shrunken stimates	All ages, all causes mortality (excluding external causes)	< 800	A00-R99	French PSAS-9 Excel spreadsheet	Apheis 3: RRs and 95% CI of the shrunken estimate for each city
					RR
				Athens	1,012 (1,008-1,017)
				Barcelona	1,009 (1,005-1,012)
				Budapest	1,005 (0,999-1,011)
				Cracow	1,004 (0,998-1,009)
				London	1,007 (1,004-1,010)
				Madrid	1,006 (1,002-1,010)
				Paris	1,005 (1,001-1,009)
				Rome	1,011(1,006-1,015)
				Stockholm	1,006 (0,999-1,013)
				Tel-Aviv	1,006 (1,002-1,011)

Table 4 (cont), Summary LONG-TERM Health impact assessment (HIA)						
	Health indicator	**ICD 9**	**ICD10**	**Tool**	**RR (95% IC) For 10 µg/m³ increase**	**Scenarios**
			Long term HIA for all-cities report			
Attributable cases						**Annual mean**
PM10	All causes mortality (excluding external causes)	< 800	A00-R99	French PSAS-9 Excel spreadsheet	Kunzli et al, 2000 1.043 (1.026 -1.061)	Reduction to 40 µg/m³ Reduction to 20 µg/m³ Reduction by 5 µg/m³
PM2.5	All causes mortality Cardiopulmonary mortality LCA	0-999 401-440 and 460-519 162	A00-Y98 I10-I70 and J00-J99 C33-C34	French PSAS-9 Excel spreadsheet	CA III Pope, 2002 1.06 (1.02 - 1.11) 1.09 (1.03 - 1.16) 1.14 (1.04 - 1.23)	Reduction to 20 µg/m³ Reduction to 15 µg/m³ Reduction by 3.5 µg/m³
YoLL						**Annual mean**
PM2.5	All causes mortality Cardiopulmonary mortality LCA	0-999 401-440 and 460-519 162	A00-Y98 I10-I70 and J00-J99 C33-C34	WHO AirQ software	CA III Pope, 2002 1.06 (1.02 - 1.11) 1.09 (1.03 - 1.16) 1.14 (1.04 - 1.23)	Reduction to 20 µg/m³ Reduction to 15 µg/m³ Reduction by 3.5 µg/m³
			Complementary LT HIA for some cities report			
Prospective scenarios on air pollution, prospective scenarios on birth numbers	Local choice	–	–	WHO AirQ software	–	–

Also different approaches were used to describe the impacts:
For BS, short-term findings are expressed in terms of number of attributed deaths per year,
For PM10, short and long-term findings are expressed in terms of number of attributed deaths per year,
For PM2.5, long-term findings are expressed in terms of:

- number of attributed deaths per year
- number of expected years of life lost for starting year of simulation due to the deaths in one year.

Short-term scenarios

We used the following scenarios to estimate the acute effects of short-term exposure to BS/ PM10 on mortality over one year:

<u>Short term HIA scenarios for BS</u>

We used three scenarios to estimate the acute health effects of BS on all causes (excluding external causes), cardiovascular and respiratory mortality over one year:

- reduction of BS levels to a 24-hour value of 50 µg/m^3 on all days exceeding this value,
- reduction of BS levels to a 24-hour value of 20 µg/m^3 on all days exceeding this value,
- reduction by 5 µg/m^3 of all the 24-hour values of BS.

<u>Short term HIA scenarios for PM10</u>

- **<u>Short-term HIA of PM_{10} on 0-1 days and cumulative HIA of PM_{10} up to 40 days</u>**

We used three scenarios to estimate the acute health effects of PM_{10} on 0-1 days and cumulative health effects of PM_{10} up to 40 days on all causes (excluding external causes), cardiovascular and respiratory mortality over one year:

- reduction of PM_{10} levels to a 24-hour value of 50 µg/m^3 on all days exceeding this value,
- reduction of PM_{10} levels to a 24-hour value of 20 µg/m^3 on all days exceeding this value ,
- reduction by 5 µg/m^3 of all the 24-hour values.

- **<u>Combined local and meta-analytic estimates for short-term HIA of PM10</u>**

We used the same scenarios than above and combined local and meta-analytic estimates to calculate the acute health effects of PM_{10} on all causes of death (excluding external causes) over one year. This sensitivity analysis was done to study the interest of including the weight of a local estimates in the combined (meta-analytic) one.

Long-term scenarios

Long-term HIA scenarios for PM10

We used three scenarios to estimate the chronic effects of long-term exposure to PM_{10} on all causes mortality (excluding external causes) over one year:

- reduction of the annual mean value of PM_{10} to a level of 40 µg/m^3 (2005 limit values for PM_{10}),
- reduction of the annual mean value of PM_{10} to a level of 20 µg/m^3 (2010 limit values for PM_{10}),
- reduction by 5 µg/m^3 in the annual mean value of PM_{10}.

Long term HIA scenarios for PM2.5

We estimated chronic effects of $PM_{2.5}$ in the Cracow in population over 30 years old as impacts on mortality due to all causes, due to cardiopulmonary and due to lung cancer deaths.

The following three pollution scenarios were considered:

- reduction of the annual mean value of PM2.5 to a level of 20 µg/m^3
- reduction of the annual mean value of PM2.5 to a level of 15 µg/m^3
- reduction by 3.5 µg/m^3 in the annual mean value of PM2.5

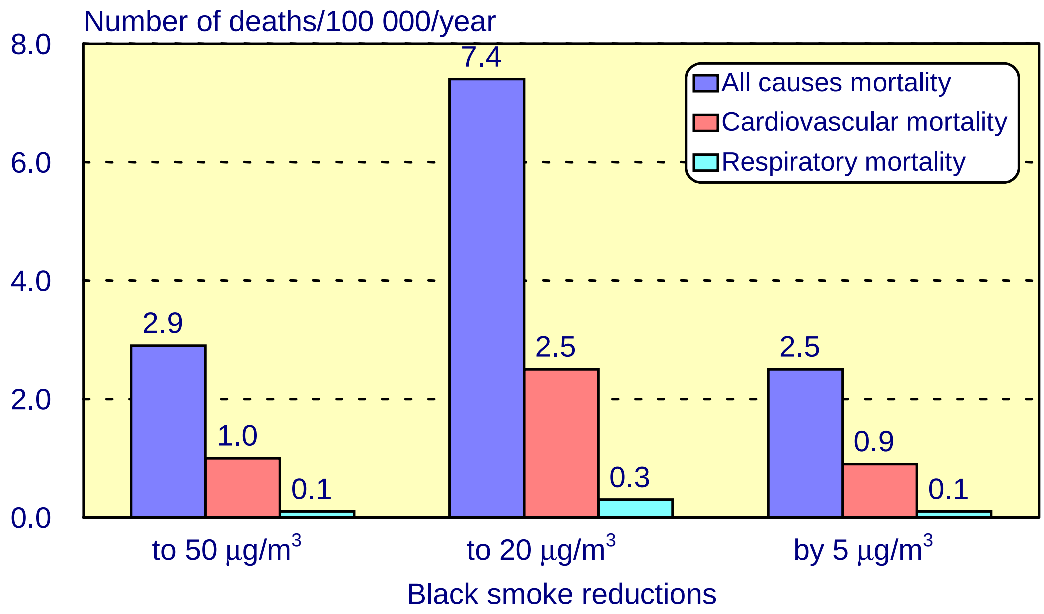
BS findings

Figure 1 shows the health impact of BS expressed as a number of deaths per 100 000 population attributed to reduction of black particles concentration over days exceeding limit values set up by scenarios.

There were 65 days during 2000 with daily concentration of BS exceeding 50 µg/m^3, almost exclusively during winter months. The reduction of daily over-concentration for these days to 50 µg/m^3 would allow to avoid 22 (95% CI: 15-33) acute deaths of Cracow inhabitants, including 7 (95%CI: 4-13) deaths from cardiovascular diseases (see the appendix for detail numbers).

Simulation done with the second scenario (reduction to 20 µg/m^3) would give greater benefit: 55 (95% CI: 36-84) avoidable deaths including 19 (95%: 9-33) from cardiovascular diseases. However this scenario is difficult to implement as for almost half of the year 2000 this limit value were exceeded.

Figure 1. Short-term health impact on total and specific mortality.
Black smoke : reductions to 50-20-by 5 µg/m³.



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*All causes mortality excluding external causes (ICD9 < 800), cardiovascular mortality (ICD9 390-459), respiratory mortality (ICD9 460-519).

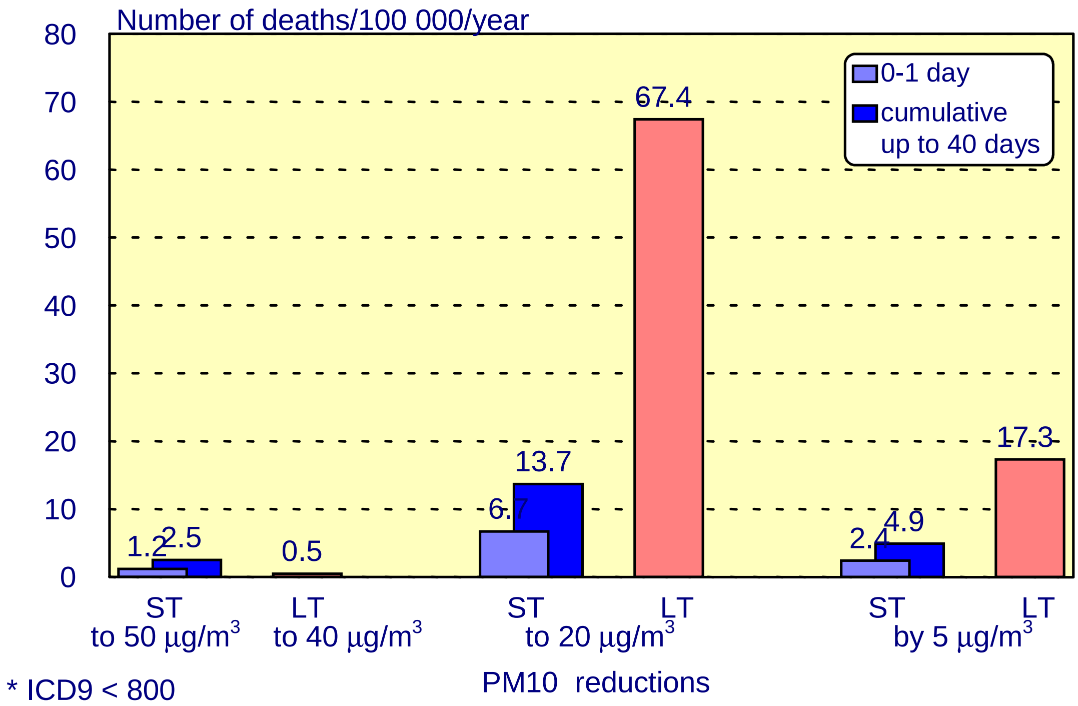
** Black smoke data for 2000, mortality data for 2000

PM10 findings

1. Short-term HIA of PM10 on 0-1 days and cumulative HIA of PM10 up to 40 days, and long term HIA of PM10 on mortality.

The following graphs (figure 2 and 3) show the health impact of PM10 on mortality for different lags: short-term-ST (0-1 day lag), cumulative effect –DL-distributed lag (up to 40 days lag) and long-term LT (years).

Figure 2. Short term (ST) and long term (LT) health impact on all causes mortality*.
PM10: reductions to 50/40-20-by 5 µg/m³.



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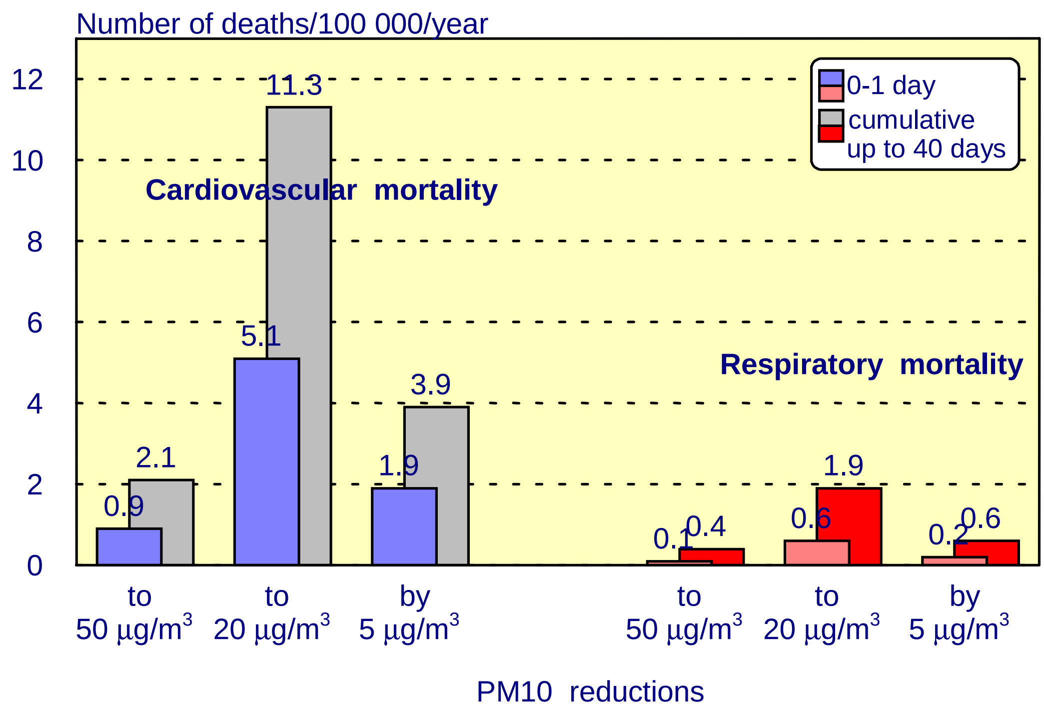
* PM10 data for 2000, mortality data for 2000

There were 49 days in 2000 when daily average concentration of PM10 exceeded 50 µg/m³. The action for reducing these values to 50 µg/m³ would allow to avoid 9 (95%CI: 6-12) acute deaths in Cracow population. The benefit would be doubled for cumulative exposure up to 40 days. For assessing long-term exposure on mortality the corrected measurements of PM10 (multiplied by local correction factor 1.25) were taken according to APHEIS rules. Even this, annual average of PM10 was exceeded only by less then 2 µg/m³, so potential benefits of reducing annual mean to 40 µg/m³ would express in 4 (95% CI: 2-5) avoidable deaths in Cracow population.

The scenario for reducing daily or annual mean concentrations of PM10 to 20 µg/m³ would express in much higher numbers of deaths which might be avoided (e.g. 499 deaths from chronic exposure to PM10, which is 8% of all deaths in Cracow in 2000). Even reduction of PM10 annual mean by 5 µg/m³ would save 128 deaths attributed to chronic effect of exposure during the year.

Figure 3. Short term (ST) health impact on specific mortality.
PM10: reductions to 50-20-by 5 µg/m³.



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*Cardiovascular mortality (ICD9 390-459), respiratory mortality (ICD9 460-519).

** PM10 data for 2000, mortality data for 2000

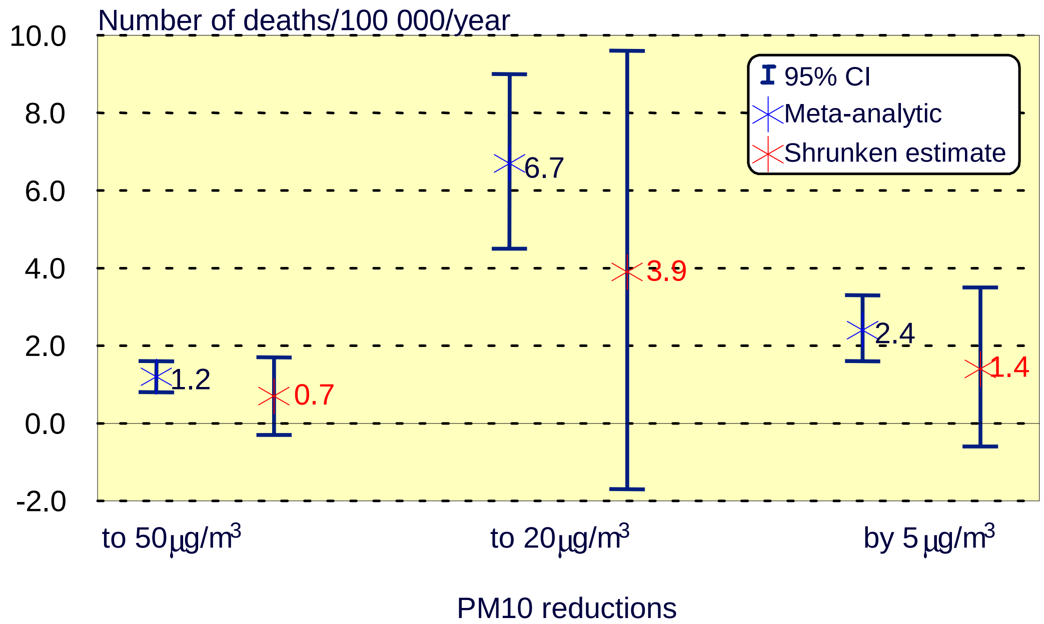
Potential benefits of reducing daily concentration of PM10 on specific mortality showed similar pattern as for total mortality. The numbers of avoidable deaths from cardiovascular mortality were two times higher for cumulative then acute 0-1 day exposure preceding death. For respiratory mortality rates even tripled for all scenarios.

2. Combined local and meta-analytic estimates for the health effects of PM_{10}

As for the city of Cracow local estimates of the acute health effects of PM10 on all causes of death (excluding external ones) were available we combined local and meta-analytic estimates to calculate the potential benefits over one year of reducing daily PM10 concentrations according to the three scenarios.

The following figure compares the HIA of PM10 on 0-1 days and that of the combined estimate (SE).

Figure 4. Meta-analytic vs shrunken estimated health impact on all causes mortality. PM10: reductions to 50-20-by 5 µg/m³



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* All causes mortality excluding external causes (ICD9 < 800)

** PM10 data for 2000, mortality data for 2000

The local estimates of total mortality cases attributed to acute exposure to PM10 were about 40% lower for all three scenarios with much wider confidence interval. This phenomenon is rather difficult to explain besides well known fact that estimates of health effects of air pollution in Eastern European cities are lower than in Western ones.

PM2.5 findings

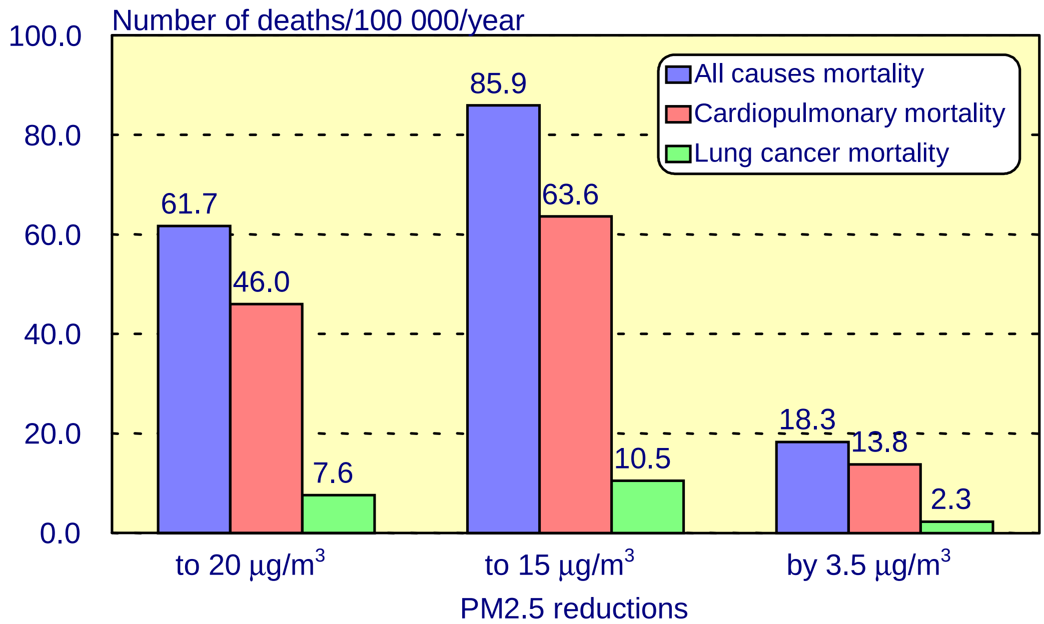
PM2.5 results for Cracow should be regarded with some caution as PM2.5 measurements were not direct ones but converted form PM10.

1. Number of attributed cases

We also used three scenarios to estimate the chronic effects of long-term exposure to PM2.5 on mortality over one year.

The following graph presents the attributable number of all causes, cardiopulmonary and lung cancer deaths expressed as per 100 000 inhabitants.

Figure 5. Long-term health impact on total and specific mortality.
PM2.5: reductions to 20-15-by 3.5 μg/m³.



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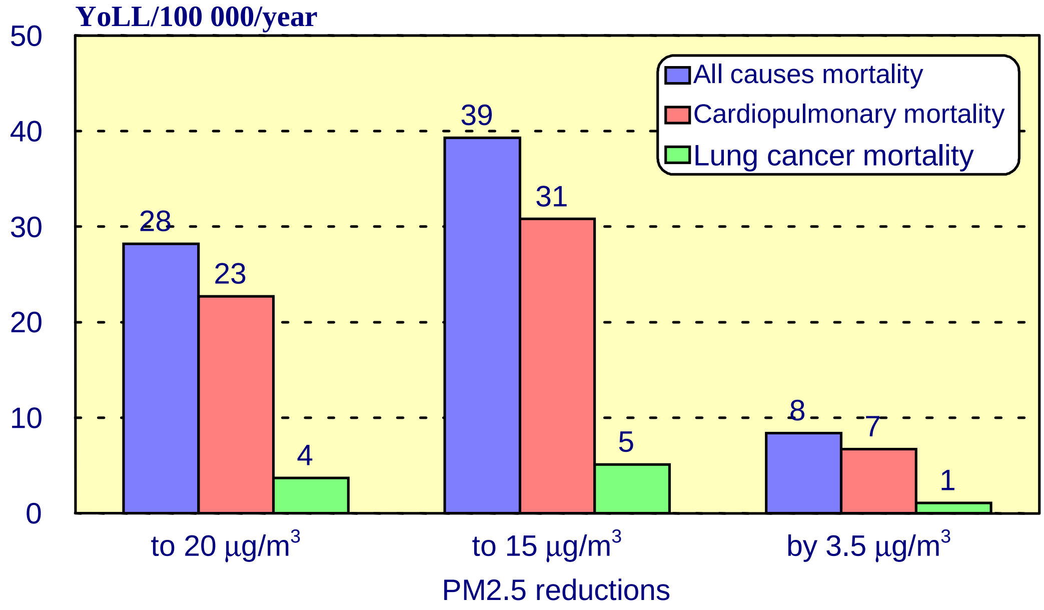
* All causes mortality (ICD9 0-999), cardiopulmonary mortality (ICD9 401-440 and 460-519), lung cancer mortality (ICD9 162).
** PM2.5 data for 2000, mortality data for 2000

Only 25% days of the year 2000 were below 20 μg/m³ and annual average of PM2.5 concentration was 32 μg/m³, so reduction of annual mean to 20 μg/m³ would result in 457 (95% CI: 117-816) deaths in Cracow population attributed to chronic effects of PM2.5 exposure, including 340 (95% CI: 119-578) deaths from cardiovascular mortality and 57 (95% CI: 18-99) deaths from lung cancer. Even reducing annual mean of PM2.5 concentration by 3.5 μg/m³ would allow avoiding 135 deaths from all causes attributed to PM2.5 exposure.

2. Years of life lost

We estimated the years of life lost (YoLL) for starting year of symulation attributable to the chronic effects of PM2.5 converted from PM_{10} measurements using the data for the year 2000. Figure 6 presents the years of life lost for all causes, cardiopulmonary and lung cancer deaths for people 30 years of age or older in the population of Cracow.

Figure 6. Expected years of life lost due to the deaths above 30 years old for total and specific mortality for starting year of simulation.
PM2.5: reductions to 20-15-by 3.5 µg/m^3.



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* All causes mortality (ICD9 0-999), cardiopulmonary mortality (ICD9 401-440 and 460-519), lung cancer mortality (ICD9 162).
** PM2.5 data for 2000, mortality data for 2000

For all causes of deaths annual reduction of PM2.5 concentration by 3.5 µg/m^3 in 2000 would save 63 years of expected life for starting year of simulation in people older than 30 years in the city of Cracow. For cardiopulmonary mortality this number would be around 50 and for lung cancer mortality more or less 8.

The following table presents the findings in terms of life expectancy.

Table 5. Life expectancy and its possible increase by reduction of air pollution to 15 µg/m^3 in Cracow

		Expected gain in life expectancy		
Age	Life expectancy	Mean	Low estimate	High estimate
At birth	77.3	1.06	0.28	1.84
30	47.8	1.06	0.28	1.85
65	16.7	0.8	0.21	1.43

In terms of life expectancy if annual mean PM2.5 levels (31 µg/m^3) were reduced to 15µg/m^3, the 48 years of life expectancy in a person of 30 years old would be increased by a bit more than 1 year, due to reduced risk of death from all causes attributed to chronic exposure to PM2.5.
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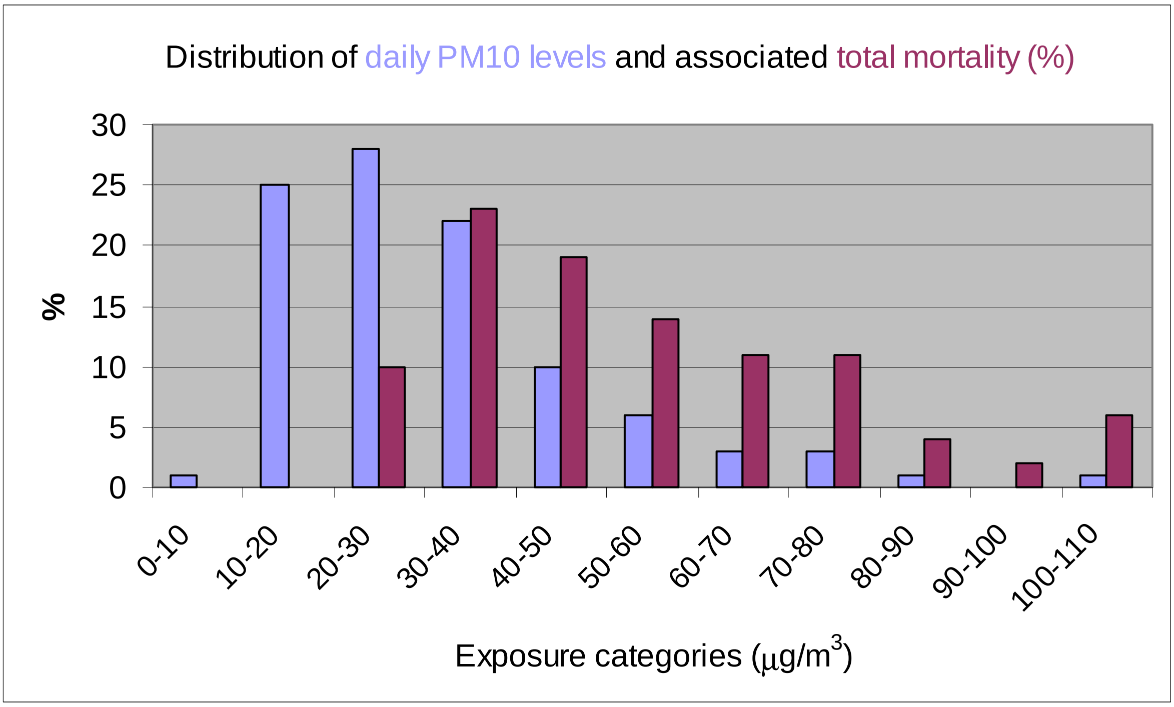
Interpretation of findings

In the previous report the exposure data were chosen from one monitoring station only, no attention was paid to the fact that air pollution level in Cracow is geographically dependent. To make the analysis more reliable I consider the measurements coming from all the stations which are located in different part of the city. As a consequence, comparing to the exposure assessment in the previous report, we get lower air pollution concentration. This makes significant difference in HIA.

In the year 2000, 6576 inhabitants of Cracow died in the city. Although the PM10 annual mean was 32.1 µg/m^3, 265 days exceeded 20 µg/m^3, and this was associated with 50 short-term deaths per year that could be prevented. The benefits doubled for the cumulative effects up to 40 days of short-term exposure. Even PM10 reduction by 5µg/m^3 would lead to a decrease of 18 short-term deaths from all causes, including 14 cardiovascular deaths per year. The figure presented below shows distribution of daily PM10 concentrations divided into 10 µg/m^3 categories and associated percentage of total mortality. Only 8% of the health impact is observed for concentrations above 80 µg/m^3 and 50% of it is attributed to the range of 10-40 µg/m^3 concentration of PM10.



The concentration of BS gives a slightly greater concern. The annual daily mean level of BS was very close to the level of PM10, but it was characterized by greater daily variability. According to the HIA, if all the days above 20 µg/m^3 of BS were reduced to 20 µg/m^3, it would result in a decrease of 55 annual short-term deaths including 19 deaths from cardiovascular diseases.

The expected benefits of reduced mortality in the long-term exposure if, according to the European directives for 2010, annual mean levels of PM10 are reduced to 20 µg/m^3, are of great significance. About 500 attributable mortality cases could be avoided, which represent 66 cases per 100 000 inhabitants.

The interpretation of inspected benefits of PM2.5 reduction should be made with some caution because PM2.5 measurements were obtain from PM10 daily values using converting factor so they set only as an approximation of real values.

Years of life lost (YoLL) attributable to the chronic effects of particulate matter (PM2.5) represents another measure of benefits of reduction air pollution level. Potential benefits of reducing annual mean values of PM2.5 to levels of 20 $\mu g/m^3$ would result in population older than 30 years of age in 209 of the years of life lost per year for starting year of simulation, including 164 YoLL for cardiopulmonary deaths.

Conclusions

Air pollution levels continue to fall in Cracow and it is anticipated that this trend will continue. In the last couple of years, certain measures to reduce air pollution have been taken in Cracow. City authorities encourage citizens to use public transport rather than private cars and the ban on traffic in the city centre is already in place. Further steps have been taken to reduce air pollution from industrial as well as the traffic sources.

It is of vital importance to inform inhabitants of the city about air quality and its impact on public health. The results of the health impact assessment show the benefits of reducing particulate matter exposure in a local scale. Within the process of the European Integration of Poland the Apheis findings should help improve air quality in the city and should serves as a basis for policy-making in the future. Results of the Health Impact Assessment will be presented to the policy makers and public health authorities in order to help them make decisions based on this information.

Average people in Poland still think that air pollution is more nuisance than threat. As this assessment show the small size of the risk from air pollution should not be underestimated in terms of its impact on public health.

Scientific research on impact of environmental factors on human health done in Cracow is usually not followed by practical conclusions directed to local policy makers. Does any effort which breaks this pattern is of great value, especially if other environmental factors are used as well.

Cracow partners

Dr. Krystyna Szafraniec, Jagiellonian University, Chair of Epidemiology and Preventive Medicine, Cracow, -coordinator since May 2003

Dr. Janusz Swiatczak – National Institute of Hygiene, Warsaw – previous coordinator (till May 2003)
Dr. Bogdan Wojtyniak - National Institute of Hygiene, Warsaw

Data for the analysis were supplied by the following institutions in Cracow:
- Malopolskie Centrum Organizacji i Promocji Zdrowia
- Wojewódzki Inspektorat Ochrony Srodowiska
- Malopolski Wojewódzki Inspektor Sanitarny

Appendix - tables for HIA findings

1. Tables for black smoke findings

Tables 1, 2, 3 present the attributable number of all causes, cardiovascular and respiratory deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 1. Deaths all causes (ICD9 < 800) (2000). Potential benefits of reducing daily BS levels (2000) above 20 to 20 µg/m^3, above 50 to 50 µg/m^3 and all days by 5 µg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of BS

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 µg/m^3	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m^3	176	54.5	36.2	84.4	7.4	4.9	11.1
50 µg/m^3	65	21.8	14.5	32.9	2.9	2.0	4.5
By 5 µg/m^3	NA*	18.3	12.2	27.4	2.5	1.7	3.7

**NA: not applicable*

Table 2. Cardiovascular deaths (ICD9 390-459) (2000). Potential benefits of reducing daily BS levels (2000) above 20 to 20 µg/m^3, above 50 to 50 µg/m^3 and all days by 5 µg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effect of BS

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 µg/m^3	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m^3	176	18.5	9.2	32.7	2.5	1.3	4.4
50 µg/m^3	65	7.4	3.7	13.0	1.0	0.5	1.8
By 5 µg/m^3	NA*	6.3	3.1	11.0	0.9	0.4	1.5

**NA: not applicable*

Table 3. Respiratory deaths (ICD9 460-519) (2000). Potential benefits of reducing daily BS levels (2000) above 20 to 20 µg/m^3, above 50 to 50 µg/m^3 and all days by 5 µg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of BS

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 µg/m^3	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m^3	176	2.3	-0.7	5.8	0.3	-0.1	0.8
50 µg/m^3	65	0.9	-0.3	2.3	0.1	-0.04	0.3

By 5 µg/m³	NA*	0.8	-0.3	1.9	0.1	-0.03	0.3

**NA: not applicable*

2. Tables for PM_{10} findings

2.1. Health effects of PM_{10} on 0-1 days

Tables 4, 5, 6 present the attributable number of all causes, cardiovascular and respiratory deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 4. Deaths all causes (ICD9 < 800) (2000). Potential benefits of reducing daily PM_{10} levels (2000) above 20 to 20 µg/m³, above 50 to 50 µg/m³ and all days by 5 µg/m³. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 µg/m³	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m³	265	49.5	33.0	66.2	6.7	4.5	9.0
50 µg/m³	49	9.0	6.0	12.0	1.2	0.8	1.6
By 5 µg/m³	NA*	18.1	12.1	24.1	2.4	1.6	3.3

**NA: not applicable*

Table 5. Cardiovascular deaths (ICD9 390-459) (2000). Potential benefits of reducing daily PM_{10} levels (2000) above 20 to 20 µg/m³, above 50 to 50 µg/m³ and all days by 5 µg/m³. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 µg/m³	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m³	265	38.0	21.0	55.2	5.1	2.8	7.5
50 µg/m³	49	6.9	3.8	10.1	0.9	0.5	1.4
By 5 µg/m³	NA*	13.8	7.7	19.9	1.9	1.0	2.7

**NA: not applicable*

Table 6. Respiratory deaths (ICD9 460-519) (2000). Potential benefits of reducing daily PM_{10} levels (2000) above 20 to 20 µg/m³, above 50 to 50 µg/m³ and all days by 5 µg/m³. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

		Attributable cases per year					

Scenarios	Number of days per year exceeding 20 and 50 µg/m³	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m³	265	4.4	1.7	7.2	0.6	0.2	1.0
50 µg/m³	49	0.8	0.3	1.3	0.1	0.04	0.2
By 5 µg/m³	NA*	1.6	0.6	2.6	0.2	0.08	0.3

NA: not applicable

2.2. Cumulative health effects of PM_{10} up to 40 days

Tables 7, 8, 9 present the attributable number of all causes, cardiovascular and respiratory deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 7. Cumulative health effects of PM_{10} up to 40 days and all causes of deaths (ICD 9 < 800) (2000).Potential benefits of reducing daily PM_{10} levels (2000) above 20 to 20 µg/m³, above 50 to 50 µg/m³ and all days by 5 µg/m³. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 µg/m³	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m³	265	101.3	66.6	136.1	13.7	9.0	18.4
50 µg/m³	49	18.7	12.3	25.1	2.5	1.7	3.4
By 5 µg/m³	NA*	36.3	24.0	48.5	4.9	3.2	6.6

NA: not applicable

Table 8. Cumulative health effects of PM_{10} up to 40 days and cardiovascular deaths (ICD9 390-459) (2000). Potential benefits of reducing daily PM_{10} levels (2000) above 20 to 20 µg/m³, above 50 to 50 µg/m³ and all days by 5 µg/m³. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 µg/m³	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m³	265	83.2	58.3	108.6	11.3	7.9	14.7
50 µg/m³	49	15.7	11.0	20.4	2.1	1.5	2.8

By 5 μg/m^3	NA*	29.2	20.6	37.7	3.9	2.8	5.1

**NA: not applicable*

Table 9. Cumulative health effects of PM_{10} up to 40 days and respiratory deaths (ICD9 460-519) (2000). Potential benefits of reducing daily PM_{10} levels (2000) above 20 to 20 μg/m^3, above 50 to 50 μg/m^3 and all days by 5 μg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 μg/m^3	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 μg/m^3	265	14.3	3.6	26.3	1.9	0.5	3.6
50 μg/m^3	49	2.9	0.7	5.2	0.4	0.1	0.7
By 5 μg/m^3	NA*	4.7	1.2	8.2	0.6	0.2	1.1

**NA: not applicable*

2.3. Combined local and meta-analytic estimates for the health effects of PM_{10}

Table 10 presents the attributable number of all causes of deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 10. Combined local and meta-analytic estimates for the health effects of PM_{10} and all causes of deaths (ICD9 < 800) (2000). Potential benefits of reducing daily PM_{10} levels (2000) above 20 to 20 μg/m^3, above 50 to 50 μg/m^3 and all days by 5 μg/m^3. Absolute number and number per 100 000 inhabitants (95% confidence limits) attributable to the acute effects of PM_{10}

		Attributable cases per year					
Scenarios	Number of days per year exceeding 20 and 50 μg/m^3	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 μg/m^3	265	29.0	-12.6	71.3	3.9	-1.7	9.6
50 μg/m^3	49	5.2	-2.3	12.8	0.7	-0.3	1.7
By 5 μg/m^3	NA*	10.7	-4.7	26.0	1.4	-0.6	3.5

**NA: not applicable*

2.4. Long term HIA for PM_{10}

Table 11 presents the attributable number of all causes of deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 11. Deaths all causes (ICD9 < 800) (2000). Potential benefits of reducing annual mean values of PM_{10} (2000) to levels of 20 and 40 µg/m^3, and by 5 µg/m^3. Absolute number of deaths and number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of PM_{10}

	Attributable cases per year					
	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
20 µg/m^3	498.8	299.1	714.0	66.4	40.4	96.5
40 µg/m^3	3.5	2.2	5.0	0.5	0.3	0.7
By 5 µg/m^3	127.8	77.6	180.6	17.4	10.5	24.4

3. Tables for $PM_{2.5}$ findings

3.1. LT PM2.5: Attributable Cases

Tables 12, 13, 14 present the attributable number of all causes, cardiopulmonary and lung cancer deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 12. Deaths all causes (ICD9 0-999) (2000). Potential benefits of reducing annual mean values of $PM_{2,5}$ (2000) to levels of 15 and 20 µg/m^3, and by 3,5 µg/m^3. Absolute number of deaths and number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of $PM_{2,5}$

	Attributable cases per year					
	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
15 µg/m^3	635.5	160.4	1149.3	85.9	21.7	155.3
20 µg/m^3	456.5	116.5	816.0	61.7	15.8	110.3
By 3,5 µg/m^3	135.4	35.2	237.3	18.3	4.8	32.1

Table 13. Cardiopulmonary deaths (ICD9 401-440 and 460-519) (2000). Potential benefits of reducing annual mean values of $PM_{2,5}$ (2000) to levels of 15 and 20 µg/m^3, and by 3,5 µg/m^3. Absolute number of deaths and number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of $PM_{2,5}$

	Attributable cases per year					
	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper

15 µg/m^3	470.5	162.3	811.1	63.6	21.9	109.6
20 µg/m^3	340.4	119.2	577.9	46.0	16.1	78.1
By 3,5 µg/m^3	102.2	36.7	169.2	13.8	5.0	22.9

Table 14. Lung cancer deaths (ICD9 162) (2000). Potential benefits of reducing annual mean values of $PM_{2,5}$ (2000) to levels of 15 and 20 µg/m^3, and by 3,5 µg/m^3. Absolute number of deaths and number of deaths per 100 000 inhabitants (95% confidence limits) attributable to the chronic effects of $PM_{2,5}$

	Attributable cases per year					
	N° of deaths central	N° of deaths lower	N° of deaths upper	N° of deaths per 100 000 central	N° of deaths per 100 000 lower	N° of deaths per 100 000 upper
15 µg/m^3	77.4	24.6	138.4	10.5	3.3	18.7
20 µg/m^3	56.5	18.3	98.8	7.6	2.5	13.4
By 3,5 µg/m^3	17.2	5.8	29.0	2.3	0.8	3.9

3.2. LT PM2.5: Years of Life Lost

Tables 15, 16, 17 present the years of life lost for starting year of simulation of all causes, cardiopulmonary and lung cancer deaths expressed as absolute numbers and as rates per 100 000 inhabitants.

Table 15. Deaths all causes >30 years, male and female, for one year (ICD9 0-999) (2000). Potential benefits of reducing annual mean values of $PM_{2,5}$ (2000) to levels of 15 and 20 µg/m^3, and by 3,5 µg/m^3. Years of life lost (YoLL) and YoLL per 100 000 inhabitants (95% confidence limits) for starting year of simulation attributable to the chronic effects of $PM_{2,5}$

	Years of life lost					
	YoLL central	YoLL lower	YoLL upper	YoLL per 100 000 central	YoLL per 100 000 lower	YoLL per 100 000 upper
15 µg/m^3	291.4	79.2	488.9	39.3	10.7	66.0
20 µg/m^3	208.6	53.1	353.6	28.2	7.6	47.7
By 3,5 µg/m^3	62.2	16.5	107.5	8.4	2.2	14.5

Table 16. Cardiopulmonary deaths >30 years, male and female, for one year (ICD9 401-440 and 460-519) (2000). Potential benefits of reducing annual mean values of $PM_{2,5}$ (2000) to levels of 15 and 20 µg/m^3, and by 3,5 µg/m^3. Years of life lost (YoLL) and YoLL per 100 000 inhabitants (95% confidence limits) for starting year of simulation attributable to the chronic effects of $PM_{2,5}$

	Years of life lost

	YoLL	YoLL	YoLL	YoLL per 100 000	YoLL per 100 000	YoLL per 100 000
	central	lower	upper	central	lower	upper
15 µg/m^3	227.9	86.4	357.0	30.8	11.7	48.2
20 µg/m^3	164.3	61.4	260.4	22.7	8.3	35.2
By 3,5 µg/m^3	49.7	2.5	11.2	6.7	2.5	10.9

Table 17. Lung cancer deaths >30 years, male and female, for one year (ICD9 162) (2000). Potential benefits of reducing annual mean values of $PM_{2,5}$ (2000) to levels of 15 and 20 µg/m^3, and by 3,5 µg/m^3. Years of life lost (YoLL) and YoLL per 100 000 inhabitants (95% confidence limits) for starting year of simulation attributable to the chronic effects of $PM_{2,5}$

	Years of life lost					
	YoLL	YoLL	YoLL	YoLL per 100 000	YoLL per 100 000	YoLL per 100 000
	central	lower	upper	central	lower	upper
15 µg/m^3	37.5	13.7	58.1	5.1	1.9	7.8
20 µg/m^3	27.3	9.8	43.1	3.7	1.3	5.8
By 3,5 µg/m^3	8.4	2.9	13.7	1.13	0.4	1.9

Annex 2003 – exposure data

Harmonised compilation of information indicating the exposure relevant area of the city, number of PM10, PM2.5 or BS monitoring sites, and the type, sampling and measurement characteristics of stations selected for the HIA of APHEIS

1. City: ___Cracow _____
2. Total area of agglomeration (km²): ___ 320_________
3. Area (km²) covered by the air monitoring network in the city: ____320________
4. Number of population in this (exposure relevant) area: ____740 000____
5. Total number of PM10 monitoring stations in this area: _____ __5_______
6. Total number of BS monitoring stations in this area: ____ __11_______
7. **Total number of PM2.5 monitoring stations in this area: ________0_______**
8. Number of selected PM10 monitoring stations for HIA: ________4_____
9. Number of selected BS monitoring stations for HIA: _____ __11_____
10. **Number of selected PM2.5 monitoring stations for HIA: __ ______0______**
11. Measurement interval (please cross)

    continuous   hourly   **24 hours x**   weekly   2 weekly

12. Quality assurance and control (please cross)

    yes x   no   do not know

13. Data quality (please cross)

    validated data x   invalidated data

14. Name, classification and sampling characteristics of the monitoring site (traffic, kerbside, building line, commercial, urban residential, sub-urban, rural, industrial, others)

Name (used for HIA):	PM10/BS/PM2.5	Classification
Rynek Główny	PM10	residential
Bulwarowa Str	PM10	residential
Krowodrza	PM10	residential
Kurczaba Str	PM10	residential
Rynek Podgórski	BS	residential
Królewska Str.	BS	residential
Jagiellonskie	BS	residential
Kąpielowa	BS	residential
Szwedzka Str	BS	residential
Brozka Str	BS	residential
Wyslouchów Str	BS	residential
Basztowa Str	BS	residential
Syrokomli Str	BS	residential
Prądnicka Str	BS	residential
Miechowity Str	BS	residential

15. Measurement method / Type of instrument

BS: ___reflectometric___________________________

PM10 automated:__Beta Gauge Monitor____________________
probe temperature (in °C):_______20_____________

PM2.5 manual:____
automated:_______________________________________
probe temperature (in °C):____________________
optical:____

16. Using PM10 data for your city HIA calculation, did you used a conversion factor in order to compensate losses of volatile particulate matter?

no

yes X if yes, a) which factor: ______________1.25_______________

b) is it a default factor? yes no X

or c) derived from own parallel measurements (reference method vs. TEOM or beta attenuation) yes X no

17. If your PM2.5 data have been calculated from your PM10 data, what conversion factor did you use? factor:_______0.8_____________________

Annex 2003 - mortality data

CITY Cracow
Type of source: Register
Year 2000
Source: Department of Epidemiology and Preventive Medicine of the Jagiellonian University Collegium Medicum, Cracow
Quality control programme: Yes
% Missing data in basic cause death 0,14%
Codification: ICD10, Manual