AIR POLLUTION DUE TO ROAD TRAFFIC IN LJUBLJANA

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Izvirni znanstveni članek
COBISS 1.01

Abstract
Air pollution is due to road traffic an inevitable outcome of internal combustion in engines of vehicles and some other processes. Air near the roads is more polluted with some pollutants, such as carbon monoxide, nitrogen oxides, ozone, particulate matter and some others. Monitoring the air quality is a key issue, when one wants to estimate environmental impacts of the road traffic. The article shows a method of passive samplers for air quality monitoring along different roads in the area of Ljubljana Municipality.

Key words: Municipality of Ljubljana, road traffic, air pollution, diffusive samplers, air quality, nitrogen dioxide.

PROMETNO ONESNAŽEVANJE OZRAČJA V LJUBLJANI

Izvleček
Cestni promet povzroča emisije izpušnih plinov in delcev, ki nastanejo kot posledica izgorevanja goriv v motorjih z notranjim izgorevanjem pogonskih goriv in nekaterih drugih procesov. Zrak ob cestah je zato obremenjen z onesnaževali kot so dušikovi oksidi, ogljikov monoksid, lahko hlapni ogljikovodiki, delci in še nekateri drugi. Spremljanje stanja kakovosti ozračja ob cestah je z vidika proučevanja vplivov prometa na kakovost zraka ključno pri ocenjevanju okoljskih vplivov prometne dejavnosti. Prispevek govori o uporabi difuzivnih vzorčevalnikov pri merjenju onesnaženosti ozračja z dušikovim dioksidom ob večjih in manjših cestah na območju Mestne občine Ljubljana (MOL).

Ključne besede: Mestna občina Ljubljana, promet, onesnaževanje ozračja, difuzivni vzorčevalniki, kakovost zraka, dušikov dioksid.

1. INTRODUCTION

Road traffic today is an inevitable feature and the main element of communication, as are its benefits and disadvantages. The air pollution is one of the most important side effects. Road infrastructure and the traffic on these roads represent a line sources. In many parts of the world, such as Europe, North America, parts of Asia and in big cities of South America and Africa, road traffic became important source of air pollution not only on a local scale, but on a global scale as well.

Slovenia faces the similar problems as the rest of Europe. In Slovenia, in the year 2004, traffic emitted 58 % of all NO_x (Energetska bilanca…,2006). In Municipality of Ljubljana, 55 % of NO_x, emitted in 2004, were caused by road traffic (Spremljanje izvajanja…2005). To get a spatial picture of NO_2 pollution in Ljubljana, a study with measuring campaigns in years 2005 and 2006 was carried out by the Department of Geography and Environmental Agency of the Republic of Slovenia (ARSO). In over 40 measuring spots (summer) and over 80 measuring spots (winter) measurements were taken with passive samplers. The aim of our research was to find out the influence of road traffic upon air quality in Ljubljana. The area of measurements was limited on the area within the Ljubljana highway ring.

2. METHODOLOGY

Measurements with passive samplers turned out to be an appropriate method when one wants to get a spatial distribution of air pollution. With passive samplers, it is possible to measure NO_2, SO_2, O_3, BTX and some other pollutants as well. The key principle for passive samplers is the Fick's diffusion law and the transport of pollutant molecule from entrance of the sampler to its end, where membrane with sorbent is located. Molecules of NO_2 react with absorbent in nitrite, which means that NO_2 concentration at the membrane is equal to zero. So the gradient of concentration due to molecular diffusion generates transport of NO_2 molecules from entrance of the sampler to its membrane at the end. The samplers are exposed to the outdoor conditions, and we do not pump the air into them. That is why we call them passive samplers. Among several kinds of passive samplers that have been developed, we have chosen Palmes-type diffusion tube samplers. They were used and described by Palmes (Palmes et al, 1976). Sampler has a shape of 7,1 cm long tube, with internal cross section 0,71 cm^2. During measurements, a tube is opened from one side, on the other there is a membrane with sorbent. After the measurements, the tube must be hermetically closed and sent to chemical analysis.

The use of passive samplers is encouraged by some important advantages compared with other measuring methods. Flexibility is one of them. Samplers are small, light and durable. They don't need any electricity or other energy support. The second advantage is their serviceableness. We can measure with over 100 samplers at one time, and in one day we can expose several 100 samplers, which give us very good spatial information of air pollution.

Also very important advantage is their price. Comparing with other methods, they are relatively cheap, so measurements can be repeated several times within reasonable costs.

However, there are also some disadvantages, which must be complied with. According to some authors, the accuracy of measurements is estimated at 30 % (Campbell et al, 1994).

The accuracy can be improved with measurements that are simultaneously done with the reference method and passive samplers at the same location. The ratio between these measured concentrations is used as a correction factor for a measuring campaign.

Second disadvantage is the fact that measurements with passive samplers give us only average concentrations. We don't get the maximum or hourly concentrations, which are many times guidelines for air protection legislation. With passive samplers we can't get results in real time, because we have to send them to analysis, so the results are available after several days or even several weeks.

During our campaigns, samplers were exposed together with shelters. We fixed shelters with samplers on objects near the roads. We chose mainly traffic lights, street lights or something similar. Samplers were set 2,5-3,5 m above the ground and in most cases 0,5-3 m away from road-side.

In Slovenia, this method was already used in 2003/2004 by ARSO in collaboration with JRC Centre from ISPRA at project AIRPECO, and good experiences from this project persuaded us to do some further researches.

We carried out two measuring campaigns. Summer campaign took 3 weeks and winter campaign 2 weeks. Analysis was done by Faculty for chemistry and chemical technology at University of Ljubljana/Slovenia and company Gradko International/ UK.

At each sampling spot we set a 3 or 2 samplers in a shelter. An average of two nearest concentrations (in case of three) and an average of two (in case of two samplers) were used as a concentration of a sampling spot. We set measuring spots on both sides of the road, so it was carried out in pairs. From concentrations of two spots at one location, each at one side of road, we calculated average concentrations of a pair. With calculating average concentrations of pairs from spots at both sides of a road we eliminated wind effects. Wind can carry away the pollutants and if sampled only on one side of the road it is possible, that pollutant would be transported away from the samplers. At measurements in urban background and at measurements in profiles we didn't set pairs, because wind effects were not important due to their distance from roads.

2.1 Estimation of annual pollution with NO_2

At the end we calculated annual NO_2 pollution estimation for all pairs or measuring spots. Estimation is based on presumption that ratios between reference measuring spot at ARSO and all other measuring spots remain the same during the year. We calculated a correction factor from summer and winter campaign. Because summer campaign lasted for 3 weeks and winter campaign only for 2 weeks, we multiplied summer factor with 0,6 and winter factor with 0,4. So annual correction factor was calculated:

$Fi_{ann}=0{,}6*Fi_{suml} + 0{,}4*Fi_{win}$,

where

Fi_{ann} is annual factor for a chosen i measuring spot,

Fi_{sum} is summer factor for a chosen i measuring spot,

Fi_{win} is winter factor for a chosen i measuring spot.

Annual NO_2 pollution estimation for each measuring spot was calculated:

$C_{ann} = F_{ann} * C_{ARSO\ ann}$,

where
Ci_{ann} is annual NO_2 concentration at a chosen measuring spot i and
C_{ARSO} ann is average annual NO_2 concentration at reference station ARSO.

2.2 Types of measuring spots

When dealing with air pollution due to road traffic, it is very important to know the density and structure of road traffic and an openness of a space near the road as well.

Local roads in an open space, with less than 1500 vehicles per day have almost negligible influence on air quality nearby the road. However, the topography of space near the road is very important and we must always consider it very seriously. Where high buildings from both sides bound the space near the roads, street canyon is formed. Due to smaller windiness in such canyons and due to smaller volume, those pollutants have for dispersion, concentrations raise.

We put all measuring spots in following groups:
- measuring spots of street canyon,
- measuring spots in open space,
- measuring spot in concentration profile,
- measuring spots in urban background.

Street canyon

Street canyons in cities, although they cover small areas, are more important than they seem. In many cases, street canyons are the most visited parts of towns. Traffic in these canyons may not be extremely high, but the average speed of vehicles is small, so due to often traffic jams, many canyons are crowded with traffic several hours a day or even more.

In Ljubljana, there are several streets, where buildings along them form street canyon. The biggest is on Slovenska Street, which is the main city street. There are canyons also on Aškerčeva Street, at the part of Poljanska Street, on Wolfova Street, on Stritarjeva Street and on Gosposvetska Street. All these streets are full of city traffic daily, however, traffic volume is not extremely high and it does not reach traffic volumes on the highway ring or other main streets that go from city centre to the suburbs such as Celovška Street or Dunajska Street. For street canyons it is very important, that most of them are also used by many pedestrians daily. Buildings that form canyons can be faculties, schools, hospitals, shopping centers or smth. similar. In Ljubljana, Slovenska Street is the most important city street so it is crowded with pedestrians and circlers every day. It is a starting point for going to the old part of city from the main bus stop, it is also very close to the University building, the Slovenian parliament is only about 100 m away, and there are also some important shopping centers or bars. All these people are exposed to high concentrations in street canyon. Also all the drivers and passengers in traffic are exposed to the high concentrations in the street canyon, especially if they get stuck in traffic. During the summer measuring campaign, on Slovenska Street an average hourly traffic was 743 vehicles, which means 17 832 vehicles per day. The average annual daily traffic for 2004 was 18 052 vehicles, so we see, that differences are small. The busiest city roads have daily traffic from 30 000 to around 70 000 vehicles a day. But, the traveling speed on Slovenska is very low, because there are 11 traffic lights in the area of 1,2 km.

Picture 1: Where street canyon on Slovenska Street opens from one side, concentrations of NO_2 *fall.*

Open space near the roads

We named space outside the street canyon as an open space near the roads. Measuring spots in such spaces usually measure lower concentrations due to the greater windiness, and pollutants have more space available for diffusion and dispersion. So concentrations in such environment are a function of traffic volume and wind conditions, and are not under influence of special conditions in street canyons. A perfect example of this type of environment would be the lonely road in vast open plains. Reality in the cities is far different from this example; we named all measuring spots, which were near the road and outside the canyon as spots in open space near the roads.

Picture 2: Along the Tržaška Street near Dolgi Most buildings along the street are too low and enough apart from each other that we put measuring spots in type open space near the roads.

Urban background

Measuring spots at urban background show level of pollution far away from sources, such as roads, factories or power plants. In urban background, concentrations are usually much more constant and significantly lower than near the roads. Urban background is calm space, such as parks or residential areas. These areas are very important, because many people live there, so they spend a big part of their lives there.

3. RESULTS

Summer campaign started on August 25, and ended on September 14 2005. Weather conditions during this period were mainly dry, often with light to moderate winds.

The winter campaign lasted from January 24 to February 7 2006. Weather in this period was stable, dry and cold, with often temperature inversion which prevented effective mixing of air within lower parts of atmosphere.

Mean annual limit NO_2 concentration for protection of human health is 40 µg/m^3. However, we must consider acceptable excess, which for the year 2005 was 25 %. Each year acceptable excess falls 5 %, so in 2010 it will be 0 %. For year 2005 this means mean annual limit value 48 µg/m^3, and for 2006 46 µg/m^3.

Table 1: Concentrations of pairs in street canyon in summer and winter campaign.

Pair	**Summer concentrations (µg/m^3)**	**Winter concentrations (µg/m^3)**	**Difference (µg/m^3)**
Pošta	83	83	0
Poljanska cesta	80	103	23
A Banka	79	85	6
Bavarski Dvor	70	87	17
Drama	68	66	-2
Kazina	65	61	-4
Šestica	64	70	6
FF	62	61	-1
Metalka	54	58	4
Uršulinke	52	59	7
Average 1	**68**	**73**	**5**
Z obvoznica	\	54	\
Gosposvetska R2	\	60	\
Gosposvetska R3	\	62	\
Aškerčeva 1	\	53	\
Aškerčeva 2	\	52	\
Aškerčeva 3	\	53	\
Average 2	**68**	**67**	****

In summer, the most polluted air with the highest concentrations of NO_2 was at pair Ljubljanska pošta (83 μg/m^3), and the lowest concentrations were measured at pair Uršulinke (52 μg/m^3). On the second place we found pair Poljanska cesta, with 80 μg/m^3. It is interesting, that despite small traffic volume (Poljanska Street is partly closed for traffic), concentrations are very high, which is due to a very closed street canyon. Average concentration of all pairs in summer was 68 μg/m^3, which is far above the limit value for 2005.

In winter time, even higher concentrations were measured many at pairs. The highest concentrations were measured at pair Poljanska. Concentrations there exceeded 100 μg/m^3 and the average winter concentration in the street canyon was 73 μg/m^3.

It was anticipated that measurements of concentrations in winter would be higher than in summer. In winter, traffic is usually more crowded, which causes higher emissions. Emissions are also higher due to higher fuel consumption, which is a consequence of bigger heat lost of engines. The atmosphere is much more stable in winter time and in Ljubljana temperature inversion forms almost every day. This prevents an effective mixing of pollutants and causes higher concentrations. In Table 1 we see, that at most pairs winter concentrations are higher, but that is not the case with all of them. The average winter concentration was 5 μg/m^3 or 7 % higher. The biggest difference was at pair Poljanska, where winter concentration was higher by 29 % (23 μg/m^3). Pair Bavarski Dvor had also significantly bigger winter concentrations. They exceeded summer concentration by 24 % (17 μg/m^3). But at three pairs (Drama, Kazina, Filozofska fakulteta), winter concentrations were a bit lower. It is possible, that lower winter concentrations are a result of air chemistry, which is different in winter than in summer. Vehicles emit mainly NO and after some time NO oxidizes in NO_2 with reaction:

$$NO + O_3 \rightarrow NO_2 + O_2$$

Oxidation of NO is fast, if enough O_3 is around. Formation of O_3 is much faster in summer, when enough sunlight is available, which is essential for formation of O_3.

In winter time, sun light is much weaker and the ozone concentrations are much lower, so it is possible, that oxidation of NO in NO_2 takes more time. This could be the reason for lower winter concentrations of NO_2 at some pairs.

Table 2: Estimates of annual NO_2 pollution in street canyon.

pair	Annual concentration (μg/m^3)		pair	Annual concentration (μg/m^3)
Poljanska	83		Kazina	62
Pošta	80		Šestica	63
A Banka	78		FF	60
Bavarski Dvor	72		Metalka	53
Drama	65		Uršulinke	51
			Average	**67**

Picture 3: Average NO_2 concentrations in street canyon of Slovenska 3a): in summer, 3b): in winter and 3c): annually.

3a 3b 3c

Picture 4: Despite limited traffic at street canyon of Poljanska Street, the highest NO_2 concentrations in Ljubljana were measured at that spots.

Picture 3 shows us NO_2 concentrations along the street canyon at Slovenska Street in summer, in winter and also estimates of annual NO_2 pollution. Concentrations were high in the whole canyon, but still, there were some differences. Air was most polluted at Bavarski Dvor and at Ljubljanska Pošta, where annual concentrations were 72 – 83 μg/m^3. Even the lowest concentrations were higher than 50 μg/m^3 and exceeded the limit value 48 μg/m^3.

Table 3: NO_2 concentrations of pairs along the roads in open space in summer and winter campaign.

Pair	**Summer concentrations (μg/m^3)**	**Winter concentrations (μg/m^3)**	**Difference (μg/m^3)**
Celovška	66	59	-7
Avtobusna postaja (AP)	59	64	5
Tunel	57	53	-4
Dunajska	46	43	-3
Average 1	**57**	**55**	**-2**
Drenikova	/	69	/
J obvoznica	/	66	/
Dalmatinova R1	/	65	/
Dalmatinova R2	/	47	/
Dalmatinova R3	/	50	/
Šmartinska	/	54	/
Zaloška Fužine	/	52	/
Zaloška bolnica	/	50	/
Tržaška	/	64	/
S obvoznica	/	61	/
Celovška kino	/	39	/
Average 2	**/**	**56**	**/**

Measuring spots near the roads in open space were exposed to smaller concentrations compared to street canyon, because pollutants can disperse easily in bigger space.

In summer campaign measurements were taken at 4 pairs (8 spots) and in winter at 15 pairs (30 spots).

The highest summer concentrations were measured at pair Celovška, where concentration was 66 μg/m^3. The lowest concentration in the same period was measured at measuring pair Dunajska, but even there concentration was still high and had reached 46 μg/m^3. In winter campaign, the same pairs as in summer were measured and the values were on average 2 μg/m^3 lower. The highest concentration was measured at pair Drenikova, where concentration was 69 μg/m^3. Winter and summer measurements exceeded average annual limit value, which gives us a special concern.

Results in Table 3 confirm that NO_2 concentrations near the roads in open space are lower than in street canyon. The traffic volume on these roads is usually bigger or at least of the same magnitude as the one in street canyon. The reason for lower NO_2 concentrations is openness of space which enables pollutants to mix and disperse.

Table 4: Estimates of annual NO_2 pollution along the roads in open space.

Pair	Annual concentration (μg/m³)
Celovška	62
Avtobusna postaja (AP)	58
Tunel	54
Dunajska	44
Average	**55**

Estimates of annual NO_2 pollution show that concentrations differ from 44 μg/m³ to 62 μg/m³. The highest NO_2 pollution was measured at pair Celovška. On this micro location road goes in underpass, so the concentrations can raise due to a worse windiness. On the other hand, two out of three other pairs exceeded 50 μg/m³. Only at Dunajska, the average annual limit value wasn't exceeded.

We didn't set pairs of measuring spots in urban background, because they weren't taken near the roads. So evidently we haven't calculated average concentrations from pairs. That is why each measuring spot represents one location.

Picture 5: Measuring spots in front of Ljubljana tunnel are specific ones, especially because a tunnel is a source of pollution. Due to the fact that the street isn't in street canyon we ranged measuring spot in spots along the roads in open space.

Table 5: NO_2 concentrations in urban background during summer and winter campaign.

Measuring spot	Summer concentration (μg/m³)	Winter concentration (μg/m³)	Difference
Tivoli	\	54	\
Vič 1	30	52	22
ARSO	21	51	30
Rudnik Jurčkova	28	43	15
VIČ 2	19	42	23
Šiška 2	26	33	7
Moste	32	30	-2
Šiška 1	31	29	-2
Bežigrad	28	28	0
Average	**27**	**40**	**12**

Average summer concentration in urban background was 27 μg/m^3 in interval from 19 μg/m^3 to 32 μg/m^3. We see, that only measured concentrations at measuring spot Vič 2, which was located near Biotechnical faculty at the edge of city park, and on spot ARSO, differ significantly. At all other spots concentrations were in short interval form 26 μg/m^3 to 32 μg/m^3.

Table 6: Estimates of annual NO_2 pollution in urban background.

Measuring spot	Annual concentration (μg/m³)
Vič 1	34
Moste	31
Rudnik	30
Šiška 1	30
ARSO	28
Bežigrad	27
Šiška 2	27
VIČ 2	23
Average	**29**

In winter time, the average concentrations at the same spots were 12 μg/m^3 (44 %) higher, and the interval was from 28 μg/m^3 to 54 μg/m^3. On 5 out of 8 spots, winter concentrations were higher, on 1 it was equal and on 2 spots concentration was slightly lower.

Results also show that differences between summer and winter campaign in urban background are bigger than at other spots or pairs. This indicates, that oxidation NO to NO_2 was more complete. However, we must also consider the individual heating, which is in winter more significant.

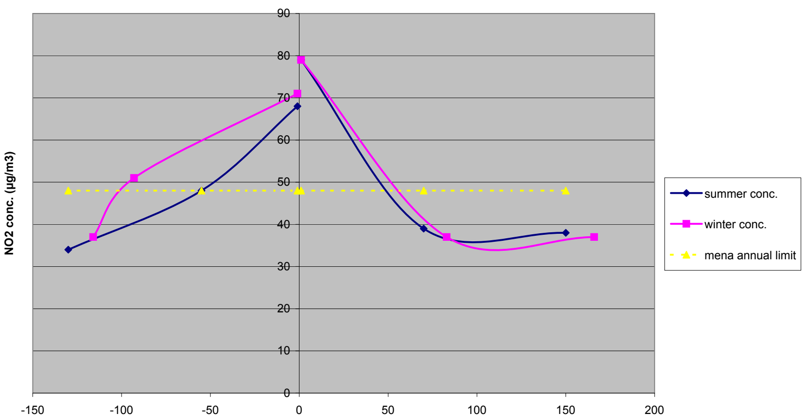
Estimates of annual NO_2 pollution show us small differences between measuring spots. All of them, except Vič 2 are in interval from 27 μg/m^3 to 34 μg/m^3. All concentrations are under mean annual limit value, although, we can't say that they are low.

We also measured profile of NO_2 concentrations perpendicular to the main street. Main street was Slovenska Street in center of Ljubljana, where two small streets: Cankarjeva Street and Čopova Street cross Slovenska Street. We wanted to see, how the concentrations changed with distance from the main source. This profile was very adequate, because on Čopova Street no traffic is allowed and it is also the case in the first part of Cankarjeva Street that the traffic is not allowed. On both streets there are only a pedestrian zones, except on Cankarjeva Street, where further on the traffic is allowed, but is nevertheless very limited. Both streets are daily crowded with visitors and residents of Ljubljana.

Measuring concentrations profiles is very useful to get an impact of traffic upon air quality in wider area along the roads. Such or similar canyons, that cross the main street, are often in cities. In Ljubljana there are also on Rimska Street, Nazorjeva Street, Kersnikova Street etc.

We set shields and samplers on city lights and on traffic signs. Similar to the measuring process in urban background; we didn't set pairs, because measurements weren't taken near the road.

Graph 1: Winter and summer concentration profile on Cankarjeva and Čopova Street.



Graph 1 shows decrease of NO_2 concentration with distance from Slovenska Street, which is the dominant source of NO_2. In both campaigns on Čopova Street decrease is steeper. The reason is small traffic on second part of Cankarjeva Street, which reduces the decrease of concentration. On Čopova Street summer and winter concentrations are almost equal, however on Cankarjeva Street winter concentrations were higher.

Picture 6: NO_2 Concentration profile from Čopova Street to Cankarjeva Street 6a): in summer and 6b): in winter.

Picture 7: Pedestrian zone goes from Cankarjeva Street (left) across Slovenska Street to Čopova Street (right). Slovenska Street pollutes the air over mean annual limit value at least 50m in each street, where traffic is not allowed.

4. CONCLUSIONS

Measurements of NO_2 concentrations in summer and winter campaign in Ljubljana showed very high values in street canyons and high values near the roads in open space. Only in urban background concentrations were under mean annual limit value. Street canyons are the most polluted areas due to small windiness and small volume, which pollutants use for dispersion.

Average concentration in street canyon was 68 $\mu g/m^3$ in summer and at the same pairs 73 $\mu g/m^3$ in winter, whereas all winter pairs had the average concentration 67 $\mu g/m^3$. At all pairs concentrations exceeded mean annual limit values, which should be a matter of concern.

Measurements of concentration profile on Čopova and Cankarjeva Street showed high concentrations of NO_2 within at least 50 m distance from Slovenska Street. On both streets, this area is a pedestrian zone with outdoor bars and shops, although the mean annual limit value is exceeded.

Measures also showed big differences between different types of measuring spots. This should encourage a new approach at researching air pollution in cities, because today in Ljubljana we have only one permanent measuring station, where with reference method is used. This station is located at Environmental Agency of the Republic of Slovenia (ARSO) and belongs to urban background. So, usual concentrations there are much lower than on other parts of the city. The highest concentrations in street canyon in the city centre prove that the main reason for NO_2 pollution in the centre of Ljubljana is traffic "in situ". Influence of air pollution from city hwy ring reaches the city in a form of well mixed pollution on a level of urban background. This doesn't mean that air pollution from city hwy ring is narrow. Traffic volumes on northern and western part are from 60 000 to 70 000 vehicles per day (Promet 2005) and it is very likely, that hwy ring causes air pollution in a wider area along the hwy, but precise inquiries haven't been done so far.

For some parts of Ljubljana measurements clearly show, that national and municipal authorities should take actions to reduce NO_2 concentrations. Environment protection law in its article 24. states that if measurements show too high concentrations of pollutants in a certain area, it must be immediately declared as the area of degradation and measures that ensure cleaner air must be taken. After all, citizens of Ljubljana have all the rights to breathe clean air within all of city's territory and the authorities are obliged to ensure it.

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PROMETNO ONESNAŽEVANJE OZRAČJA V LJUBLJANI

Povzetek

Cestni promet je neizogiben element človeške družbe, s svojimi prednostmi in slabostmi. Poleg nesreč, zastojev in hrupa, je onesnaževanje ozračja eden najpomembnejših negativnih posledic prometa. Članek opisuje onesnaževanje ozračja zaradi cestnega prometa znotraj obroča mestne obvoznice v Mestni občini Ljubljana (MOL). 55 % emisij NO_x v je letu 2004 prispeval promet (Spremljanje izvajanja…, 2005), glavni cilj raziskave pa je bil izmeriti onesnaženost zraka z dušikovim dioksidom ob cestah. Za meritve smo uporabili Palmesove difuzivne vzorčevalnike. Metoda, ki v Sloveniji širše pred tem še ni bila poznana, se je izkazala za zelo uporabno. Glavne prednosti so zlasti nizka cena priprave in analize vzorčevalnikov ter praktičnost metode, saj lahko z njo hkrati merimo na poljubnem številu mest. Slabost metode je slabša točnost meritev in pa dejstvo, da nam metoda ne nudi podatkov v realnem času, saj so na voljo šele po kemijski analizi in da z njo dobimo le podatke o povprečni koncentraciji za čas merjenja, ne moremo pa izmeriti najvišje koncentracije.

Meritve so potekale v različnih tipih prostora. V cestnem koridorju, v odprtem prostoru ob cestah in tudi nekoliko dlje od cest, v tako imenovanem urbanem ozadju. Poleg tega smo ugotavljali tudi spremembo koncentracij dušikovega dioksida z oddaljevanjem od ceste. Opravili smo zimsko in poletno merilno kampanjo, ki sta pokazali pomembne razlike v onesnaženosti med

letom v vseh tipih prostora. Na podlagi zimske in poletne kampanje smo izračunali oceno povprečne onesnaženosti z dušikovim dioksidom za merilna mesta. Zrak je bil najbolj onesnažen v cestnem koridorju. Na Slovenski cesti, ki je najbolj prometna cesta v središču Ljubljane, so povprečne letne koncentracije presegle mejne koncentracije za leto 2006 s sprejemljivim preseganjem za 70-100%, kar je zaskrbljujoče, saj ta koridor dnevno uporablja mnogo ljudi, ki so tem koncentracijam izpostavljeni. Podobni so bili rezultati meritev na krajšem odseku cestnega koridorja Poljanske ceste. Meritve profilov koncentracij z oddaljevanjem od Slovenske ceste kot glavnega vira onesnaževanja so potekale po Čopovi in Cankarjevi ulici. Na obeh ulicah je urejeno območje za pešce. Rezultati so pokazali, da so koncentracije nad dopustnimi v 50-metrskem pasu od Slovenske ceste v območje za pešce.

Meritve so pokazale tudi pomembne razlike v onesnaženosti zraka z dušikovim dioksidom med različni tipi prostora. To potrjuje upravičenost uporabe difuzivnih vzorčevalnikov, saj lahko z njimi precej bolje zaobjamemo raznolikost mestnega prostora oziroma prostorske razlike v onesnaženosti zraka. Na območju MOL imamo danes samo eno stalno referenčno postajo za merjenje kakovosti zraka, ki jo umeščamo v urbano ozadje, občasno pa se opravljajo tudi meritve z mobilno postajo. Obe postaji upravlja Agencija Republike Slovenije za okolje (ARSO). Obstaja še merilna postaja Mestne občine Ljubljana, ki meri onesnaženost zraka pri Figovcu, vendar metoda še ni povsem primerljiva z referenčno metodo, ki jo uporablja ARSO.

Najvišje koncentracije dušikovega dioksida v cestnem koridorju so dokaz, da v središču Ljubljane največji vir onesnaževanja s tem onesnažilom predstavlja promet v samem mestnem središču in ne prenos onesnažil od drugje (npr. z mestne obvoznice). To ne pomeni, da je mestna obvoznica majhen vir onesnaževanja, saj so povprečne dnevne prometne obremenitve tam dosežejo 60 000-70 000 vozil dnevno (Promet, 2005). Promet z obvoznice pomembno onesnažuje prostor ob obvoznici, medtem ko vpliv onesnaževanja z dušikovim dioksidom proti centru mesta slabi.

Za predele mesta, kjer smo ugotovili previsoke koncentracije dušikovega dioksida, bi morale mestne oblasti v sodelovanju z državnimi takoj sprejeti ukrepe sanacije, saj to zahteva tudi Zakon o varstvu okolja v svojem 24. členu. Prebivalci in obiskovalci Ljubljane imajo do tega vso pravico.