Original scientific paper

Variation in Indicators of Respiratory Functions among Warsaw Adolescents in Relation to Ambient Air Pollution and Smoking

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A B S T R A C T

This work presents results of studies on secondary school adolescents inhabiting two regions of Warsaw: Sródmiescie district (Downtown) and Miedzylesie (Wawer district – Vicinity), conducted in 2006. These two districts significantly differ according to air pollution, which is much higher in Downtown than in Vicinity. The sample consists of 219 boys and 225 girls aged 13–16 years. The measurements included body height and weight and 8 respiratory variables of lung function: VC, FEV1, TV, MV, IRV, ERV, Ap, RR. Additionally information about education of parents, number of children in family, number of rooms in a house/apartment, smoking habits of pupils and their parents were provided. Sib-sib size, parents education level and number of rooms in apartment or house were included in a principal component analysis (PCA) to obtain a common factor representing general socio-economic status (SES) for families. First factor scores were used as covariates in the further analysis. The influence of air pollution on respiratory variables was evaluated using the analysis of covariance (ANCOVA). The results show that there are significant relations of air pollution to Ap, MV and IRV and smoking habits of individuals on their MV and TV. In the heavier polluted region there are observed longer time of Ap and higher values of IRV. There is an opposite reaction of MV on air pollution and smoking. The MV values are lower in the heavier polluted area but presents greater values in smoking individuals. Also values of TV are greater if individuals smoke comparing with non smokers.

***Key words**: Adolescents, respiratory variables, air pollution and smoking*

Introduction

Breathing is one of the most important function of our body. In order to be efficient mammals have possessed the multi-organ system of oxygen supply and carbon dioxide exclusion. People have no choice but to breath the air around them which may have many pollutants. Air pollution can cause coughing, burning eyes, and breathing problems[1]. The elderly, the young, and those with cardiopulmonary disease, such as asthma or severe bronchitis, are the most vulnerable to air pollution exposure. Children and youth are at greater risk because their lungs are still developing[2]. Fortunately, respiratory system is not defencelessness towards air pollutants and people usually start to feel better as soon as the air quality improves, but not always[3].

Another problem concerns effects of smoking on the respiratory system. Smoker patients showed a longer history of recurrent tonsillitis, difficulties in clinical management and evident morphostructural changes than non-smokers[4]. In 2003 according to General Sanitary Inspectorate, in Poland 10% of boys and 5% of girls aged 11–15 years were daily smokers, the number of children addicted to nicotine increases and children smoke 3–4 billion cigarettes annually[5]. Other investigations found an association between socio-economic status and respiratory health. This can partly be explained by living conditions indicated by occupational exposure, smoking behaviour and ambient air pollution. A relevant part of the social differences in respiratory health, however, remained unexplained[6].

The main aim of this study is the evaluation of respiratory system of young individuals living in areas characterized by moderately strong and less air pollution. The

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hypothesis states that the differences in respiratory variables between pupils living in the two Warsaw districts should be observed. The moderate level of air pollution may have an influence on basic respiratory variables, measured mostly at rest, whereas variables expressing working capacity of lungs may stay unchanged.

Materials and Methods

The material comprises of individuals attending two junior high schools. One in the downtown of Warsaw – Sródmiescie district and the second one located in the south-east part of Warsaw, named Miedzylesie (Wawer district, called Vicinity). Both schools are located in the Warsaw region to eliminate the difference in the school physical activity program which may be very distinct outside of Warsaw. These two districts significantly differ according to air pollution, which is much higher in Sródmiescie (Downtown) than in Miêdzylesie (Vicinity). The junior high school in Downtown has cooperated with the University of Cardinal Stefan Wyszynski for many years; the school in Mêdzylesie is the only one in this region, surrounded by recreational areas and nearby forest. There were 219 boys and 225 girls, aged 13–16 years, under study; 112 boys and 117 girls from downtown and 107 boys and 108 girls from vicinity. Individuals of not Polish origin (e.g. Vietnamese, Chinese, Ukrainians etc) were excluded from the sample. Only adolescents living in the selected area were taken into account. The information about migration within those particular districts was hard to obtained. We only assume that most adolescents have lived there since birth. The study were conducted from March to June, 2006, during morning hours, by the same person (D.S.). The subjects were asked to fulfil the questionnaire form and underwent anthropometric and respiratory measurements. The questionnaire form let us to obtain information about education of parents, number of children in family, number of rooms in a house/apartment, smoking habits of pupils and their parents. The measurements included body height and weight and 8 respiratory variables of lung function:

- VC – Vital capacity – the amount of air that can be inhaled in the deepest breath and exhaled completely (in L)
- MV – Minute Ventilation – volume of expired air in L per minute
- FEV_1 – Forced expiratory volume – lung volume measured after 1 second forced expiration, in L
- RR – Respiration rate per minute
- TV – Tidal volume – the amount of air that moves in or out in one normal breath (expirational and inspirational volumes during normal respiration, in L)
- IRV – Inspiratory reserve volume – further inspiration starting from the normal inspiration level, in L
- ERV –Expiratory reserve volume – possible further expiration staring from the normal expiration level, in L
- Ap – Apnoea – temporary suspension of breathing, in s.

Body height was measure using a Harpenden anthropometer, and body weight was measure using a calibrated beam-type balance to the nearest 0.1 kg, then body mass index (BMI) was calculated (weight in kg/height^2 in m), according to the methods described by Martin and Seller[7]. Using the Harpenden anthropometer a measurement error of height does not exceed 0.5 cm[8]. The registration of respiratory variables was done using Spirometer SP-10 made by Welch Allyn Schiller (San Diego, CA, USA). All patients were informed how to proceed all procedures during taking the test. All tests were taken three times and the best results were selected.

Both districts were very distinct according to the air pollution, The difference in air pollution between two Warsaw districts is based on the CSO data[9] and presented in Table 1. There is also an information about air pollution in other Polish city named Dabrowa Górnicza, located in the most polluted area of Poland[10]. It shows that the pollution in Downtown of Warsaw is rather moderate, however according to the dust and gas pollution as well as CO, CO_2 and SO_2 emission is much higher in Downtown than in Vicinity, thus those two regions of Warsaw were distinguished as higher and lower polluted area and were used as a factor in the further analysis.

The principal component analysis (PCA) was used to obtain a common factor representing general socio-economic status (SES) for families. Sibship size, parents education level and number of rooms in apartment or house were then included in a principal component anal-

TABLE 1
AIR POLLUTION FOR SILESIA REGION AVERAGE FOR 2006 YEAR, AND WARSAW CITY AVERAGE FOR 2005 YEAR, AND FOR TWO DISTRICTS OF WARSAW: ŒRÓDMIEŒCIE (DOWNTOWN) AND WAWER (VICINITY)

Emission of air pollutants (tons/year)	Dabrowa Górnicza (2006)	Warsaw (2005)	District	
			Downtown	Vicinity
Dust pollution	4,247	2,350	1,294	99
Dust pollution per 1 km^2	22.6	4.5	36.6	1.2
Total gas pollution	5,345,244	6,488,639	3,438,978	49,307
SO_2 pollution		28,496	17,782	281
Nitrogen oxides pollution		9,340	5,929	90
CO pollution		1,382	507	79
CO_2 pollution		6,448,914	3,414,760	48,857
Total gas pollution per 1 km^2	28,432.2	12,550.6	97146.3	618.7

ysis (PCA) The PCA produced two meaningful components with an eigen values of 1.62 and 1.15, sharing 40.4% and 28.8% of the variance, respectively. Loadings of four proxy measures of SES varied from 0.26 to 0.82. Since usually a first factor presents a size effect of applied variables, and all loadings were positive, the first factor scores were used as covariates in the further analysis (Table 2). Individuals who received higher values of PC1 scores represented the higher status of SES.

TABLE 2
RESULTS OF PRINCIPAL COMPONENT ANALYSIS (PCA) DETERMINING COMMON SOCIO-ECONOMIC FACTOR (SES)

Features included in PCA	PCA first factor loadings
Father's education	0.823
Mother's education	0.771
Number of rooms in apartment/house	0.523
Sibship size	0.264

Eigen value=1.62,% variation explained=40.38

The influence of air pollution on respiratory variables was evaluated using the analysis of covariance (ANCOVA) using Generalized Linear Model with logit link function. Appropriated parameters of lung function were dependent variables, the SES, smoking habits of parents and examined individual's and area of habitation were independent variables, the age, and body size (height, weight and BMI) were covariates. Differences in values of lung variables between two regions were presented graphically.

Results

Table 3 shows number of subjects, means and SD of height and BMI for boys and girls by their age group.

Distribution of percentage across parental education, number of children, information about smoking within their parents as well as emission of air pollutants by sex of studied individuals did not show significant differences. There is only a clear evidence that smoking is more popular in boys than in girls (χ^2=6.36; $p<0.05$).

The results of ACOVA showing the relation of air pollution and smoking habits to the respiratory indices are presented in the Table 4. There is a strong relation of height, sex, BMI and age of individuals to the respiratory variables, whereas the relation of SES concerns AP and TV only. The most important results show that independently on the associations described above, there are significant relations of air pollution to Ap, MV and IRV and smoking habits of individuals on their MV and TV. The direction of this relation is shown in figures from 1 to 5. In the heavy polluted region there are observed longer time of AP (Figure 1) and higher values of IRV (Figure 3). There is an opposite reaction of MV on air pollution and on smoking. The MV values are lower in the

TABLE 3
MEANS AND STANDARD DEVIATIONS OF HEIGHT AND BMI IN BOYS AND GIRLS

Age in years	N	Height		BMI	
		$\overline{X}$	SD	$\overline{X}$	SD
BOYS					
13	13	164,37	8.52	19.40	2.07
14	66	166.09	8.25	20.50	3.32
15	80	173.11	7.91	21.41	3.90
16	60	176.59	7.66	22.57	3.19
GIRLS					
13	12	158.78	5.86	19.76	3.04
14	78	161.82	5.46	20.71	3.02
15	82	164.64	5.41	20.82	2.61
16	53	165.10	5.95	21.31	2.43

TABLE 4
THE RELATION OF AIR POLLUTANTS AND SMOKING HABITS OF STUDIED INDIVIDUALS AND THEIR PARENTS TO THE 8 LUNG INDICES CONTROLLING BY AGE, SEX, HEIGHT AND BMI OF INDIVIDUALS AND SES. THE RESULTS OF THE ACOVA COVARIANCE ANALYSIS USING LINEAR MODEL WITH LOGARITHMIC JOINED FUNCTION (WALD χ^2)

Independent variables	Dependent variables/ lung characteristics							
	AP	RR	MV	TV	IRV	ERV	SVC	FEV1
Sex	7.86**	8.90***	12.69***	1.53	14.15***	8.08**	92.22***	28.61***
Age	8.48**	0.14	0.40	0.51	2.64	12.96***	24.46***	13.06***
Height	19.26***	0.38	18.98***	27.61***	51.09***	78.61***	340.92***	309.39***
BMI	0.00	3.79*	3.34	16.31***	17.88***	1.50	70.04***	50.57***
SES	4.74*	2.20	0.67	7.51**	3.24	1.03	1.29	0.08
Patient's moking	0.00	0.42	11.13**	5.27*	0.08	0.009	1.79	1.83
Mother's smoking	0.15	0.57	3.54	5.02*	0.01	0.02	0.10	0.98
Father's smoking	2.70	5.30*	1.22	8.18**	1.51	0.01	0.63	2.55
Level of air pollutants	51.70***	0.11	4.06*	4.04	15.64***	0.23	1.45	1.60

*p<0.05; **p<0.01; ***p<0.001

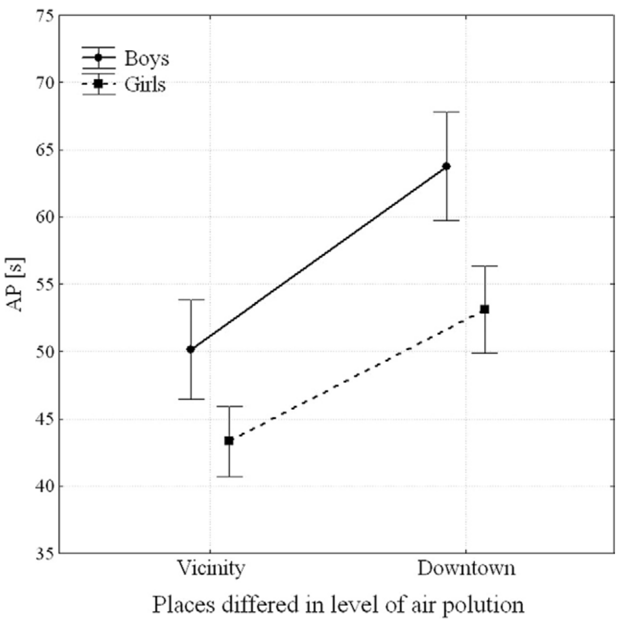

Fig . 1. *Values of apnoea (Ap in s) in youth 13–16 years of age coming from downtown and vicinity (Miêdzylesie) of Warsaw.*

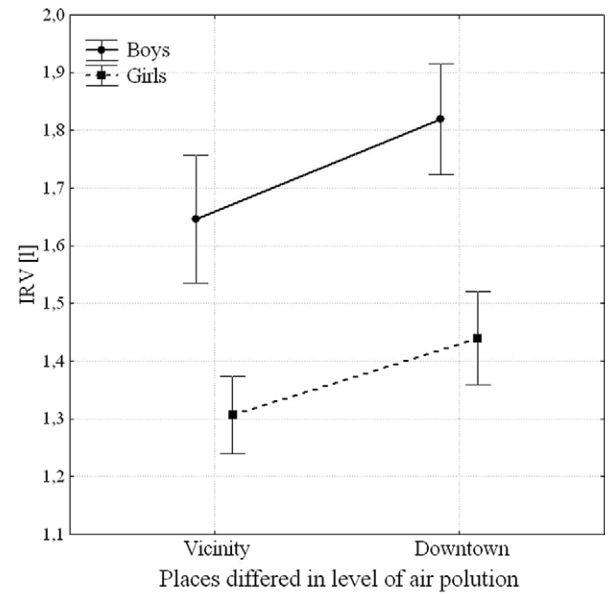

Fig 3. Values of inspiratory reserve volume (IRV in L) in youth 13–16 years of age coming from downtown and vicinity (Miêdzylesie) of Warsaw.

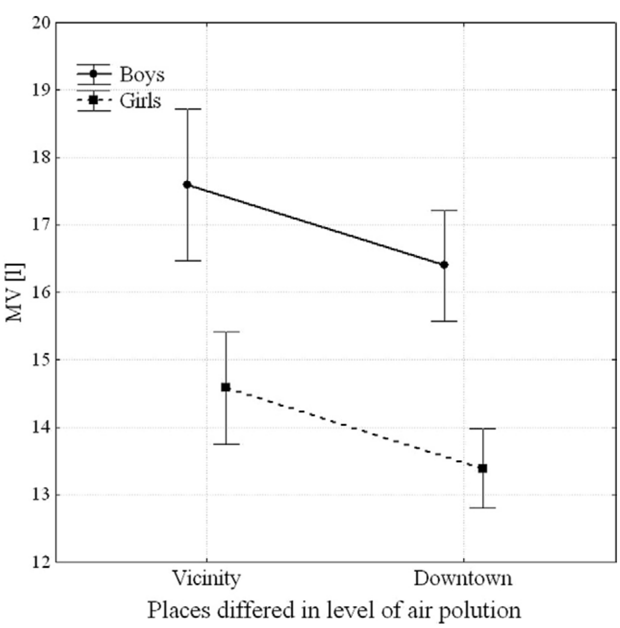

Fig . 2. Values of minute ventilation (MV in L) in youth 13–16 years of age coming from downtown and vicinity (Miêdzylesie) of Warsaw.

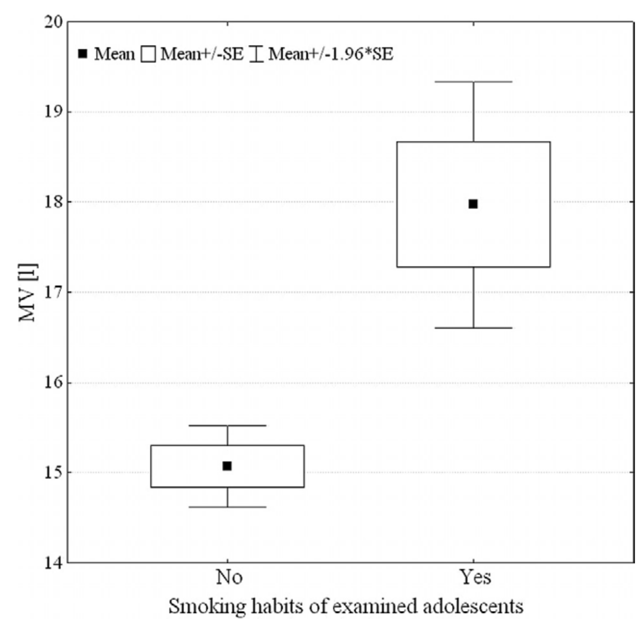

Fig 4. Values of minute ventilation (MV in L) in smoking and nonsmoking youth 13–16 years of age coming from downtown and vicinity (Miêdzylesie) of Warsaw.

heavy polluted area (Figure 2) but presents greater values in smoking individuals (Figure 4). Also values of TV are greater if individuals smoke comparing with non smokers (Figure 5).

Discussion and Conclusion

The examinations of heavy polluted areas (Silesia region) in Poland in late sixties of XX century revealed that all respiratory functions of individuals living there were higher than in non polluted regions[11]. The authors named this phenomenon »overadaptation«, what means the lack of reserves of the organism for further changes. The similar survey conducted at the end of seventies of XX century found that the lung system works the best in the rural areas (VC, IRV, ERV, MV), the lowest values of respiratory indices were found in inhabitants of regions under industrialization, but the volume of FEV_1 (forced expiratory volume) was the lowest in Silesia[12], the most polluted region of Poland. Further Polish examination

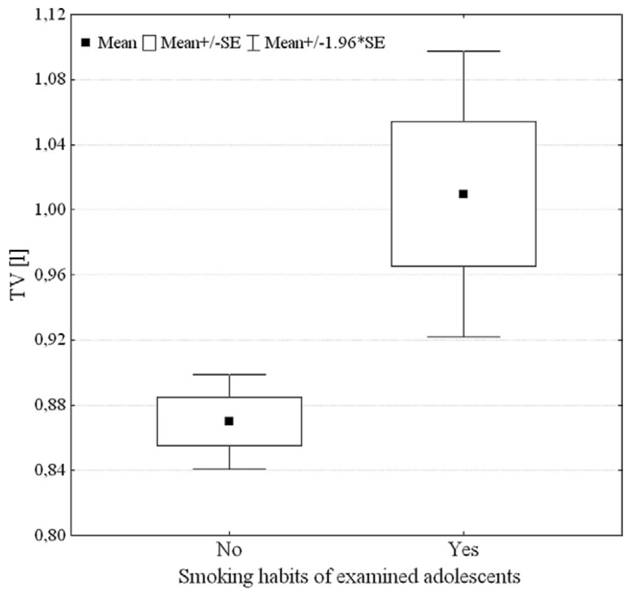

Fig 5. Values of tidal volume (TV in L) in smoking and nonsmoking youth 13–16 years of age coming from downtown and vicinity (Miêdzylesie) of Warsaw.

conducted in nineties in the Pomorze district also revealed that more polluted regions were manifested by the less efficient respiratory system of their inhabitants[13]. Letter on, the same results were found for young men (nonsmoking) inhabiting different Polish regions[13]. Lithuanian studies have also revealed that VC and FEV_1 have lower values in children coming from regions with greater air pollution[15].

Currently, the examination of lung system efficiency includes mostly two indices: VC and FEV_1. The wide spectrum of investigations were conducted in California during 11 years examining longitudinally respiratory system of adolescents 10–18 years old who were exposed to nitrogen dioxide, acid vapour and elemental carbon. There was observed statistically significant deficits in the FEV_1 attained at the age of 18 years[16].

Also results of Chinese studies on children's lung function in areas with heavy air pollution revealed that the level of FVC (forced vital capacity), FEV_1 and MMEF (mid-expiratory flow rate) are lower than in areas with light ambient air pollution[17].

The present results did not show any relation of air pollution presented for Downtown of Warsaw (Table 1) to VC and FEV_1 of studied adolescents 13–16 years of age. The answer probably lies in the level of pollution which in Warsaw is not the extremely heavy comparing with other regions of Poland (e.g. Silesia), or other quoted earlier regions in the World. However it presents the relation to other respiratory variables, showing the preliminary changes which might be under control. The most important results of present study revealed that in the air polluted areas the lung function of individuals is characterized by longer apnoea (Ap), greater inspiratory reserve volume (IRV) and lower minute ventilation (MV) than in less polluted regions. This might suggest that when there are many pollutants in the breathing air the lung system reacts by extending suspension in breathing (in case of odours etc), and prolonging further inspiration (after the normal one, so more oxygen can get to lungs). However the final result is manifested by diminishing volume of expired air per 1 min because lungs tray to utilize all oxygen contained in breathing air.

Similarly to presented results concerning relations between air pollution and the status of respiratory system, smoking also decreases efficiency of lungs. There were many studies carried out which revealed the negative influence of smoking on respiratory system. Polish workers of steel industry who smoked exhibited lower volumes of FEV_1 as the direct influence of nicotine[18]. The longitudinal studies on the effects of cigarette smoking in a cohort of 5158 boys and 4902 girls 10 to 18 years of age in the United States revealed that cigarette smoking is associated with evidence of mild airway obstruction and slowed growth of lung function in adolescents. Adolescent girls may be more vulnerable than boys to the effects of smoking on the growth of lung function[19]. The survey in Japan on male workers showed up that smoking decreased VC and FEV_1 of their respiratory system[20]. Also the Brazil young smokers exhibited lower values of FEV_1[21].

In the present studies there is no relation between smoking and VC and FEV_1. However such relation was found with other respiratory variables. The young Warsaw individuals who smoked exhibited higher values of MV and TV (expirational and inspirational volumes during a normal respiration). This means that their lungs inspire and expire more air.

At the end of this discussion it is worth to mention that there is one result which is opposite in case of the relation of air pollution and smoking to respiratory variables. Minute ventilation which measures volume of expired air in 1 minute is lower in air polluted region but higher when individuals smoke. For human health smoking is considered more dangerous than a polluted area[22]. The direct influence of nicotine on respiratory system in young individuals may at the beginning increase the properties responsible for breathing in order to extend the volume of inspire air, however such results were not proof by outcomes of other studies.

As the conclusion it should be mentioned that lower minute ventilation in youth found in more polluted region shows the direction of future changes of respiratory system, and that young individuals at the beginning of smoking might represent the higher values of MV and TV.

We have also to remember that both tobacco and air pollution are controllable: one by individual will, the other by public effort.

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VARIJACIJE U POKAZATELJIMA RESPIRATORNIH FUNKCIJA MEĐU VARŠAVSKIM ADOLESCENATIMA U ODNOSU PREMA ATMOSFERSKOM ONEČIŠĆENJU ZRAKA I PUŠENJA

SAŽETAK

Ovaj rad predstavlja rezultate istraživanja srednjoškolske mladeži iz dviju Varšavskih regija: Sródmiescie regije (Downtown) i Miedzylesie (Wawer district – Vicinity), provedenog 2006. Te se dvije regije značajno razlikuju prema onečišćenju zraka, koje je znatno više u Downtown regiji. Uzorak se sastoji od 219 dječaka i 225 djevojčica u dobi od 13 do 16 godina. Mjerenja uključuju visina tijela i težinu i 8 respiratorne varijable plućne funkcije: VC, FEV1, TV, MV, Irv, ERV, Ap, RR. Pružene su informacije o edukaciji roditelja, broju djece u obitelji, broju soba u kući/stanu, pušačkim navikama učenika i njihovih roditelja. Sib-Sib veličina, razina obrazovanja roditelja, kao i broj soba u stanu ili kući su uključeni u analizi glavnih sastavnica (PCA) usmjerenoj u dobivanju zajedničkog faktora koji predstavlja opći društveno-ekonomski status (SES) za obitelj. Prvi rezultati su korišteni kao kovarijanta za daljnju analizu. Utjecaj onečišćenja zraka na respiratorne varijable dobiven je analizom kovarijante (ANCOVA). Rezultati pokazuju kako postoje značajni odnosi između onečišćenja zraka i Ap, SN i Irv, kao i navike pušača s obzirom na njihov MV i TV. U teže zagađenim regijama primijećeno je duže trajanje Ap i veće IRV vrijednosti. Imamo suprotnu reakciju MV vrijednosti prema onečišćenju zraka i pušenju. MV vrijednosti su niže u teže zagađenim područjima, ali nalazimo više vrijednosti kod pušača. Također, TV vrijednosti su više kod pušača.