

THE IMPACT OF CONSTRUCTION WORKS CONDUCTED ON THE ROUTE DTŚ ON A LOCAL AIR QUALITY EVALUATED WITH THE USE OF NO₂ MEASUREMENTS

Walter MUCHA ^{a*}, Jacek ŻELIŃSKI ^b

^a PhD Eng.; The Silesian University of Technology, Department of Air Protection, ul. Konarskiego 22B, 44-100 Gliwice
E-mail address: walter.mucha@polsl.pl

^b PhD Eng.; Institute for Chemical Processing of Coal, ul. Zamkowa 1, 41-803 Zabrze

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Abstract

One of the basic documents of the Environmental Impact Assessment (EIA) procedure is the Environmental Impact Report. It contains information obtained during the investor's assessment of any impact on the environment that may be caused by the object – also from the side of construction works at the investment stage. The authors, on the basis of nitrogen dioxide concentration data obtained from continuous, multi month measurements carried out with the use of the OPSIS device over the diametrial route DTŚ construction site in Gliwice, have evaluated the NO₂ emission impact on the atmospheric air at the construction phase. The measurements made by the authors enabled in verifying the correctness of the assessments and comments regarding the impact of construction works conducted on the route DTŚ on the atmospheric air in the construction phase, contained in the Environmental Impact Report.

Keywords: Air pollution; Nitrogen dioxide; Motoring sources of NO₂; Differential optical absorption spectroscopy; OPSIS.

1. PREFACE

The rout Drogowa Trasa Średnicowa (DTŚ) Katowice – Gliwice (diametrial highway) creates an important way from the communication and economic point of view for the whole, strongly urbanized area of the so-called Katowice conurbation, which is a polycentric urban form. It integrates 52 municipalities of the Śląskie Voivodeship and 2 municipalities from the Małopolskie Voivodeship, covering an area of 1354 km² inhabited by 2,631.2 thousand inhabitants (in 2017) [1]. This conurbation forms the largest agglomerated area in Poland. In the conurbation area there is an important transport hub, located at the intersection of two routes of European importance - A1 and A4 motorways. About 12% of traffic in the Conurbation is the transit traffic running mainly through the system of these highways, the remaining 88% is about local origin [2]. Its high intensity forced

the implementation of locally integrated public transport system, which DTS is the most important element.

The main tasks of DTŚ include [2]:

1. Providing basic road links between individual functional units of the conurbation,
2. Increasing the speed of communication, and therefore saving time of travel,
3. Ensuring traffic safety for all road users and reducing the number of accidents,
4. Introduction of new quality in the post-industrial landscape, creating its positive image, which strengthens the attractiveness of these areas for investors.
5. Reduction of environmental nuisance.

From the point of view of the last task, the great infrastructural investment as DTŚ appears not only as opportunity for solving – at least in part – local problems with air purity. It also creates a real threat due to additional air contamination steaming from the vast construction works right in a center of the city.

2. INTRODUCTION

The reducti of environmental nuisance after the start of DTŚ exploitation is carried out by increasing the flow of traffic enabling to maintain the vehicles speed at the optimum level and directing the part of vehicles out of usually narrow and densely built-up streets of the urbanized area. As a result a reduction in the concentrations of traffic-based air pollutions, noise, vibration and the number of road collisions were expected. Works on DTŚ were started in Katowice in 1979, commissioning of the last of its planned sections – section G2 in Gliwice (Fig. 1) – took place on March 22, 2016.

Section G2 in Gliwice, located in the downtown part of the city, has a length of 5.565 km and links the existing interchange DK 88 with Portowa street (north-west of the center) with the existing section of the G1 DTŚ. These areas adhere directly to the ones belonging to the Silesian University of Technology in Gliwice. On the described section, DTŚ is a G2/2 class road (2 roadways with 2 lanes in each direction). The scope of investment on the aforementioned section of the route included: road works, engineering structures, retaining walls, drainage and lighting of the route, reconstruction of the municipal infrastructure. The elements of environmental protection in the form of oil derivative separators, acoustic screens and green insulation belts were also implemented. Construction works related to the construction of the route create the source of the pollutants emission into the atmosphere. Such emission has a temporary and local character – it varies depending on the place of work and the phase of task implementation, and ceases when the investment is completed.

These works are mostly performed with use of diesel-powered machines. They are characterized by emissions regulated and thus limited in a less strictly manner than road vehicle motors of various type [3, 4]. As one can estimate, with the sales of diesel-powered construction machines up to 1 mln units in the first decade of XXI century [5] and 10–12 year working life expectancy [6] with the run of about 50,000 hours each [7], the total work hours number of



Figure 1.
The line of the sections G2, G1, Z4 and Z3 run

such machines $50 \cdot 10^9$ could be reached, not accounting heavily exploited old vehicles of this type still working in many regions in the world. Also the manner they work – in groups of several units concentrated on a relatively small area, results in the danger of emitted contaminants hot-spots creating. It creates the especially important element of overall air contamination in towns and other populated areas. Due to presented numbers, facts and highly adverse health and environmental impacts associated with diesel exhaust gases [8], the work of construction machines appears as a remarkable environmental problem.

For this reason, the environmental aspects of construction machines work creates the object of interest for environmental management authorities and construction management. Following this interest, the research is conducted in order to evaluate the level and characteristics of emission. The results are presented mainly in a shape of emissions factors related to work hours or fuel used, also more comprehensive forms of emission data management are met – mainly in a form of emission models. The best known among them is the NONROAD2008a emission model prepared by the U.S. EPA [9]. It comprises emission factors of main substances emitted from diesel-engines used in construction machines, measured with the use of steady-state modal engine dynamometer tests, as: HC, CO, NO_x, CO₂, SO₂, PM₁₀, PM_{2.5}.

Also other measurement results can be found in literature, mainly touching the real work conditions, collected with use of portable measuring systems [5, 6, 10, 11]. Also the comparisons between real data and the EPA NONROAD model have been done [11] which shown important differences in their values, with the lower ones revealed in real work measurements [12].

The knowledge of emission factors creates the base for emission control activity. The emissions can be modified in a way incorporating several factors. These factors can be divided in 4 main groups [13]:

1. Equipment – type, year of manufacture, engine model, size, power etc.
2. Operating conditions – different work types and conditions are reflected by load conditions, engine wear, fuel consumption and emission levels.
3. Equipment adaptation – the optimal selection of the machines and their configuration in order to match the specifics of the work and thus to maintain possibly high productivity along with lower costs.
4. Maintenance – consistency with the general maintenance rules and manufacturer's instruction manuals.

All these parameters are vital – first three of them should be thoroughly considered on preparatory stage of the investment, the last one depends mainly on the knowledge and the maintenance culture of operators.

Emission from construction equipment is not the only one appears during construction works. Also particles and gases appearing along with high temperature processes are realized – like bitumen heating [14] or smashing and removing of asphalt by a saw and an excavator and renewal of asphalt pavement by a finisher and a road roller [15]. Also several accompanying works – from grading of subsoil to cleaning of mechanically treated road have been taken into consideration. This second investigation enabled to estimate the yearly average NO_x emissions by all construction works in Germany for 13500 Mg, therein 6300 Mg from earthworks, and 170 Mg from asphalt paving.

While emissions connected with construction works are quite good recognized, the influence of construction works on local air quality are not so frequently evaluated. In this scope such positions as [15, 16, 17, 18] should be pointed.

In measurements of air contamination portable measuring systems have been used, as the like of mobile aerosol research laboratory (MoLa) equipped with instruments for real-time measurements of trace gases concentrations (NO_x, CO, SO₂, O₃, CO₂) as well as particle concentration, composition (including particulate polycyclic aromatic hydrocarbons) and size distribution [19]. The concentrations are usually measured in a distances 20–100 meters from the work area, downwind, on the altitude of a few meters. Main meteorological data are also observed locally and logged during measurements (wind speed, direction, gusts, air temperature, humidity and pressure) [19]. It helps to relate the concentrations obtain to weather conditions.

From the formal point of view, several tasks should be done and documents prepared prior to start of construction investment process in order to fulfill the rules of the law, also those connected with environment protection. One of the basic task to do is to complete the Environmental Impact Assessment (EIA) procedure which requires preparing the Environmental Impact Assessment Report. It contains information obtained during the investor's assessment of impacts that may be caused by construction, operation and liquidation carried out as part of the project. Elements of the Report listed in art. 66 of the EIA Act contain, include point 6: "Report on the impact of the undertaking on the environment should take into account the impact of the project at the stages of its implementation, operation or use and decommissioning". In the report the background concentrations are used as the measure of overall air contamination. These concentrations are summed with concentrations caused by specific sources under concern, creating the overall concentration level. For this particular investment of DTŚ route, the assessment was carried out in view of the lack of relevant calculations in the Environmental Impact Report: "... Due to the fact that the emission of pollutants into the air is unorganized, variable in time and space, transient – many of its aspects are difficult to modelling. Considering that the nuisance related to the investment will cease with the completion of construction, calculations of emissions and spread of pollutants for this phase have not been carried out" [20]. This approach to estimating the air load in the investment phase while preparing the Environmental Impact Report is commonly found in Poland.

In order to verifying the correctness of presented approach, the long-time measurements have been undertaken. On the basis of the nitrogen dioxide concentration data obtained from continuous measurements carried out with the use of the OPSIS device over the DTŚ construction site, an evaluation of the NO₂ emission impact on the atmospheric air in the neighborhood of this road facility in the investment phase has been made.

3. MEASUREMENT METHODOLOGY

To measure the concentrations of nitrogen dioxide, an OPSIS Optical Analyzing System AR 500 device was used, which operation is based on the DOAS technique (Differential Optical Absorption Spectroscopy). This method uses the Lambert's – Beer absorption law which defines the relationship

between the amount of radiation absorbed on the route of the light beam and the number of molecules that are located along the measuring path. The measurement is based on the emission of a light beam from a source, which is a high-pressure xenon lamp, along a specially selected measuring path. This type of lamp emits light of constant intensity and a broad spectrum, including infrared and ultraviolet radiation, among others. Like the transmitter, the receiver is also equipped with a mirror in which the light is concentrated at the end of the optical fiber located in the focus of the mirror. After passing through the measurement path, the beam reaches the receiver from where it is sent to the spectrometer. At this point, the beam is subject to analysis, which makes it possible to determine the amount of light loss due to absorption along the measuring path [21, 22].

For technical reasons (measurement unit partial malfunction), measurements have been limited to NO_2 only – nitrogen monoxides NO concentration measurement proved to be impossible. They were carried out over the construction site at the exit of the route from the excavation near Konarskiego street (Fig. 2),



Figure 2.
A general view of the measurement area

covered over the period of the most intense works on the observed section, covering the months from February to June 2015.

The light source was placed on the Emergency Service building, a receiver in the window of the building of the Faculty of Engineering and Environment of the Silesian University of Technology (Fig. 3).

The measurement parameters are as follows:

- The height of the source foundation: approx. 5 m above the land surface,



Figure 3.
A photo of the light beam transmitting and receiving device





Figure 4.
Measurement area plan [Google maps]

- The height of the receiver's foundation: approx. 8 m above the ground surface,
- Active length of the measuring path: 144 meters,
- Direction of the measuring axis in relation to the north: approx. 231° (Fig. 5),
- Direction of the DTŚ (east-west) axis: around 299° (Fig. 5),

The measurement area plan is presented in Fig. 4.

After processing measurement results, the analysis was conducted with taking into account results obtained from the automatic station belonging to the Provincial Inspectorate of Environmental Protection (WIOŚ) in Katowice [23]. The station is located in Gliwice on Mewy street (Sikornik estate) about 2,600 meters south-east of the OPSIS system receiver. It is located in the center of a typical housing estate, consisting mainly of 4 or 11-storey buildings connected to the heating network. There is no road

of a supra-local character going through the estate, from the west and south – that is from the appearance of dominant winds – the estate borders with farmlands.

4. MEASUREMENTS

NO₂ measurements obtained from the OPSIS device, available with a time interval of 4 minutes (15 measurements per hour), were averaged for periods of full clock hours. For individual months and the entire 5-month measurement period, maximum and average values of NO₂ concentrations were found – they are presented in Table 1. Along with them the values obtained from WIOŚ monitoring station are presented. They are considered as the air contamination background which in formal documents creates the measure of overall air contamination for the whole

Table 1.
Maximum and average values of NO₂ concentrations in particular months, µg/m³

	month:	February	March	April	May	June	5 months
WIOŚ	maximum	99	100	93	77	87	100
OPIS	maximum	130	132	120	107	104	132
WIOŚ	average	34	29	19	20	17	24
OPIS	average	89	87	83	83	81	85

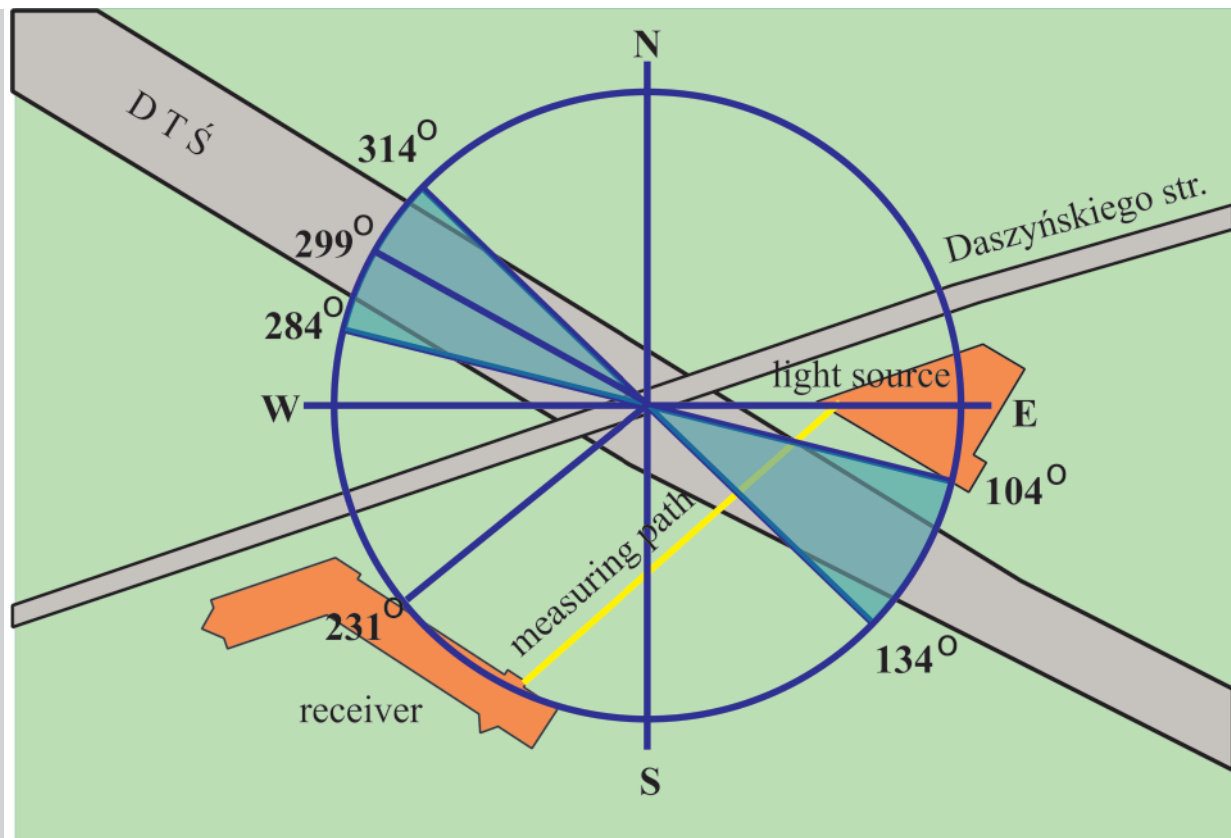


Figure 5.
The ranges of wind rose directions used for the construction works impact calculations

city. In reality it does not – as for the absolute value. Despite this, the dynamics of differences between this value and value under investigation reveals the behavior and the character of the latter which leads to useful conclusions.

In order to separate meteorological situations implying the impact of work carried out along DTŚ on the results of measurements from situations not having such impact, available data were divided into two groups: in the first there were concentrations obtained from 6.00 to 16.00 with wind directions in the range of 104°–134° or 284°–314°, in the second group all other results (Figure 5). Choosing the time interval and the range of wind directions deciding on the belonging of the results to the first group was guided by the following premises:

- according to recommendations included in the impact report, the most onerous work due to noise should be performed from 6.00 to 19.00. In practice – as shown by the authors' observations – they were performed in a shorter period of time, covering the time interval from 6.00 to 16.00. This interval was considered an effective period of increased emis-

sion, characteristic for works carried out at the DTŚ construction site,

- the range of wind directions 104°–134° and 284°–314° represents the directions of inflow of air masses to the vicinity of the measuring beam, which can be identified with emission sources related to works performed at the DTŚ construction site. Such selection is related to the mutual position of the axis of the measuring beam and the longitudinal axis of the route being constructed and takes into account the assumption that the emission sources placement with respect to the route axis can be deviated by no more than $\pm 15^\circ$ (Fig. 5).

5. RESULTS

The mean values of NO_2 concentration in the measurement period for data group 1, which includes works on DTŚ and for data group 2 – in which the impact of these works on NO_2 concentrations in the air was not included are presented in Table 2. It spans concentrations obtained from the OPSIS system, concentrations measured in WIOŚ station (treated as

Table 2.
Average 5 months NO_x concentrations measured by OPSIS system and WIOŚ station, the difference between them (local sources) and share of local sources in overall concentration

	OPSIS measurement	WIOŚ station (background)	Local sources	Share of local sources
	µg/m ³	µg/m ³	µg/m ³	%
group 1	84	18	66	79
group 2	85	24	61	72
				Difference: 7%

NO₂ background), the difference between them assumed as the concentration level generated by local sources and the percentage share of concentrations generated by local NO₂ sources in concentrations measured by the OPSIS system.

6. DISCUSSION OF RESULTS AND CONCLUSIONS

Along with the Polish law, the impact of construction works on the air quality should be evaluated in advance, before they start. Such assessment is incorporated usually in the Environmental Impact Report which is a part of documentation prepared for every investment. In practice, the assessment has overall, vague character, sometimes only it is based on calculations and analysis of main contaminants concentrations. By far there was a lack of the concentration measurements in the neighborhood of the big road facility in the construction stage.

Using the nitrogen dioxide concentration data obtained from 5 months continuous measurements of NO₂ emission carried out with the use of the OPSIS device over the DTŚ construction place in Gliwice, the more precise impact assessment of construction works on the atmospheric air in the neighborhood has been possible. For technical reasons, nitrogen monoxides NO concentration measurement in this experiment proved to be impossible. Despite the fact that NO is the basic compound in nitrogen compounds emission to the air from internal combustion engines, after introduction into the atmosphere, it is relatively quickly oxidized to nitrogen dioxide NO₂ which becomes the main nitrogen oxides compound and pollutant in the air. Thus the NO_x long – term, very uncommon in Poland, concentrations measurement results helps to present a few interesting conclusions.

The difference in shares of local NO₂ emission sources between both groups of the measured concentrations, manifested by the increased value for the first data group, seems to be connected with the additional influence from the sources related to the works on DTŚ construction. This difference is not significant, but noticeable – it amounts to approx. 7%. It can be assumed that it reflects the share of sources related to construction works of DTŚ in measured concentrations. This result is comparable with the conclusions of other investigations. For instance Helms and Heidt [17] found that up to 6% of NO_x (and up to 10% of PM) traffic related emissions in Germany are caused by mobile construction machinery. Under the assumption, that concentrations in the air in a case of emission sources of low height, are proportional to emissions (what is fulfilled roughly in city-centers) and taking into consideration the 48% share of NO_x emission from road-transport sector in total [24, 25, 26, 27] (39% road transport + 9% non-road transport), the share of construction machines in total NO_x concentration yields about 3%. The similar calculations made by Millstein and Harley [18], which assigned 11% of NO_x (and 14% of total PM_{2.5}) emissions to such sources means over 5% share in total concentration. Both presented values are below the 7% presented in this work, although the conditions of the construction works investigated here are especially difficult – due to the considerable works concentration, and a recessed type of terrain (the access to a road tunnel) hindering dispersion of emitted substances. In a work of Peter Faber [15] the straight NO_x concentrations connected with employment of specific types of construction machines or specific construction operation are presented (mg/m³):

Earthworks	5.5–50
Road roller	40
Road roller/sweeper	38
Asphalt sawing	12
Asphalt smashing	139
Plate compactor	14
Asphalting	98

Taking into consideration that several machines of various type and different operations have been carried out in the same time, both: maximum (132 mg/m³) and average (85 mg/m³) concentration values obtain in the presented work seem to be quite representative.

The measurements have shown that the permissible

1-hour NO₂ level in the air in the vicinity of the conducted construction works was not exceeded. At the same time, it is likely the permissible annual NO₂ level in the air to be exceeded independently from construction works, due to emission connected with local sources, concentrated in that part of the town (average 5 months concentration for group 2 reaches 61 µg/m³ – more than 150% of permissible annual value). The most important conclusion stemming from the presented data is that comments and assessments regarding the lack of significant impact of investments on the atmospheric air in the construction phase (except dust) contained in the Environmental Impact Report seem – at least regarding NO₂ concentrations – to be confirmed in the presented measurements.

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