ARCHIVES OF ENVIRONMENTAL PROTECTION
ARCHIWUM OCHRONY ŚRODOWISKA
vol. 33 no. 4 pp. 3 - 15 2007
PL ISSN 0324-8461

AIR CONTAMINATION WITH NITROGEN DIOXIDE IN THE VICINITY OF GLIWICE TRANSPORT ROUTES BEFORE OPENING THE A4 MOTORWAY FRAGMENT KLESZCZÓW - GLIWICE

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Keywords: air pollution, motorization pollutants, nitrogen dioxide.

ZANIECZYSZCZENIE POWIETRZA DWUTLENKIEM AZOTU W SĄSIEDZTWIE SZLAKÓW KOMUNIKACYJNYCH GLIWIC W OKRESIE POPRZEDZAJĄCYM ODDANIE DO UŻYTKU FRAGMENTU AUTOSTRADY A4 KLESZCZÓW - GLIWICE

W artykule przedstawiono wyniki badań jakości powietrza atmosferycznego w bezpośrednim sąsiedztwie szlaków komunikacyjnych Gliwic. Celem badań była ocena stanu zanieczyszczenia powietrza dwutlenkiem azotu pochodzenia motoryzacyjnego w warunkach typowych dla miast o dużym natężeniu ruchu tranzytowego nieposiadających obwodnic miejskich. Zaprezentowane wyniki wykorzystane zostaną w przyszłości do określenia wpływu uruchomienia obwodnicy na stan zanieczyszczenia powietrza w mieście. W badaniach wykorzystywano pasywną metodę pobierania próbek powietrza z późniejszym zastosowaniem techniki spektrofotometrycznej do oznaczania stężeń dwutlenku azotu. W oparciu o stężenia średniodobowe dwutlenku azotu zmierzone w okresie od lipca 2004 do czerwca 2005 r. w 16 punktach pomiarowych obliczone zostały średnie wartości stężeń średniodobowych w tych punktach. Ze względu na spełnienie warunków o losowym rozkładzie dni pomiarowych i pokryciu czasu pomiarowego, potraktowano je jako średnie stężenia dwutlenku azotu w roku kalendarzowym i porównano ze stężeniem dopuszczalnym w celu dokonania oceny jakości powietrza.

Summary

Results of testing air quality in the vicinity of Gliwice transport routes are presented in the paper. Assessment of air contamination with nitrogen dioxide from motor transport, for typical conditions dominating in big cities of high transit movement without any ring roads was the studies objective. Presented results will be used in the future to determine the impact of opening the ring road on air quality in the city. In the studies, the passive method of sampling, with further application of spectrophotometric technique to determine nitrogen dioxide concentration, was used. Average annual nitrogen dioxide concentrations were based on average daily concentrations measured from July 2004 to June 2005 at 16 measuring points. As they meet conditions for random distribution of measuring days and cover the measuring time, they were treated as average concentrations of nitrogen dioxide in a calendar year and were compared with a permissible concentration to make an assessment of air quality.

INTRODUCTION

Fast development of motor transport, observed in recent years, contributes to the deterioration of air quality and confirms a conviction that cars are one of the greatest ecological problems. The problem first of all concerns urban areas, which are characterized by high intensity of motor transportation and disadvantageous conditions for operation of engines and dispersal of pollutants they produce.

Among numerous pollutants emitted by motor transport, nitrogen oxides (NO_x) have the greatest share of emission from motor transport in its total emission. For example from 1998 in Poland the share of NO_x emitted from motor transport has been almost constant at the level of 30% (29.1–30.9%). Share of other pollutants emission from motor transport is lower and in 2004 it was e.g.: 19.1% for CO, 16.1% for NMVOC and 3.5% for particulate matter [5].

By comparison, in 2001 in UK emission of NO_x from motor transport was 46% of its total emission [14], while in 15 old European Union countries (EU-15) that share in 1999 was 45%, but in new member states (UE-10) in the same period that share was 37% [3]. Thus in Poland the transportation sector is less oppressive for environment in comparison with emission sources in other countries. It results from smaller number of vehicles per one inhabitant of Poland, as Poland is the worst motorized country among OECD states and it has relatively high emission of pollutants from power industry and other sectors, which results form limited measures taken to reduce that emission (reduction of coal consumption, taxes imposed on fuels used in stationary burning places) [17].

Pollutants emission from road transportation shows a significant declining tendency: in the years 1990–2000, in Poland, NO_x emission from road transportation was reduced by 30%, despite an increase of number of cars by 64% and almost double increase of their mobility at the same time, expressed in kilometers per vehicle [5, 17]. Reduction of emission of motor transport pollutants with a simultaneous increase of cars number and increase of their mobility was possible due to increase of fuel combustion efficiency in new designed engines, use of better quality fuels and due to increase of share of cars fitted with catalytic converters from 1% in 1994 to 45% in 2000 (for example in Denmark share of such vehicles was greater by 25% and in Switzerland even greater by 37% than in Poland) [2, 6, 17]. However, it should be stated that despite a significant decline of emission from transport sources, reduction of total emission of NO_x in Poland is mainly determined by power industry due to changes in fuels burning technology. Changes in emission rate of NO_x in that sector have been more evident since 1995 [7].

From a toxicological point of view, most attention is paid to nitrogen dioxide, from all nitrogen oxides, which together with nitrogen monoxide is present mainly in urban agglomerations, causing a direct and indirect hazard to the health of inhabitants. Nitrogen dioxide is generally present as a mixture with other nitrogen compounds. Its activity on human body depends to a large extend on a type and chemical composition of accompanying compounds. In chronic intoxication its activity consists in irritation of throat and oral mucosa as well as conjunctiva, which can lead to tracheobronchitis or even to pulmonary edema. Nitrogen dioxide is biochemical more active than nitrogen monoxide and its harmful activity results in its high affinity to hemoglobin [30]. Those who suffer from illness of respiratory system like asthma are especially susceptible to the presence of nitrogen oxides in air. World Health Organization (WHO) determined the permissive concentration of NO_2 on the level of 200 $\mu g/m^3$ in the case of hour time of averaging of samples and 40 $\mu g/m^3$ for a year [30]. The similar permissive levels of NO_2 concentration are included in a decree of the Ministry of the Environment [24]. Nitrogen oxides are precursors for carcinogenic and mutagenic compounds and in the presence of volatile organic compounds they make photochemical smog in specific atmospheric conditions, and in the presence of steam they also participate in acid rainfalls.

Motor transport plays a very significant role in a formation of healthful conditions in urban areas, especially in the vicinity of transport routes of high traffic intensity. According to WHO estimations, share of cars in NO_x total emission is about 30%, while in town centers that share increases up to 70% [31], contributing in that way, to high pollutants concentration in those regions.

Studies on NO_x levels in air have been carried out for many years in the world and the results can be found in literature [1, 4, 9, 10, 12, 19, 21, 22, 26, 27, 29].

NO_x concentration in Polish urban areas was in 2001 2.5 times higher than outside cities, and in the vicinity of transport routes it was even more than two times higher than it was found in urban areas.

In 2001 the average NO_2 concentration in Polish cities was 18.6 $\mu g/m^3$ and outside cities 7.4 $\mu g/m^3$. At over half of measuring points located in cities outside the zone of motor transportation influence, the average annual NO_2 concentration was in 2001 lower than 20 $\mu g/m^3$. In the vicinity of streets of high traffic intensity, NO_2 concentration is generally higher and it happens that it exceeds permissible value [7].

High NO_2 average annual concentration in urban areas in Poland e.g. in Cracow or Łódź, does not differ significantly from NO_2 concentration measured in big European cities (Rome, Madrid, Amsterdam) and is slightly lower than concentration recorded in European metropolises (e.g. London). While NO_x concentration measured in the immediate vicinity of roads is in the Polish conditions lower than in big European cities, probably due to much lower traffic intensity [7].

Types of moving vehicles, traffic intensity as well as flow of the traffic are the factors which definitely have an impact on pollutants concentration recorded close to the roads. Construction of ring roads undoubtedly reduces the number of cars passing through the cities as well as reduces the share of trucks in city traffic in downtowns, so it helps to improve the vehicles movement. As there is lack of such ring roads, even in cities smaller than Warsaw, Cracow, Poznań or Gdańsk, like Gliwice, which is located on the transit transport route connecting East and West border in the south of Poland as well as connecting two big urban agglomerations: Cracow and Wrocław, we can observe a significant arduousness of car traffic. The problem is more difficult because building development and existing transport system did not allow for construction an of arterial route through the city, which resulted in high intensity of traffic flow through the downtown, with high share of trucks, especially TIRs, on single or dual carriageways with many crossroads with light signaling systems. Some of these roads cross the main trade route and others are neighbor from both sides university center.

OUR OWN STUDIES

Concept of the studies

Up till October 2005 Gliwice was an example of a city in which, due to lack of ring road, the whole road traffic, both local and transit (Cracow – Wrocław), run through the city centre. One-lane roads of high traffic intensity, with a high share of lorries, and of a high ribbon development made the potential places of hazard of high concentration of pollutants emitted together with off gases. To assess air pollution caused by the automotive sources, the measurements of NO_2 concentration in air along the transport routes in Gliwice were taken. Among many pollutants emitted by cars, attention was paid to nitrogen oxides as the pollutants typical for automotive sources.

Measurements of pollutants concentration were carried out before a part of A4 motorway, which is a ring road for Gliwice, was put into use.

The studies, of similar character and range, planned for 2007 will enable to compare the concentration levels and to assess in the future the influence of change in organization of traffic flow in the city on air quality.

Measurements methodology

The samples of air, in which the daily average concentrations of nitrogen dioxide were determined, were taken between July 2004 and June 2005.

Air sampling was conducted near the transport routes in Gliwice, at 16 measuring points. Traffic intensity, character of traffic flow and engines operation (constant speed, acceleration, braking, and operation in the neutral gear) as well as their neighborhood was the criteria for selection of measuring point's location. The characteristic of measuring points is presented in Table 1.

Table 1. Characteristics of measuring points

No.	Location of measuring point	Road character	Neighborhood	Type of vehicle*
1.	Częstochowska – Wrocławska – Strzody – Akademicka	cross-road	dense building development 4-storey	c, l, b
2.	Pszczyńska – Wrocławska – Mikołowska – Nowy Świat	cross-road	dense building development 5-storey	c, l, b
3.	Pszczyńska – Bojkowska	cross-road	dense building development 5-storey	c, l, b
4.	Śliwki – Portowa – Orlickiego	cross-road	lack of building development, single trees	c, l, b
5.	Bohaterów Getta Warsz. – Duboisa – Dworcowa – Piwna (Plac Piastów)	cross-road	nearest buildings in a distance of about 50 m (dense)	c, l, b
6.	Rybnicka	road of high traffic intensity	dense building development 5-storey	c, l, b
7.	Chorzowska	road of high traffic intensity	dense building development 4-storey	c, l, b
8.	Tarnogórska	road of high traffic intensity	low buildings, single houses	c, l, b
9.	State road No. 88 (E40)	road of high traffic intensity	fast traffic road, lack of building development, green, bushes	c, l, b
10.	Daszyńskiego	road of high traffic intensity	few single houses, greenery, neighborhood of planned A4 motorway	c, l, b
11.	Akademicka	road of medium traffic intensity	4-storey buildings, single trees	c, l
12.	Górnych Wałów	road of medium traffic intensity	3-storey buildings, single trees	c, l
13.	Kochanowskiego	road of medium traffic intensity	4-storey buildings, single trees	c, l, b
14.	Kujawska	road of medium traffic intensity	lack of building, green, development, single trees	c, l, b
15.	ZWM	community road	6-storey buildings, single trees	c
16.	Paderewskiego	community road	6-storey buildings, bus stop	c, b

* c – cars, l – lorries, b – buses

The measurements were done at the points situated directly near the transit road which runs through the city centre (points no. 1–4) and the clearway which runs outside the city centre (point no. 9), main transport routes of the city (points no. 5–8, 10) and routes of moderate traffic intensity in the city centre (points no. 11–14). Additional points were located near the housing estate routes (points no. 15–16).

Fifteen daily measurements were carried out at each measuring point in randomly selected time. Additional 37 measurements (totally 52 measurements) were taken at point no. 5 to meet the requirements made for results of periodic measurements, specified in a Decree of the Ministry of the Environment, i.e. to cover 14% of measuring time [25].

The spectrophotometric analysis with passive sampling was used for measurements of nitrogen dioxide concentration. Absorption of nitrogen dioxide took place on the Whatman absorbent paper, soaked with absorbing solution, placed inside a passive sampler. Passive box samplers were used for measurements. They were suspended 1.5 m above the ground level.

After 24-hour exposure absorbent paper was leached by Saltzman solution. Obtained extract was analyzed by spectrophotometric analysis. The measurements of rays' absorption were taken by SHIMADZU UV-2101 PC spectrophotometer at wavelength equal to 540 nm.

Concentration of nitrogen dioxide in tested air was calculated according to relationships presented in [18].

According to the standard [20], nitrogen dioxide concentration was calculated as an arithmetic mean from the concentrations obtained from three samplers, exposed at the same time in the same measuring point. The values, which differed from arithmetic mean by more than 20%, were rejected [20].

Passive methods of air sampling have been commonly used for many years in tests of air conducted at work places and currently they are more frequently used for air quality testing. Their advantages in analysis are following: precision, possibility of determination of low concentrations as well as possibility of elimination of impact of atmospheric conditions and the useful advantages such as: small dimensions, low weight, simple maintenance, reliability or lack of supply requirements cause that passive methods are automatically used to determine air pollutants e.g. by Voivodeship Inspectorate for Environmental Protection. Comparable tests of the passive method with the reference automatic chemiluminescence's method have shown good consistence of results. Average difference in concentrations between both methods did not exceed 10% [8].

A disadvantage of the passive sampling is averaging of concentrations within the time of exposition, which is relatively long. Thus, it is not possible to measure momentary concentrations. [8]. In literature one can find many references to the passive methods used to determine NO_x concentrations, mainly NO_2, as well as to other methods for determination of a concentration of those air pollutants [4, 9, 11, 19, 15, 16, 23, 26, 28, 29].

Measurements of nitrogen dioxide concentrations at roads were accompanied by measurements of traffic flow intensity during peak hours, measurements of traffic intensity during the whole day and distribution of movement of cars and lorries at the selected measuring points, complemented the analysis of nitrogen dioxide concentration in air.

At the crossroads (points no. 1–5), traffic flow intensity during peak hours varied from 1800 to 2220 vehicles per hour, at the point close to a road of high traffic intensity (point no. 9) it was about 2000 vehicles per hour, at the points close to roads of medium traffic intensity it was between 570 (point no. 13) and 940 vehicles per hour (point no. 11).

An example of changeability of traffic flow during a day, at the measuring point located at a crossroad on one of the transit roads in the city centre, is shown in Figure 1.

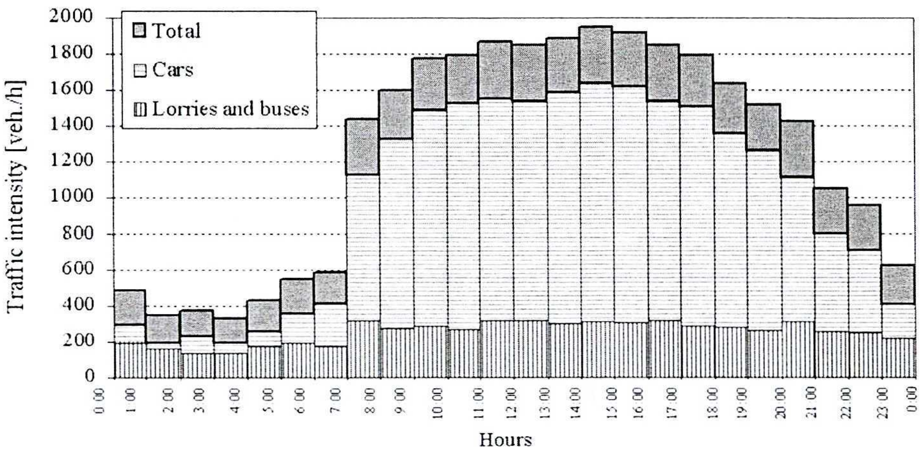

Fig. 1. Daily traffic intensity distribution at the measuring point no. 3

The highest flow intensity, at measuring point no. 3, was observed between 8 a.m. and 8 p.m. without any evident peak. Traffic intensity during that time was high and varied from 1440 to 1950 vehicles per hour. The results show a relatively high share of lorries in a total number of moving vehicles, which is 20% during a whole day. In the morning hours and during the night traffic intensity decreases to the level about 500 vehicles per hour, and during those hours the share of lorries increases to about 40%.

RESULTS OF ANALYSES

Average values of daily concentration, treated as databases attributed to a given measuring point, were statistically analyzed to interpret the obtained results. Diversity of topographical conditions and conditions of engine operation at each measuring point, leads to a high diversity of concentration of air pollutants. Giving the characteristics, which describe typical concentration values, which are expressed by: arithmetic mean, median and 25th percentile and 75th percentile is one of the methods used to assess this diversity. Also characteristics of diversity, e.g. deviation from mean value, which most frequently is expressed by standard deviation, interpreted as mean diversity of results or as relative error, which is a standard deviation of mean value [13].

Table 2 presents statistical descri-ption of nitrogen dioxide concentration in air at each measuring point.

Despite high variability of nitro-gen dioxide's daily average concentration in air at each of measuring points, there are some specific features of concentration distributions, presented as the box-and-whisker plot in Figures 2 and 3.

Table 2. List of selected measures of statistical characteristics of daily average concentration of nitrogen dioxide in air at measuring points no. 1–16

Characteristics	Measuring point																
	1	2	3	4	5 [1)]	5′ [2)]	6	7	8	9	10	11	12	13	14	15	16
Number of tests	15	15	15	15	15	52	15	15	15	15	15	15	15	15	15	15	15
Minimum [μg/m³]	30.2	23.3	26.9	24.9	22.7	22.6	15.1	9.5	9.5	13.0	7.4	16.6	9.7	11.4	9.7	9.3	8.9
Maximum [μg/m³]	66.1	69.4	66.6	63.0	60.7	60.7	70.1	49.0	43.9	64.5	40.3	40.8	41.0	45.2	44.8	32.9	48.5
Mean value [μg/m³]	49.4	43.6	47.3	39.4	38.3	36.0	35.5	27.2	28.7	31.6	21.5	29.7	26.7	28.7	27.4	20.6	20.9
Median [μg/m³]	50.7	41.5	49.2	37.3	38.4	35.2	35.7	28.1	26.7	30.0	20.5	30.9	30.2	26.7	27.1	21.5	17.0
25th percentile [μg/m³]	37.9	34.5	40.0	31.2	26.7	29.3	24.8	19.8	22.6	18.8	14.3	26.4	17.2	21.6	22.3	14.4	9.7
75th percentile [μg/m³]	59.4	55.3	54.2	44.6	48.0	41.8	42.1	33.2	37.9	42.1	28.0	34.0	34.7	36.2	34.5	24.1	27.4
Standard deviation [μg/m³]	10.6	13.1	10.2	10.9	11.3	8.6	12.8	11.1	10.8	14.0	9.6	6.6	10.3	9.0	8.7	7.4	12.3
Relative standard deviation [%]	21.5	30.0	21.6	27.7	29.5	23.9	36.1	40.8	37.6	44.3	44.7	22.2	38.6	31.4	31.8	35.9	58.8
Standard error [μg/m³]	2.7	3.4	2.6	2.8	2.9	1.2	3.3	2.9	2.8	3.6	2.5	1.7	2.6	2.3	2.2	1.9	3.2

[1)] values for 15 all day measurements (Piastów Square)
[2)] values for 52 all day measurements (Piastów Square)

The first plot presents a box made of 25th percentile and 75th percentile. The cross inside the box determines value of median, i.e. 50th percentile. The values that were far from the central point of distribution (median), were separated as diverged values.

Location of point in a distance longer than one box length, i.e. gap between two end quartiles, was a criterion for separation. Extreme values, for which the criterion of location in a distance longer than 2 boxes, beginning from 25th percentile and 75th percentile, was accepted, were not found in the results. Whiskers illustrate the values of the lowest and the highest observed concentrations, which are not diverged values. Also values of acceptable annual average NO_2 concentration (D_a) as well as value of acceptable concentration increased by a margin of tolerance (MT), being accepted in 2005, were marked on a plot.

Figure 3 presents mean concentration, standard error and standard deviation. Determined standard deviations, as a measure of absolute differentiation of measured concentration, presented in a form of whiskers, serve to specify a typical range of concentration changeability at each measuring point. Boxes, which illustrate the standard error, determine a random error made during estimation of arithmetic mean concentration.

Standard procedures included in Statistica version 5.0 package of Stat Soft Inc. Company, were used for statistical analysis of results.

Values relating to points no. 5 and 5′ concern the measurements taken at the same measuring place. In the first case (point no. 5) they were related to series of 15 measurements in which air samples were taken on the same days

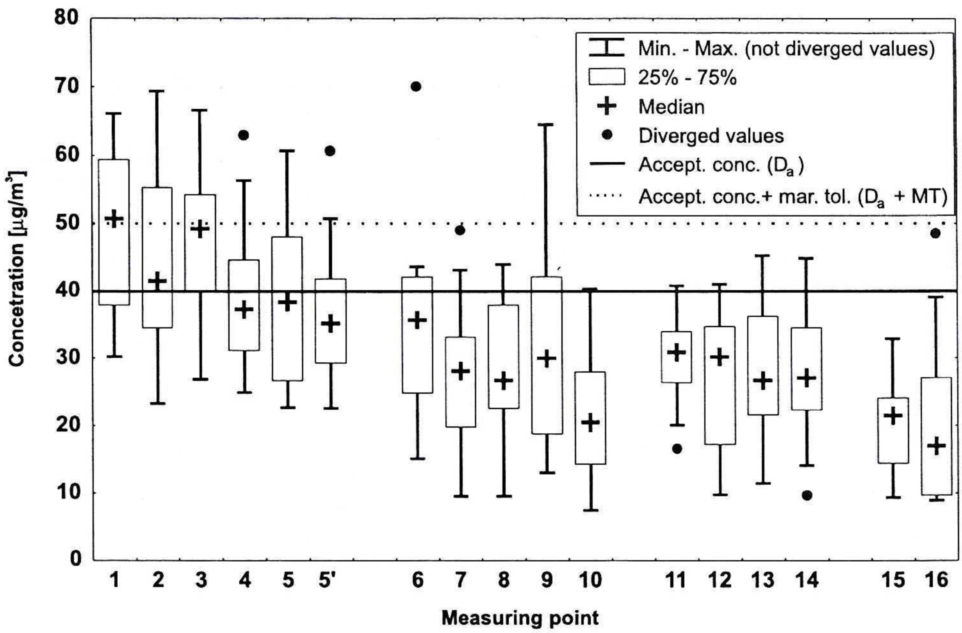

Fig. 2. Box-and-whisker plot of nitrogen dioxide concentration: mean concentration values, standard error and standard deviation

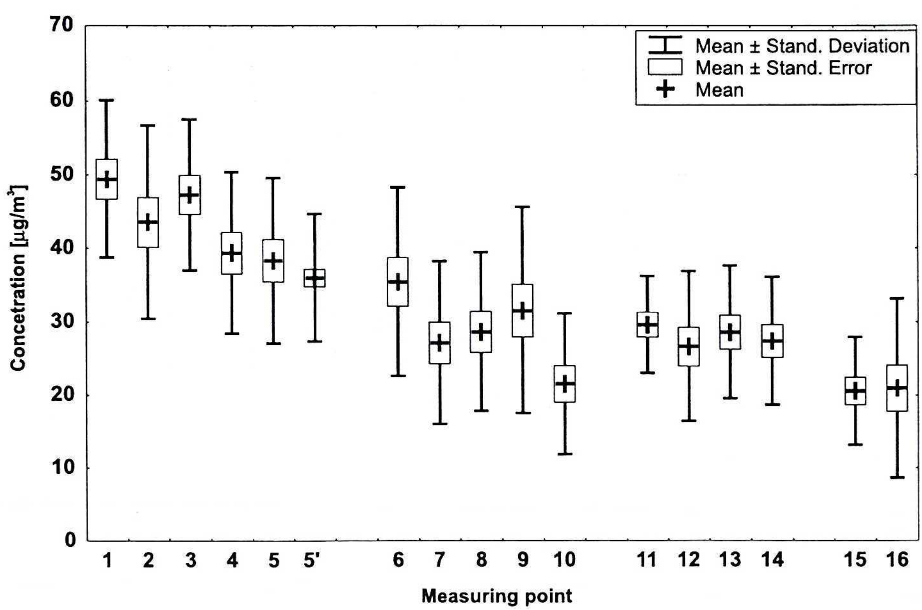

Fig 3. Box-and-whisker plot of nitrogen dioxide concentration: minimal values, maximal values and quartiles of concentration distribution

as in other measuring points (no. 1–4 and 6–16). In the second case (point no. 5') they were related to full 52 measurement series made at this point, covering the measuring time required for periodic measurements included in the Decree of the Ministry of Environment.

DISCUSSION ON RESULTS

Range of minimal nitrogen dioxide concentration was between 7.4 $\mu g/m^3$ and 30.2 $\mu g/m^3$ for all the measuring points. At crossroads the minimal concentration was between 22.7 $\mu g/m^3$ and 30.2 $\mu g/m^3$, and at roads of high and medium traffic intensity it was between 7.4 $\mu g/m^3$ and 16.6 $\mu g/m^3$, and on local roads it varied from 8.9 $\mu g/m^3$ to 9.3 $\mu g/m^3$.

Maximal concentration of nitrogen dioxide was between 32.9 $\mu g/m^3$ and 70.1 $\mu g/m^3$. At the measuring points located close to crossroads it was between 60.7 $\mu g/m^3$ to 69.4 $\mu g/m^3$ at the city roads it was between 40.3 $\mu g/m^3$ and 70.1 $\mu g/m^3$ and at the local roads it was from 32.9 $\mu g/m^3$ to 48.5 $\mu g/m^3$.

Mean values of average daily concentrations at all measuring points for 15 measurement series varied from 20,6 $\mu g/m^3$ to 49,4 $\mu g/m^3$. The highest mean concentration was at crossroads (38.3 $\mu g/m^3$ to 49.4 $\mu g/m^3$), lower at roads (21.5 $\mu g/m^3$ to 35.5 $\mu g/m^3$), and the lowest along the local roads (20.6 $\mu g/m^3$ to 20.9 $\mu g/m^3$).

The lowest average daily NO_2 concentration recorded in the whole measurement period was equal to 7.4 $\mu g/m^3$ and it was recorded at the measuring point no. 10, located at the outlet road at a distance of about 7 km from the city center. Only a few houses and some trees, meadow fields surrounded the point. Such a way of land development ensures advantageous conditions of pollutants propagation.

The highest average daily NO_2 concentration equal to 70.1 $\mu g/m^3$ was recorded at the measuring point no. 6 located at a place surrounded by compact four-storey buildings with very bad ventilation. This was the road of high traffic intensity with a lot of cars, buses and lorries. Due to close crossroads, there was a traffic jam at that measuring point during peak hours and a traffic flow was very slow and engines operational conditions were very differentiated. In a statistical analysis (Fig. 2) the mentioned above concentration value was treated as the diverged one. The highest not diverged average daily concentration value equal to 69.4 $\mu g/m^3$ was recorded at the measuring point no. 2, at very busy crossroads of five single, dual and triple carriageways, surrounded by compact building development.

As regards analyses, the most important are those NO_2 concentration values, which were averaged for the whole measuring time. The lowest average daily concentration for the whole period of measurements i.e. 20.6 $\mu g/m^3$ was observed at the measuring point no. 15. That point was located at a community road of low traffic intensity, where only cars were moving. The highest average daily NO_2 concentration for the whole measurement period equal to 49.4 $\mu g/m^3$ was recorded at the crossroad of dual and triple carriageways, at the measuring point no. 1. At that point there was an intense traffic flow of vehicles including lorries, and due to light signals operational conditions for car engines were disadvantageous, i.e. braking, acceleration and neutral gear operation.

Figures 2 and 3 as well as data from Table 2 indicate for similarity of nitrogen dioxide concentration changeability in some groups of measuring points. Generally, a division into groups coincided with a division into points located at crossroads, at city

Table 3. Ranges of selected statistical parameters for different road categories

Statistical parameter	Crossroads	City roads	Community roads
Medium concentration [μg/m³]	38.3–49.4	21.5–35.5	20.6–20.9
Minimal concentration [μg/m³]	22.7–30.2	7.4–20.1 [2)]	8.9–9.3
Maximal concentration [μg/m³]	56.3–69.4 [1)]	40.3–49.0 [2)]	32.9–39.1 [3)]
25th percentile [μg/m³]	26.7–40.0	14.3–26.6	9.7–14.4
75th percentile [μg/m³]	44.6–59.4	28.0–42.1	24.1–27.1 [3)]
Median [μg/m³]	37.3–50.7	20.5–35.7	17.0–2 1.5

[1)] diverged value in point no. 4 was rejected
[2)] diverged values in points no. 6, 7 and 11 were rejected
[3)] diverged value in point no. 16 was rejected

roads and at community roads in Table 1. A list of ranges of selected statistical parameters for indicated three categories of roads is presented in Table 3.

The highest values of average minimal, medium and maximal NO_2 concentrations as well as 25th percentile, 75th percentile and medians of average daily concentrations were observed at crossroads. The values were relatively smaller at city roads and the smallest at community roads.

Analysis of range of measured concentrations (gap) as well as standard deviation and standard error for individual measuring points does not enable to group the points, as wide and overlapping intervals of changeability of mentioned statistics are observed for each mentioned above 3 categories of measuring points.

At one of the measuring points (point no. 5) full series of 52 measurements were taken. That is a number required to cover the measuring time for periodic measurements, according to [25]. The 15 values of NO_2 concentration, which were taken at the same time as at the rest measuring points, were separated from all the 52 measurements. Two series of measurement data for the same location enabled a statistical comparison of results, which were presented in Table 4.

Table 4. Statistical parameter for 15 and 52 measurement series for measuring point no. 5

Statistical parameter	Number of measurements		Relative error [%]
	n = 15	n = 52	
Mean [μg/m³]	38.3	36.0	6.0
Median [μg/m³]	38.4	35.2	8.3
Minimum [μg/m³]	22.7	22.6	0.4
Maximum [μg/m³]	60.7	60.7	0.0
25th percentile [μg/m³]	26.7	29.3	8.9
75th percentile [μg/m³]	48.0	41.8	12.9
Standard deviation [μg/m³]	11.3	8.6	23.9
Standard error [μg/m³]	2.9	1.2	58.6

From the Table 4 it results that a reduction of number of measurements from 52 to 15 raised only a little the value of calculated average concentration and median, and practically did not influence the minimal or maximal concentration, while an error in estimation of 25th percentile, 75th percentile and median was about 10%. Increase of number of analyzed samples causes a significant decrease of standard deviation and especially of standard error.

ASSESSMENT OF AIR QUALITY

According to the Decree of the Ministry of the Environment [25] the periodic measurements of nitrogen dioxide concentration require covering 14% of time. This condition was met only at one measuring point located at Piastów Square (point no. 5). At this point 52 measurements were taken, both in the summer and in wintertime.

Comparing average annual NO_2 concentration calculated on the basis of average daily concentration (36.0 $\mu g/m^3$) with permissible annual concentration, equal to 40 $\mu g/m^3$, it could be found that permissible nitrogen dioxide concentration had not been exceeded at that measuring point. Obtained value of average annual nitrogen dioxide concentration was equal to 90% of permissible concentration.

Fifteen measurement series were taken in all selected measuring points (no. 1–16). Such number is insufficient to meet the condition determined in the Directive [25]. However, the impact of reduction of covering the measuring time on accuracy of determination of NO_2 average annual concentration was estimated on the basis of measurements taken at point no. 5. Average annual nitrogen dioxide concentration at this point, calculated for 52 measurement series is smaller by 6% than concentration calculated for series of 15 measurements. Thus it can be found that shorter measurement series than recommended in [25] have not a significant impact on obtained average NO_2 concentration. Therefore, average daily NO_2 concentration at points no. 1–16, calculated on the basis of 15 all day measurements, can be treated as an average annual concentration and an error will not be significant when it is assumed that the time of measurements is selected randomly and includes both summer and winter months.

When comparing obtained average annual nitrogen dioxide concentration at points no. 1–16 with permissible concentration level, it was found that permissible concentration was exceeded at points 1, 2 and 3 located at the crossroads. NO_2 concentration exceeded permissible value at those points by 8.5% to 23.5%. In other points, where permissible concentration was not exceeded, average annual concentration of nitrogen dioxide was equal to 95.7–98.5% of permissible concentration level for crossroads, 53.7–88.7% of permissible concentration level for city roads and about 51.5% for community roads.

Obtained average annual NO_2 concentration values were also compared with permissible concentration extended by a margin of tolerance, which was established for 10 $\mu g/m^3$ in 2005. When that margin of tolerance was included none of the concentration values exceeded the permissive level at any measuring point.

Average year NO_2 concentrations measured from July 2004 to June 2005 at communication routes in Gliwice can not be referred to the concentrations measured at air monitoring stations located at communication roads in Chorzów and Częstochowa, as at the end of 2004 and the beginning of 2005 there was a reorganization of the entire Silesian Air Monitoring System. Average year NO_2 concentrations measured at Chorzów and Częstochowa stations were in 2005 respectively 42 $\mu g/m^3$ and 33 $\mu g/m^3$ [35]. NO_2 concentrations at crossroads with density of buildings (points no. 1–3) were higher from average year NO_2 concentration in Chorzów by 11% and in Częstochowa by over 40%. At other crossroads (points no. 4 and 5) the concentrations were between concentrations measured in Chorzów and Częstochowa. However, the concentrations are lower than average year NO_2 concentrations measured at transport measurement stations in big Polish cities: Warsaw, Wrocław and Cracow, were concentrations were equal respectively to 65.3 μg/m³ (in 2006), 67.5 μg/m³ (in 2005), and 63.0 μg/m³ [32–34]. However, traffic intensity is much higher in those cities due to higher traffic capacity of roads.

CONCLUSIONS

1. Average annual nitrogen dioxide concentration exceeded permissible value at measuring points located in Gliwice at crossroads with high traffic intensity and of high share of lorries. The permissive concentration level was not exceeded at roads of high and medium traffic intensity and at community roads.
2. Average annual nitrogen dioxide concentration did not exceed permissible value extended by a margin of tolerance, which was set for the year 2005, at any measuring point located in Gliwice.
3. Average year nitrogen dioxide concentration in Gliwice at crossroads of high density of buildings and high traffic intensity are higher than concentrations in other cities of Silesian Voivodeship by 11% to even 40%.
4. Reduction of number of measurement days in relation to a number required by the Ministry of Environment Decree has no an important impact on the value of average year nitrogen dioxide concentration. Relative error between 15-day and 52-day measurements, made during determination of average annual nitrogen dioxide concentration is equal to 6%.

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Received: April 9, 2007; accepted: September 3, 2007.