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IMPACT OF AIR POLLUTION WITH PM_{10} ON PRIMARY HEALTH CARE CONSULTATIONS FOR RESPIRATORY DISEASES IN CHILDREN IN ZASAVJE, SLOVENIA: A TIME-TREND STUDY

VPLIV ONESNAŽENOSTI ZRAKA S PRAŠNIMI DELCI PM_{10} NA ŠTEVILO OBISKOV V PRIMARNEM ZDRAVSTVENEM VARSTVU ZARADI BOLEZNI DIHAL PRI OTROCIH V ZASAVJU: ŠTUDIJA ČASOVNEGA TRENDA

Andreja Kukec[1], Ivan Erzen[1,2], Jerneja Farkas[1,3], Lijana Zaletel Kragelj[1]

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Abstract

Aim: *The aim of our study was to assess the temporal association between the number of consultations in the primary health care unit due to respiratory diseases in children and the level of particular matter of 10 micrometres in diameter (PM_{10}) pollution in the Zasavje region.*
Methods: *A time-trend ecological study was carried out for the period between 1 January 2006 and 31 December 2011. The daily number of first consultations for respiratory diseases among children in the Zasavje region was observed as the outcome. Poisson regression analysis was used to investigate the association between the observed outcome and the daily PM_{10} concentrations, adjusted to other covariates.*
Results: *The results showed that the daily number of first consultations were highly significantly associated with the daily concentrations of PM_{10} in the Zagorje ($p<0.001$) and Trbovlje ($p<0.001$) municipalities. In the Hrastnik municipality, a significant association was not observed in all models.*
Conclusions: *It can be concluded that evidence of association between the daily PM_{10} concentration and the daily number of first consultations for respiratory diseases among children exists, indicating that there is still a need for public health activities in the sense of reduction of harmful environmental factors in the region. Additionally, on the basis of these results, it can be assumed that with some improvements linkage of existing health and environmental data in Slovenia in general could be feasible in identifying a grounded need for future public health action.*

Key words: outdoor air pollution, PM_{10}, respiratory diseases, children, the Zasavje region, time-trend study

Izvirni znanstveni članek
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Izvleček

Namen: *Namen študije je bil oceniti časovno povezanost med številom obiskov v primarnem zdravstvenem varstvu zaradi bolezni dihal pri otrocih in prašnimi delci premera 10 mikrometrov (PM_{10}) v Zasavju.*
Metode: *Ekološka študija časovnega trenda je bila izvedena za obdobje od 1. januarja 2006 do 31. decembra 2011. Opazovani izid je bil dnevno število prvih obiskov zaradi bolezni dihal pri otrocih v Zasavju. Za oceno povezanosti med opazovanim izidom in dnevnimi koncentracijami PM_{10}, standardizirano na preostale pojasnjevalne dejavnike, je bila uporabljena Poissonova regresijska analiza.*
Rezultati: *Rezultati so pokazali močno statistično povezanost med dnevnim številom prvih obiskov in dnevnimi koncentracijami PM_{10} v občinah Zagorje ($p < 0,001$) in Trbovlje ($p < 0,001$). V občini Hrastnik nismo opazili značilne povezanosti pri vseh modelih.*
Zaključek: *Sklenemo lahko, da v Zasavju obstaja povezanost med boleznimi dihal pri otrocih in koncentracijo PM_{10}, kar kaže na to, da je v tej slovenski regiji še vedno prisotna potreba po javnozdravstvenih ukrepih v smislu*

[1]University of Ljubljana, Faculty of Medicine, Public Health Centre, Zaloška 4, 1000 Ljubljana, Slovenia
[2]National Institute of Public Health, Trubarjeva 2, 1000 Ljubljana, Slovenia
[3]University Clinic of Respiratory and Allergic Diseases Golnik, Golnik 36, 4204 Golnik, Slovenia
Correspondence to: e-mail: lijana.kragelj@mf.uni-lj.sii

zmanjševanja škodljivih okoljskih dejavnikov. Dodatno lahko na podlagi rezultatov študije sklepamo, da bi bilo lahko v prihodnje v Sloveniji povezovanje okoljskih in zdravstvenih podatkov z nekaterimi izboljšavami uporabno pri ocenjevanju utemeljenih potreb za javnozdravstveno ukrepanje.

Ključne besede: onesnaženost zunanjega zraka, PM_{10}, bolezni dihal, otroci, Zasavje, študija časovnih trendov

1 INTRODUCTION

Given the scale and widespread distribution of outdoor air pollution, this negative health determinant is considered as one of the major public health concerns of today (1-8). It has been proven to be associated with a variety of adverse health outcomes, however most of the recent evidence focuses mainly on respiratory and cardiovascular effects (1, 6, 8-15). The most susceptible population group to respiratory effects of air pollution is children (16-18). One of the most important reasons is that children have a larger lung surface area per kilogram of body weight than adults and, under normal breathing, breathe in 50% more air per kilogram of body weight than adults. The other is that they have increased exposure to many air pollutants because of higher minute ventilation and higher levels of outdoor physical activity (16-20).

A variety of pollutants can be found in the outdoor air, however one of the most important is particulate matter (PM) of 10 micrometres in diameter (PM_{10}). It can penetrate deep into the bronchial tree and trigger respiratory symptoms. Several studies have consistently demonstrated an association between emergency department visits or hospital admissions due to respiratory diseases and concentration of PM_{10} (1, 6, 8). In the last decade, many studies have applied time-series methods to study the association between air pollution with PM_{10} and its health effects (21-23). These studies mostly rely on routinely available outdoor air pollution and health registry data (24). Many of them have indicated a positive association between a short-term variation in outdoor levels of PM_{10} and daily frequencies of events (e.g. primary health care visits, hospital admissions, deaths) for respiratory diseases (1, 4-6, 8).

In regards to air pollution, Slovenia is no exception. One of the most polluted areas in the country is the Zasavje region (or Zasavje) (Figure 1), which is located in the central part of the country and consists of municipalities Zagorje ob Savi (or Zagorje), Trbovlje and Hrastnik (Figure 2) (25, 26). In this region, there are three narrow valleys located more or less perpendicular to the larger Sava river valley. The main characteristics of Zasavje are coal mines and various different kinds of heavy industry (cement, glass, chemical, etc.) (Figure 2) that were established in Zasavje in the past. Among others, one of the biggest steam power plants in Slovenia is located there, having the highest chimney in Europe (25). This is due to the proximity to the source of energy and the fact that the Sava river valley with the railway line for decades represented one of main transport pathways of Slovenia. Most industrial plants considered as the largest emitters in the region are situated in the Sava river valley or at the intersection of the Zagorje, Trbovlje and Hrastnik valleys and the Sava river valley (Figure 2). Ever since the establishment, this industry has had a huge impact on the outdoor air pollution. The most important pollution in the past has been due to sulphur dioxide (SO_2) and PM_{10}. However, according to the report of the Slovenian Environmental Agency (SEA), the situation in SO_2 has greatly improved, and the national legally defined maximum values are exceeded only occasionally, while measurements of PM_{10} and ozone (O_3) levels show that they constantly exceed the national legally defined maximum values at the existing monitoring stations in Zasavje (26, 27). On the bottoms of the valleys, the temperature inversions are also frequently present in winter and autumn. Unfortunately, only few studies have studied the association between outdoor air pollution and the health of the Zasavje population in the past (28, 29). In the last few years, there have been some new studies carried out. The first study was the study of Eržen et al. (30), which indicated the association between the level of outdoor air pollution and prevalence of chronic respiratory diseases in the Zagorje municipality by using a rough assessment of level of pollution in different parts of the municipality. In the study of Kukec et al. (31), researchers upgraded these research methods with multivariate statistical analyses in all three municipalities in the Zasavje. However, further research is needed in order to bring up evidence to prove the health impact due to the environmental factors.

Figure 1. *Location of the Zasavje region in Slovenia.*
Slika 1. *Lokacija regije Zasavje v Sloveniji.*

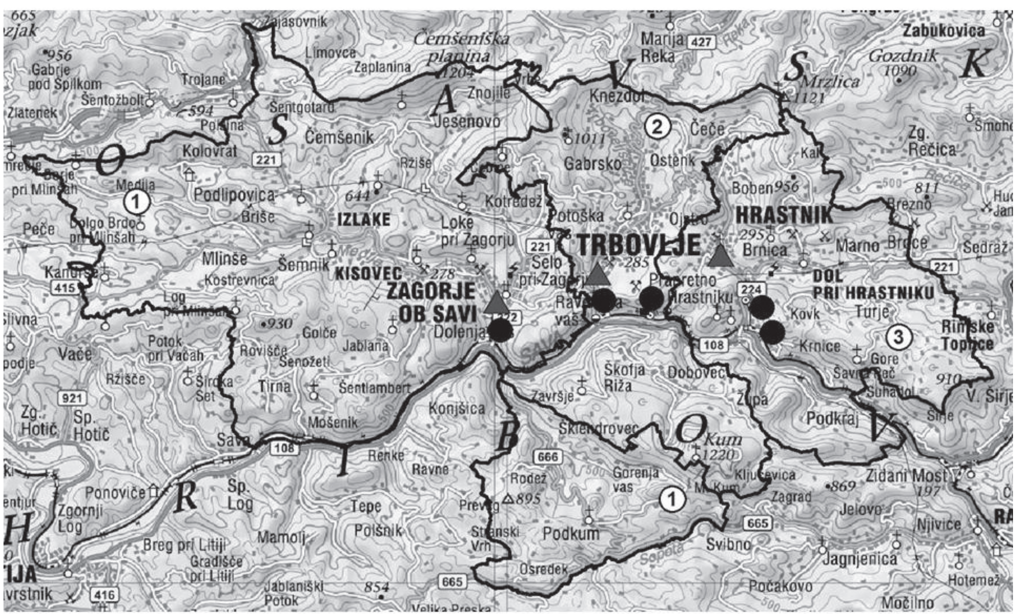

Figure 2. *Zasavje region, Slovenia, map with locations of main point sources of outdoor air pollution in the region. Legend: ① = Zagorje municipality; ② = Trbovlje municipality; ③ = Hrastnik municipality; ● = location of cement, steam power, chemical, and glass plants; ▲ = location of environmental and meteorological data measuring stations;■ = houses/settlements (font size of the settlement name indicate the rough size of the settlement).*
Slika 2. *Lokacija najpomebnejših točkovnih virov onesnaževanja zunanjega zraka v regiji Zasavje, Slovenija. Legenda: ① = občina Zagorje; ② = občina Trbovlje; ③ = občina Hrastnik; ● = lokacija kemične in cementne industrije, termoelektrarne in steklarne; ▲ = lokacija ekoloških in meteoroloških merilnih postaj; ■ = hiše/naselja (velikost črk naselja prikazuje okvirno velikost naselja)*

The so-called linkage methods for environment and health analysis were proposed more than a decade ago by the World Health Organization (WHO) (24, 32). They belong to a wider group of epidemiological methods called ecological studies – a study design in which the relationships between environment and health are studied on population level, by analysing spatial and/or temporal variations in exposure and health outcome (33-35).

The aim of our study was to assess the feasibility of linkage of existing health and environmental data in Zasavje in identifying a grounded need for public health action. The specific goal of the study was to assess the temporal association between the number of consultations in primary health care units due to respiratory diseases in children and the level of PM_{10} pollution in Zasavje. The hypothesis was that a positive temporal relationship between the daily number of first consultations for respiratory diseases and the daily concentration of PM_{10} exists in the municipalities of Zasavje. The study was part of larger project that was performed at the Chair of Public Health, Faculty of Medicine, University of Ljubljana in collaboration with environmental and health experts (36).

2 METHODS

2.1 Study design and study population

The study design was an ecological time-trend study (34). The unit of observation was a single day of the observed period. The study population consisted of all children, aged 1-11 years, residing permanently in Zasavje, who visited the Community Health Centres in (CHC) Zagorje, Trbovlje or Hrastnik due to selected respiratory diseases between 1 January 2006 and 31 December 2011 (37). Altogether, 2,191 days were observed (365 in the years 2006, 2007, 2009, 2010 and 2011 and 366 in the year 2008).

2.2 Data acquisition

2.2.1 Health data

Routinely collected health data were obtained from the health information systems of the CHCs of Zagorje, Trbovlje and Hrastnik. Daily numbers of first consultations due to the following diagnoses according to the WHO International Classification of Diseases, version 10 (ICD-10), were obtained: J00-J06 (acute upper respiratory tract infection), J10-J18 (influenza and pneumonia), J20-J22 (other acute lower respiratory tract infection), J30-J32 (other diseases of upper respiratory tract) and J40-J46 (chronic lower respiratory tract disease).

2.2.2 Environmental data

Immission data on daily PM_{10} concentrations could be obtained at three fixed measuring stations in Zasavje, located in Zagorje, Trbovlje and Hrastnik (Figure 2), which are a part of the National automated network for monitoring air quality operated by SEA. In Zagorje and Trbovlje, the data could be obtained for the entire observation period, while in Hrastnik PM_{10} measurements were only just started on 1 January 2010. Consequently, the observed period in Hrastnik only lasted between 1 January 2010 and 31 December 2011.

Immission data on other important outdoor air pollutants (co-pollutants) in Zasavje: SO_2, O_3 and nitrogen dioxide (NO_2), were obtained as well. Data on daily SO_2 and O_3 concentrations could be obtained at all the measuring stations for the entire observation period, while data on daily NO_2 concentration were only available at the Trbovlje measuring station.

Daily data on meteorological factors: air temperature and relative humidity, could be obtained at all the measuring stations for the entire observation period.

2.2.3 Data on seasonal factors

In the analysis, the following seasonal factors were considered: season of the year (spring, summer, autumn, winter), work day (yes/no), holiday (yes/no) and influenza season (yes/no). Data on influenza season were obtained from annual reports (Epidemiological surveillance of communicable diseases in Slovenia) of the National Institute of Public Health of the Republic of Slovenia (38).

2.3 Statistical analysis

2.3.1 Data description

The distributions of health and environmental data were statistically described by non-parametric typical statistical values (mean, standard deviation, minimum, maximum, 1st, 2nd and 3rd quartile). The temporal patterns of health and environmental data were presented by using sequence plots (33, 34).

2.3.2 Relationship analysis

In the relationship analysis, the daily number of first consultations for all respiratory diseases was considered as the observed outcome, daily concentration of PM_{10} (24-hr average PM_{10} concentration) as the explanatory factor and co-pollutants (24-hr average SO_2 concentration, 8-hr maximum average O_3 concentration), and 24-hr average NO_2 concentration), meteorological and seasonal factors were considered as covariates. In all pollutants, like in other similar studies (11, 39-44), lags from zero up to five days from exposure to the consultation day (lag 0, lag 1, lag 2, lag 3, lag 4 and lag 5 days respectively) were examined to determine the amount of time between exposure and effect. The association between the observed outcome, explanatory factor and covariates was analysed using Poisson regression models (45, 46). The modelling procedure was performed in three stages. In the first stage, univariate models for lags 0-5 days were built by relating the observed outcome to only the explanatory factor. In the second stage, single-pollutant models for lags 0-5 days were built by adding the explanatory factor to a core covariate model that included seasonal (season of the year, work day/weekend day, holiday/non-holiday day and influenza season) and meteorological factors (air temperature and relative humidity). In this stage, the best lags for the explanatory factor and co-pollutants were defined. In the third stage, multi-pollutant models were built by including best lags of the explanatory factor and co-pollutants along with the meteorological and seasonal factors. In order to achieve comparability of results for the Zagorje and Trbovlje municipalities, multi-pollutant models that only included SO_2 and O_3 as co-pollutants were built first. Afterwards, an additional model that included SO_2, O_3 and NO_2 was defined only for the Trbovlje municipality. The multi-pollutant model for the Hrastnik municipality was not defined due to the short observation time. The interpretable end result was the incidence rate ratio (IRR) (47). It was presented together with its 95% confidence interval (CI). P-value of 0.05 or less was considered as statistically significant in all the statistical tests.

All statistical analyses were carried out by using SPSS 18.0 software (SPSS Inc., Chicago, IL, USA).

The study protocol was approved by the National Medical Ethics Committee of the Republic of Slovenia.

3 RESULTS

3.1 Data description

Complete health data were available at all three Zasavje CHCs for all 2,191 days of the study period. In the Zagorje municipality, there were 128/2,191 (5.8%) days with no first consultations for all respiratory diseases, and in the municipalities of Trbovlje and Hrastnik, there were 577/2,191 (26.3%) and 685/2,191 (31.3%) such days respectively. A statistical description of the distribution of the daily number of first consultations for all respiratory diseases is presented in Table 1. Temporal patterns of the daily number of first consultations for the observed outcome are presented in Figures 3a, 4a, and 5a. In all three municipalities, the observed outcome was the highest in winter months (from December to February).

Table 1. *Descriptive statistics for the daily number of first consultations for respiratory diseases among children and environmental data in the Zasavje region, Slovenia, for 2,191 days between January 1, 2006 and December 31, 2011.*

Tabela 1. *Opisna statistika dnevnega števila prvih obiskov zaradi bolezni dihal pri otrocih in okoljskih podatkov v regiji Zasavje, Slovenija, za 2.191 dni med 1. januarjem 2006 in 31. decembrom 2011.*

	Typical value/*Tipična vrednost*						
	Mean	**SD**	**Min**	**Q_1**	**Q_2**	**Q_3**	**Max**
	Povprečje	***SD***	***Min***	***Q_1***	***Q_2***	***Q_3***	***Max***
Zagorje municipality/*Občina Zagorje*							
Number of consultations due to respiratory diseases Število *obiskov zaradi bolezni dihal*	4.99	4.0	0.0	2.0	4.0	7.0	29.0
PM_{10} 24-hr average concentration (μg/m³) PM_{10} *24-urna povprečna koncentracija (μg/m³)*	40.3	23.9	4.3	23.5	33.8	49.6	231.1
SO_2 24-hr average concentration (μg/m³) SO_2 *24-urna povprečna koncentracija (μg/m³)*	5.8	4.6	0.0	2.7	5.1	7.8	47.0
O_3 maximum 8-hr average concentration (μg/m³) O_3 *maksimalna 8-urna povprečna koncentracija (μg/m³)*	59.6	31.1	1.2	34.6	58.9	82.3	149.3
Temperature 24-hr average (°C) *24-urna povprečna temperatura* (°C)	11.4	8.0	-10.2	4.9	11.9	18.1	28.3
Relative humidity 24-hr average (%) *24-urna povprečna relativna vlažnost* (%)	73.4	14.6	3.0	65.7	75.1	83.9	98.4
Trbovlje municipality/*Občina Trbovlje*							
Number of consultations due to respiratory diseases Število *obiskov zaradi bolezni dihal*	4.91	4.9	0.0	0.0	4.0	8.0	33.0
PM_{10} 24-hr average concentration (μg/m³) PM_{10} *24-urna povprečna koncentracija (μg/m³)*	36.3	21.8	1.3	21.2	30.2	46.0	188.6
SO_2 24-hr average concentration (μg/m³) SO_2 *24-urna povprečna koncentracija (μg/m³)*	4.0	4.5	0.0	1.0	3.0	5.6	43.0
O_3 maximum 8-hr average concentration (μg/m³) O_3 *maksimalna 8-urna povprečna koncentracija (μg/m³)*	67.3	33.6	1.6	42.5	66.5	91.8	164.0
NO_2 24-hr average concentration (μg/m³) NO_2 *24-urna povprečna koncentracija (μg/m³)*	20.0	9.1	1.7	19.6	18.9	25.0	60.5
Temperature 24-hr average (°C) *24-urna povprečna temperatura* (°C)	11.3	8.0	-10.5	4.9	11.9	17.8	27.9
Relative humidity 24-hr average (%) *24-urna povprečna relativna vlažnost* (%)	76.8	11.7	34.2	68.7	77.7	85.7	99.2
Hrastnik municipality/*Občina Hrastnik*							
Number of consultations due to respiratory diseases Število *obiskov zaradi bolezni dihal*	2.61	3.0	0.0	0.0	2.0	4.0	23.0
PM_{10} 24-hr average concentration (μg/m³) PM_{10} *24-urna povprečna koncentracija (μg/m³)*	28.0	16.2	3.1	17.3	23.9	34.7	123.4
SO_2 24-hr average concentration (μg/m³) SO_2 *24-urna povprečna koncentracija (μg/m³)*	5.8	3.9	0.0	3.0	5.0	8.0	44.0
O_3 maximum 8-hr average concentration (μg/m³) O_3 *maksimalna 8-urna povprečna koncentracija (μg/m³)*	73.5	33.1	3.8	48.3	72.8	97.0	178.1

Temperature 24-hr average (°C) *24-urna povprečna temperatura* (°C)	11.1	8.0	-10.4	4.8	11.7	17.6	28.1
Relative humidity 24-hr average (%) *24-urna povprečna relativna vlažnost* (%)	76.2	11.9	34.2	67.9	76.7	85.5	99.9

Legend/*Legenda*: SD -standard deviation/*standardni odklon*; Q_1 - the first quartile/*prvi kvartil*; Q_2 -the second quartile/*drugi kvartil*; Q_3 -the third quartile/*tretji kvartil*; Min/*Min* -minimum/*najnižja vrednost*; Max/*Max* -maximun/*najvišja vrednost*; * = data available only for the period from January 1, 2010 to December 31, 2011/*podatki so dostopni le za obdobje od 1. januarja 2010 do 31. decembra 2011*

Complete data for the daily concentration of PM_{10} were available for 2,135/2,191 (97.4%) days in the Zagorje municipality, 1,985/2,191 (90.6%) days in the Trbovlje municipality, and 730/730 (100%) days in the Hrastnik municipality. Statistical description of the distribution of daily PM_{10} concentration is presented in Table 1. Temporal patterns of daily PM_{10} concentration at all three measuring stations are presented in Figures 3b, 4b, and 5b. The highest daily PM_{10} concentrations were observed in the months from November to February at all three measuring stations.

Complete data for the daily concentration of SO_2 were available for 2,080/2,191 (94.9%) days in the Zagorje municipality, 2,159/2,191 (98.5%) days in the Trbovlje municipality, and 2,132/2,191 (97.3%) days in the Hrastnik municipality. Complete data for the daily concentration of O_3 were available for 2,131/2,191 (97.3%) days in the Zagorje municipality, 2,101/2,191 (95.9%) days in the Trbovlje municipality, and 2,120/2,191 (96.7%) days in the Hrastnik municipality. Complete data for the daily concentration of NO_2 were available for 2,067/2,191 (94.3%) days in the Trbovlje municipality. Statistical description of the distribution of daily co-pollutants (SO_2, O_3 and NO_2) concentration is presented in Table 1.

Complete data for the daily meteorological factors (air temperature and relative humidity) were available for 2,189/2,191 (99.9%) days in the Zagorje municipality, 2,184/2,191 (99.7%) days in the Trbovlje municipality, and 2,170/2,191 (99.0%) days in the Hrastnik municipality. Statistical description of the distribution of daily meteorological factors is presented in Table 1. In the observed period there were in total 541/2,191 (24.7%) winter days, 552/2,191 (25.2%) spring days, 552/2,191 (25.2%) summer days and 546/2,191 (24.9%) autumn days. There were also in total 626/2,191 (28.6%) weekend days and 1,565/2,191 (71.4%) workdays. In the observed period there were in total 1,588/2,191 (72.5%) non-holiday days and 603/2,191 (27.5%) holiday days (school holidays and work-free days). Also, there were in total 1,505/2,191 (68.7%) days without an influenza epidemic and 686/2,191 (31.3%) days with an influenza epidemic.

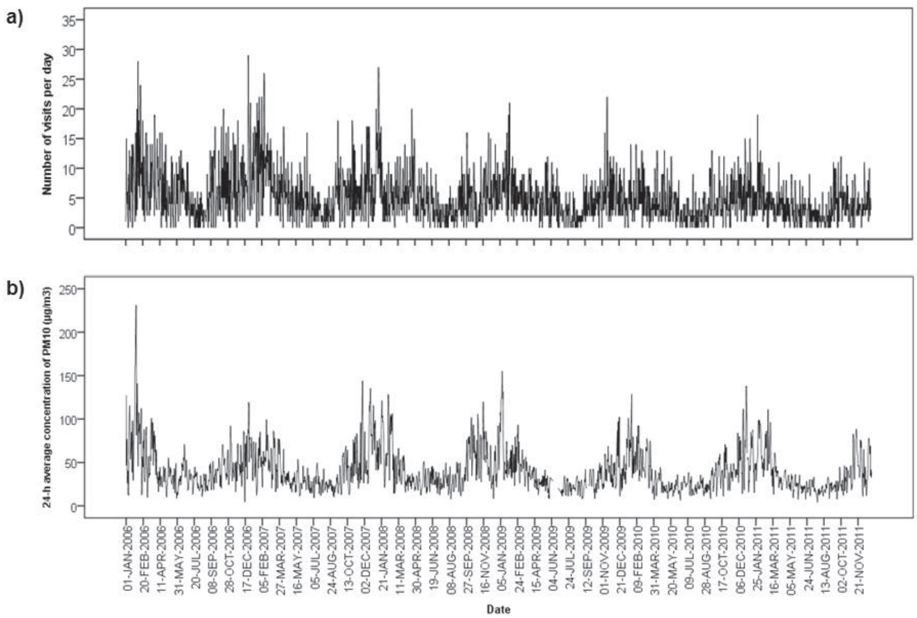

Figure 3. *Temporal pattern of: a) daily number of consultations for respiratory diseases in children, and b) daily 24-hr average concentration of PM_{10} (µg/m^3) in the Zagorje municipality, Slovenia, between January 1, 2006 and December 31, 2011.*

Slika 3. *Časovno spreminjanje: a) dnevnega števila obiskov zaradi bolezni dihal pri otrocih in b) dnevne 24-urne povprečne koncentracije PM_{10} (µg/m^3) v občini Zagorje, Slovenija, med 1. januarjem 2006 in 31. decembrom 2011.*

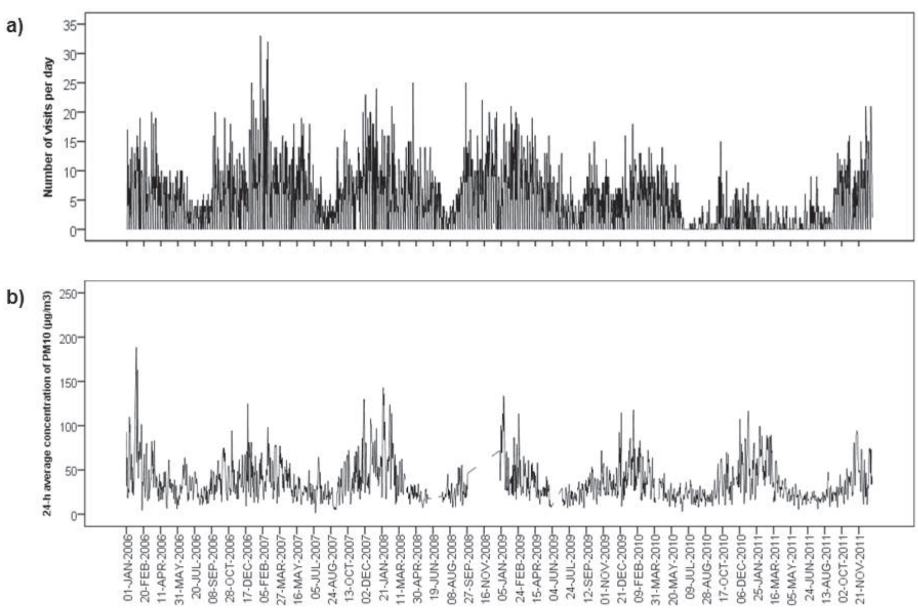

Figure 4. *Temporal pattern of: a) daily number of consultations for respiratory diseases in children, and b) daily 24-hr average concentration of PM_{10} (µg/m^3) in the Trbovlje municipality, Slovenia, between January 1, 2006 and December 31, 2011.*

Slika 4. *Časovno spreminjanje: a) dnevnega števila obiskov zaradi bolezni dihal pri otrocih in b) dnevne 24-urne povprečne koncentracije PM_{10} (µg/m^3) v občini Trbovlje, Slovenija, med 1. januarjem 2006 in 31. decembrom 2011.*

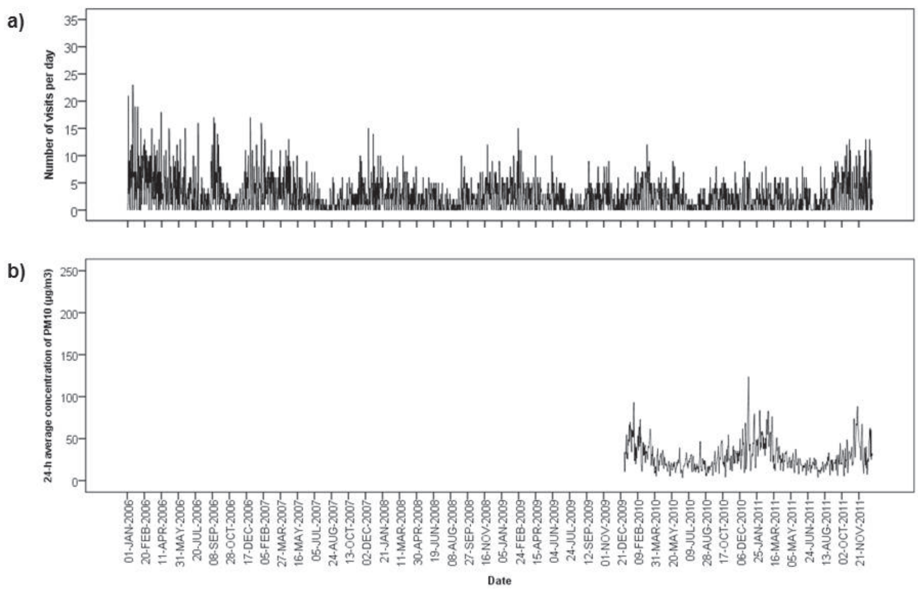

Figure 5. *Temporal pattern of: a) daily number of consultations for respiratory diseases in children, and b) daily 24-hr average concentration of PM_{10} (μg/m³) in the Hrastnik municipality, Slovenia, between January 1, 2006 and December 31, 2011.*

Slika 5. *Časovno spreminjanje: a) dnevnega števila obiskov zaradi bolezni dihal pri otrocih in b) dnevne 24-urne povprečne koncentracije PM_{10} (μg/m³) v občini Hrastnik, Slovenija, med 1. januarjem 2006 in 31. decembrom 2011.*

3.2 Relationship analysis

The results of the univariate analysis showed that the daily number of first consultations for respiratory diseases among children was statistically significantly associated with PM_{10} concentrations in all three municipalities. In all of them, the strongest association was observed in lag 0 (Zagorje municipality - IRR: 1.007, 95% CI: 1.007-1.008; p<0.001; Trbovlje municipality - IRR: 1.010, 95% CI: 1.009-1.011, p<0.001; Hrastnik municipality - IRR: 1.009, 95% CI: 1.006-1.011; p<0.001).

The results of single-pollutant multivariate models once again showed that the daily number of first consultations for respiratory diseases among children in the Zagorje and Trbovlje municipalities was statistically significantly associated with PM_{10} concentrations. In both municipalities, the strongest association was observed in lag 0 (Zagorje municipality - IRR: 1.003, 95% CI: 1.002-1.004; p<0.001; Trbovlje municipality - IRR: 1.003, 95% CI: 1.001-1.005; p<0.001). In the Hrastnik municipality, the association was no longer significant (IRR: 1.000, 95% CI: 0.995-1.005: p=0.969).

The results of the multi-pollutant multivariate models with SO_2 and O_3 included as co-pollutants showed that daily number of first consultations for respiratory diseases among children was still significantly associated with PM_{10} concentrations in both the Zagorje and Trbovlje municipalities. The detailed results are presented in Table 2. The results for co-pollutants are presented in the same table as well. In the Trbovlje municipality, the results didn't change much after the inclusion of NO_2 as an additional co-pollutant in the model (IRR: 1.004, 95% CI: 1.002-1.006, p=0.001).

Table 2. *Results of the Poisson regression analysis of association between consultations for respiratory diseases and PM_{10} concentration, controlling for selected covariates between January 1, 2006 and December 31, 2011 in the Zasavje region, Slovenia ($N_{days\ Zagorje}$=1.996); ($N_{days\ Trbovlje}$=1.927).*

Tabela 2. *Rezultati Poissonove regresijske analize povezanosti med obiski zaradi bolezni dihal in PM_{10} standardizirano na izbrane pojasnjevalne dejavnike med 1. januarjem 2006 in 31. decembrom 2011 v regiji Zasavje, Slovenija ($N_{dni\ Zagorje}$=1.996); ($N_{dni\ Trbovlje}$=1.927).*

Explanatory factor/Covariates *Pojasnjevalni dejavnik/Sopojavi*		**IRR** *RIS*	**95% CI limits for IRR** *95 % IZ za RIS* **Lower** *Spodnji*	**Upper** *Zgornji*	**p** *p*
Zagorje municipality/*Občina Zagorje*					
PM_{10} 24-hr average concentration (µg/m^3) / PM_{10} *24-urna povprečna koncentracija (µg/m^3)*		1.003	1.002	1.004	<0.001
SO_2 24-hr average concentration (µg/m^3) / SO_2 *24-urna povprečna koncentracija (µg/m^3)*		0.983	0.976	0.989	<0.001
O_3 maximum 8-hr average concentration (µg/m^3) / O_3 *maksimalna 8-urna povprečna koncentracija (µg/m^3)*		1.002	1.001	1.004	0.003
Temperature 24-hr average (°C) / *24-urna povprečna temperatura* (°C)		0.998	0.991	1.005	0.633
Relative humidity 24-hr average (%) / *24-urna povprečna relativna vlažnost* (%)		1.003	1.001	1.005	0.014
Season of the year	Summer/*Poletje*	1.000			
Letni čas	Winter/*Zima*	1.732	1.478	2.030	<0.001
	Spring/*Pomlad*	1.111	1.039	1.188	0.002
	Autumn/*Jesen*	1.092	1.057	1.128	<0.001
Work day	No/*Ne*	1.000			
Delovni dan	*Yes/Da*	2.297	2.125	2.486	<0.001
Holiday	No/*Ne*	1.000			
Počitnice	Yes/*Da*	0.739	0.674	0.809	<0.001
Influenza season	No/*Ne*	1.000			
Sezona gripe	Yes/*Da*	1.260	1.160	1.369	<0.001
Trbovlje municipality/*Občina Trbovlje*					
PM_{10} 24-hr average concentration (µg/m^3) / PM_{10} *24-urna povprečna koncentracija (µg/m^3)*		1.004	1.002	1.006	<0.001
SO_2 24-hr average concentration (µg/m^3) / SO_2 *24-urna povprečna koncentracija (µg/m^3)*		0.986	0.977	0.995	0.002
O_3 maximum 8-hr average concentration (µg/m^3) / O_3 *maksimalna 8-urna povprečna koncentracija (µg/m^3)*		0.998	0.996	1.001	0.180
Temperature 24-hr average (°C) / *24-urna povprečna temperatura* (°C)		1.004	0.995	1.014	0.370
Relative humidity 24-hr average (%) / *24-urna povprečna relativna vlažnost* (%)		0.996	0.992	1.001	0.132
Season of the year	Summer/*Poletje*	1.000			
Letni čas	Winter/*Zima*	1.805	1.474	2.212	<0.001
	Spring/*Pomlad*	1.207	1.107	1.316	<0.001
	Autumn/*Jesen*	1.100	1.054	1.148	<0.001
Work day	No/*Ne*	1.000			
Delovni dan	Yes/*Da*	5.103	4.436	5.903	<0.001
Holiday	No/*Ne*	1.000			
Počitnice	Yes/*Da*	0.641	0.566	0.724	<0.001
Influenza season	No/*Ne*	1.000			
Sezona gripe	Yes/*Da*	1.148	1.032	1.278	0.012

Abbreviations/okrajšave: IRR/*RIS* – incident rate ratio/*razmerje incidenčnih stopenj*; CI/*IZ* – confidence interval/*interval zaupanja*; N – number of days/število dni

4 DISCUSSION

The main results of our study have consistently showed that in the Zagorje and Trbovlje municipalities the daily number of first consultations for respiratory diseases among children was significantly associated with the daily concentration of PM_{10}. Only in the Hrastnik municipality was a significant association not observed in all models. This result is clearly in relation to the much shorter time series in this municipality compared to the other two municipalities in Zasavje. The hypothesis that a positive temporal relationship exists between the daily number of first consultations for respiratory diseases and the daily concentration of PM_{10} was thus certainly confirmed in the Zagorje and Trbovlje municipalities. Moreover, these results are consistent with the results of many similar studies (23, 48-50) that also confirmed the positive association between respiratory diseases and PM_{10} concentration.

Our study, in addition to the main results, also provides some additional findings. For example, in the Zagorje municipality, the daily number of first consultations for respiratory diseases among children was also significantly associated with the daily O_3 concentrations. Since the dynamics of this pollutant differ from the PM_{10} dynamics, it would be useful to analyse this problem in depth in a separate study.

Our study has some potential limitations. First, when assessing the usefulness of environmental data for Zasavje as the input data for time-trend studies, we encountered some problems. The results of our study namely showed that all observed pollutants lacked a certain percentage of the measurement. The SEA provided an oral explanation that this was mainly due to the calibration of instruments or filter blockage of the measuring device but certainly not a deliberate shutdown of instrumentation. For the present study, the biggest problem was the lack of PM_{10} data in the Hrastnik municipality. In this municipality, SEA only started with continuous measurements of 24-hr concentrations of PM_{10} from 2010 onwards (26), however it is still not clear whether or not the measurements will continue to be implemented in the future (51-53). An additional problem related to PM_{10} measurements, which must be stressed at this point, is that for now in Slovenia only concentrations of PM_{10} are routinely measured, while concentration of $PM_{2.5}$ are only measured at three locations (Biotechnical Faculty, Ljubljana, Maribor and Maribor centre Vrbanski plateau) (26). Furthermore, the chemical composition of PM_{10} is provided only in individual cases (27). However, these data are crucial for unbiased estimates of the health impact due to the environmental factors. PM_{10} can vary significantly and thus also have different effects on human health. Second, we have to take into account the potential problem with health data that was observed in the larger project that our study was a part of (36). In this project, the usefulness of health data for Zasavje as input data for time-trend studies was assessed, and some potential problems were encountered (36). On one side, there were no problems with the completeness of data collection - at all Zasavje CHCs, data for all days of the observed 6-year period were available. On the other side, certain ambiguities related to the outcome variable were encountered. In the Zagorje municipality, compared to the Trbovlje or Hrastnik municipalities, 1.3 to 1.4 times higher numbers of days were detected with at least one consultation due to respiratory diseases, among which acute respiratory diseases dominated (36). The project assumed that there may be a difference in the encoding of individual diagnoses. However, this problem could only be confirmed if time-trend studies of larger dimensions would be carried out in Slovenia. According to our knowledge, only two studies similar to ours were carried out in Slovenia so far. In both, the researchers observed the association between O_3 concentrations and the number of consultations due to respiratory diseases at CHCs. The first was carried out in the Nova Gorica (54, 55) and the second one in the Koper municipality (56). In both studies, only the data obtained at one CHC were analysed. As a result, the problems that surfaced in our study could not be observed. Third, a potential limitation could be that in our study the association between the observed outcome and explanatory factors was adjusted for covariates that were available in the frame of routinely collected data by SEA in Zasavje. However, we considered most of the generally recommended covariates in similar studies (50, 57, 58). Unfortunately, we could not take confounding factors such as the concentration of pollen into account, because the concentration of pollen is not monitored in the Zasavje region.

On the other hand, this study has several strengths. First, it is still one of the first and few such studies that actually need to become routine in monitoring the health of the population in relation to air pollution. Second, the results of the study indicate a positive association between PM_{10} concentration and the daily number of first consultations for all respiratory diseases among children in Zasavje. Consequently, the study provides important information for further work in the field of public health activities, especially the implementation of environmental health promotion activities in the region. While there has been much done in the Zasavje region in recent years in the sense of reduction of some air pollutants (for example installation of filter systems to reduce SO_2 emissions in the local cement and steam power plants), some problems still remain. The biggest problem at the moment is certainly the outdoor air pollution with PM_{10}, but the results of our study also indicate a problem of the outdoor air pollution with O_3. Here, new problems related to the chemical composition of PM_{10}, in which a lot of invisible hazards could be hidden, are posing along the old problems related to PM_{10} concentrations. Another important strength of our study is that it showed important deficiencies in the currently available input data for studies that integrate routinely collected health and environmental data in Slovenia. These deficiencies could be eliminated to a large extent and consequently make these kinds of studies in Slovenia more viable and useful in the field of health policy (59).

All issues arising during our study represent a new challenge for future research in the field of linkage of environmental and health data in Slovenia. Since this kind of research is in the beginning stages, there is a lot that has to be done. Although we now have some knowledge in the use of linkage methods for environment and health (24, 32), we first need to make the routinely collected data in both information systems - health and environment – more reliable. Although there will be a lot of difficulties in solving these problems, especially since changes in legislation should be addressed in this process, they are not unsolvable. Certainly, the multidisciplinary approach would be the most appropriate and successful.

5 CONCLUSIONS

In conclusion, we found positive correlation between concentrations of PM_{10} and the daily number of first consultations for all respiratory diseases among children in the Zagorje and Trbovlje municipalities. On the basis of these results, it can be assumed that with some improvements (at least a uniform method to collect health-related data, more air pollution measuring sites in the more polluted areas and more detailed geographical studies), linkage of existing health and environmental data in Zasavje could be feasible in identifying a grounded need for public health action.

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