The Influence of the New National Clean Air Law on the $PM_{2.5}$ Air Pollution in the Campus of the UMPh Tirgu Mures During the Implementation of the Smoke-free University Project

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Measurement of $PM_{2.5}$ concentration is a widely used marker of air pollution, including exposure to secondhand smoke. The tobacco smoking ban in March 2016 prohibited smoking in all confined public places in Romania, which should lower the exposure to $PM_{2.5}$ if well-implemented and enforced. Our research team started in 2014 a unique program in Romania to implement a smoke-free medical university project. The aim of this study was monitoring the air quality based on $PM_{2.5}$ measurements prior and after the ban. $PM_{2.5}$ air pollution was measured prior to and after the ban in five buildings of the campus of University of Medicine and Pharmacy in Tirgu Mures: the main educational building and four student dormitories. Measurement was obtained using the Aerosol Monitor Side Pak AM 510. We observed significantly improved air quality ($p<0.0001$) in each building, with the most radical changes recorded in two student dormitories: from very unhealthy levels of exposure prior to the ban (exceeding 170-185 µg/m³) to the unhealthy for sensitive groups (40 µg/m³) and moderate air pollution (under 20 µg/m³) after the ban. In the main educational building the $PM_{2.5}$ concentration decreased from moderate pollution to very close to the threshold of good air quality. The decrease in air pollution of our university campus is likely due to the new legislation banning indoor smoking and the result of our smoke-free university project. However, despite improvements, $PM_{2.5}$ was not eliminated and needs continued efforts to enforce the ban particularly in student dormitories.

Keywords: tobacco ban, air pollution, smoke-free university, $PM_{2.5}$ concentration

According to recent WHO data, an estimated 12.6 million deaths each year are attributable to unhealthy environments. Efficient strategies to reduce environmental risks in the cities, homes and workplaces are crucial, and implementing them can significantly reduce the rick of cancer, respiratory and cardiovascular diseases, while leading to reduced healthcare costs [1]. Air quality is highly influenced by $PM_{2.5}$ concentration, which are fine particles with a diameter of 2.5µm or less. The most common source of outdoor $PM_{2.5}$ is the the burning of fossil fuels, caused by vehicle exhaust emissions, smelting, metal processing [2]. Elevated $PM_{2.5}$ levels are observed in highly dense, urban populations with limited green space. A recent epidemiologic study on particulate air pollution in 16 Chinese cities revealed that short-term exposure to PM_{10} is associated with increased mortality risk [3]. Indoor air quality has become increasingly important in the 21st century. Sources of indoor air pollution include combustion-related activities, such as secondhand smoke, cooking, fireplaces and burning candles [4, 5]. A recent study conducted in 21 world regions estimated that indoor air pollution was responsible for 3.9 million premature deaths per year, ranking it highest among environmental risk factors examined, and considered one of the major modifiable risk factors of any type affecting human health [6].

$PM_{2.5}$ particles can penetrate deeply into the lung, irritate and corrode the alveolar wall, and consequently impair lung function. Exposure to these particles has been shown to cause serious respiratory problems, and can lead to severe lung and heart disease causing premature death (6). The mechanism of action is based on the generation of oxidative stress by organic and inorganic components of $PM_{2.5}$, with inorganic fine particulate matter likely impacting the respiratory system, while the organic particles increasing the risk of cardiovascular disease [7]. In addition to its negative effect on human health, $PM_{2.5}$ pollution also affects the environment, and involves additional costs on the population [8, 9]. According to prediction of the specialists, a set of air quality improvement policies proposed in 2005 would bring a welfare gain of 37-49 billion Euros in 2020 for the entire Europe [10)]. The most affected country, China, is estimated to experience, without an efficient $PM_{2.5}$ pollution control policy, a 2.00% GDP loss and 25.2 billion USD in health expenditure from $PM_{2.5}$ pollution in 2030 [11].

Smoking in public places represented a major public health problem in Romania at the beginning of the 21st century. According to an international study conducted between 2003-2007 based on the data collected from 1822 places in 32 countries, the three countries with the highest geometric mean $PM_{2.5}$ values were Syria (372 mg/m³), Romania (366 mg/m³) and Lebanon (346 mg/m³), while $PM_{2.5}$ pollution levels were lowest in Ireland (22 mg/m³), Uruguay (18 mg/m³) and New Zealand (8 mg/m³), where comprehensive national clean indoor air policies were implemented [12].

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In 2015/6 Romania introduced a complementary tobacco control law to the existing legislation (law nr. 349/2002). The new law, nr. 15/2016, includes strategies of smoking prevention especially in the young population. In this context the document entitled *2035 – First Tobacco-Free Generation of Romania* should me mentioned, which is a commitment paper and a work program in the same time, an initiative of representatives of civil and medical societies aiming to protect the population of Romania from tobacco use, following the principles and aims of the National Health Strategy 2014-2020.

The new national clean air law includes complete banning of indoor smoking in all public spaces including educational buildings, healthcare institutions, pubs, restaurants. Our research group, which led the first-ever smoke-free medical university project in Romania, participated in implementation of these changes in the legislation. Members of our team were in direct contact with the committee in the government to support their legislative efforts. Several suggestions made by our research team were incorporated into the new law voted by the Parliament of Romania in January 2016.

The aim of our study was monitoring the air quality and estimating exposure to $PM_{2.5}$ as a measure of legislation control in a medical university campus before and after the national clean air law that went into effect in Romania on the 17th March 2016, which banned indoor smoking in public buildings. Making the results public, our initiative has also an educational role for students and employees of our university, increasing the consciousness of risk related to smoke exposure to complement the smoke-free policies.

Experimental part

Material and methods

We estimated $PM_{2.5}$ pollution in the 3rd (top) floor of the central building of the University of Medicine and Pharmacy, Tîrgu Mures and on the top floor of four student dormitories on the campus using the TSI Aerosol Monitor Side Pak AM 510[13]. Measurement were taken prior to implementation of the new law (21.01.2015-16.03.2016) and after the law (17.03.2016-22.12.2016). In the central building there were, 153 and 80 measurements taken before and after the law, respectively. Likewise, 150 measurements before and 89 after the new law were taken in the student dormitories. Measurements were performed weekly, after calibration of the equipment, on Wednesdays, between 13-14 o'clock (in the main building) and between 20-22 o'clock in the student dormitories. The $PM_{2.5}$ particle concentration values were compared to the North Carolina Air Quality Standard revised in 2013. SPSS version 22 and GraphPad InStat were used for statistical processing of the experimental data.

Results and discussions

Air quality significantly improved during this period. In the central building of the university, the average $PM_{2.5}$ concentration was 28.75 $\mu g/m^3 \pm 22.12$ (SD) before the new law, which corresponds to moderate pollution, approaching the highest limit of the range (12.1-35.4 $\mu g/m^3$). After the legislation, $PM_{2.5}$ decreased to 12.89 $\mu g/m^3 \pm 8.81$ (SD) approaching the range of good air quality ($p<0.0001$) (fig. 1).

A similar pattern was observed in the student dormitories (table1). The mean $PM_{2.5}$ concentration significantly decreased from 121.90 $\mu g/m^3 \pm 162.2$ (SD) measured before the law went into effect to 21.91 $\mu g/m^3 \pm 30.02$ (SD) after implementation of the new law ($p<0.0001$).

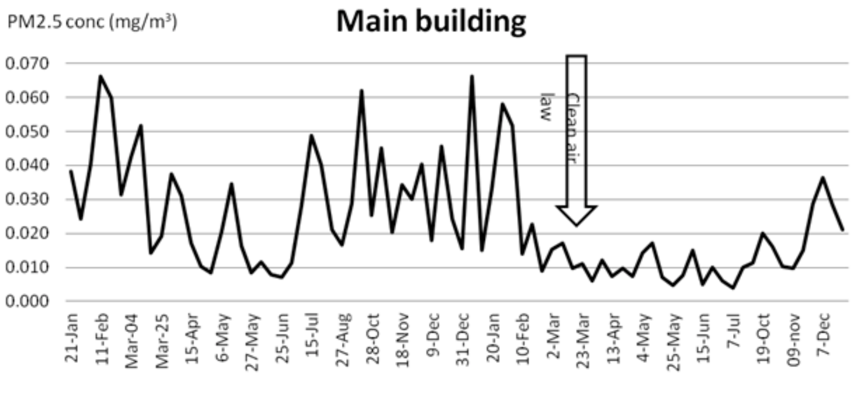

Fig. 1. Dynamics of $PM_{2.5}$ air pollution in the main building of the UMPh Tirgu Mures before and after the national clean air law

Table1

AVERAGE $PM_{2.5}$ CONCENTRATIONS IN SOME BUILDINGS OF THE UMPh TIRGU MURES UNIVERSITY CAMPUS BEFORE AND AFTER THE NATIONAL CLEAN AIR LAW

	Mean PM2.5 concentration before the new law (mg/m3)	Mean PM2.5 concentration after the new law (mg/m3)	Significance
All measurement sites	0.07487	0.01764	<0.0001
Main building total values	0.02875	0.01289	<0.0001
Central staircase	0.03204	0.01233	<0.0001
Hygiene	0.02937	0.01308	<0.0001
Microbiology	0.02484	0.01326	0.0005
Student dormitories total values	0.1219	0.02191	<0.0001
Dormitory nr. 1 (family dorm)	0.05985	0.01239	<0.0001
Dormitory nr. 2 (female students dorm)	0.07438	0.01632	<0.0001
Dormitory nr. 3 (male students dorm)	0.1861	0.04014	<0.0001
Dormitory nr. 5 (female students dorm)	0.1708	0.01923	<0.0001

This change corresponds to a transition from *unhealthy* air quality (55.5-150.4 μg/m^3) to *moderate* air pollution (12.1-35.4 μg/m^3).

Despite a positive impact of the law on decreasing $PM_{2.5}$ all spaces, the post-law air quality in male bedroom remained high, the prevalence of smoking amongst male medical students of our campus being 41%. In this building of the campus the average $PM_{2.5}$ concentration was 186.10 μg/m³ ± 195.6 (SD) before the law (very unhealthy, range 150.5-250.4 μg/m³), and 40.14μg/m³ ± 49.44 (SD) after the law (unhealthy for sensitive groups, range 35.5-55.4 μg/m³), $p<0.0001$ (fig. 2).

In the other three bedrooms the improvement of $PM_{2.5}$ air pollution was also significant ($p<0.0001$). The best air quality was observed before and also after the law in the family dormitory, where the average $PM_{2.5}$ concentration decreased from 59.9 μg/m³ ± 89.38 (SD) (unhealthy) before the new law to 12.4 μg/m³ ± 9.76 (SD) (approaching good air quality) after the law (fig. 3).

The most notable change was observed in one of the female student dormitories, where after implementing the new legislation the $PM_{2.5}$ air pollution decreased 9-fold ($p<0.0001$) from a very unhealthy level - 170.80 μg/m³ ± 209.2 (SD) - to a moderate pollution - 19.23μg/m³ ± 23.04 (SD) (fig. 4).

Needs to be mentioned that 2/3 of the medical students in our university campus are female individuals, their smoking prevalence being 31%. The high $PM_{2.5}$ concentrations measured in this building are most probably due to an arhitectural feature (a side staircase being the preferred smoking place of female students). In the other student dormitories air pollution decreased by about 4.5-fold after the new law compared to previous values ($p<0.0001$).

Exposure to $PM_{2.5}$ represents an important public health problem worldwide. Ambient fine particulate matter air pollution ($PM_{2.5}$) represents a major risk factor for severe diseases and death. Epidemiological studies showed that long-term exposure to $PM_{2.5}$ increases the risk of premature mortality due to respiratory diseases, lung cancer, heart disease and stroke, and overall substantially reduce life expectancy [14].

Several mechanisms have been proposed in the toxicology and epidemiology literature explaining how longterm exposure to $PM_{2.5}$ may cause cardiovascular disease, such as inducing systemic inflammation, oxidative stress, progression of atherosclerosis and immune function alteration. Population-based studies found evidence on an association between acute myocardial infarction and $PM_{2.5}$ exposure (15). Recent research data showed that in animal experiments, particle

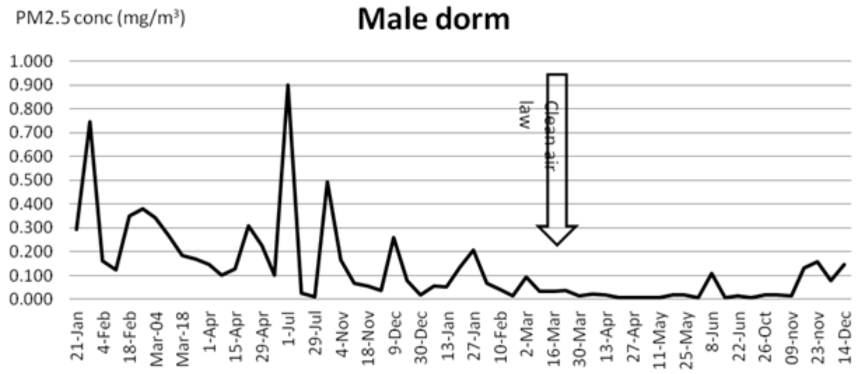

Fig. 2. Dynamics of $PM_{2.5}$ air pollution in the male student bedroom of the UMPh Tirgu Mures before and after the national clean air law

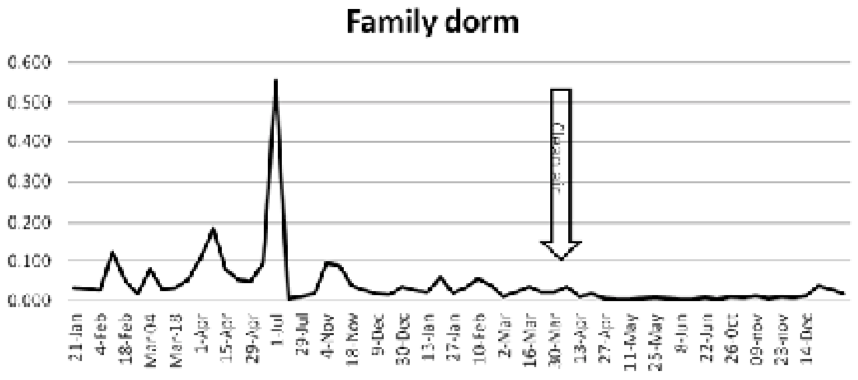

Fig. 3. Dynamics of $PM_{2.5}$ air pollution in the family bedroom of the UMPh Tirgu Mures before and after the national clean air law

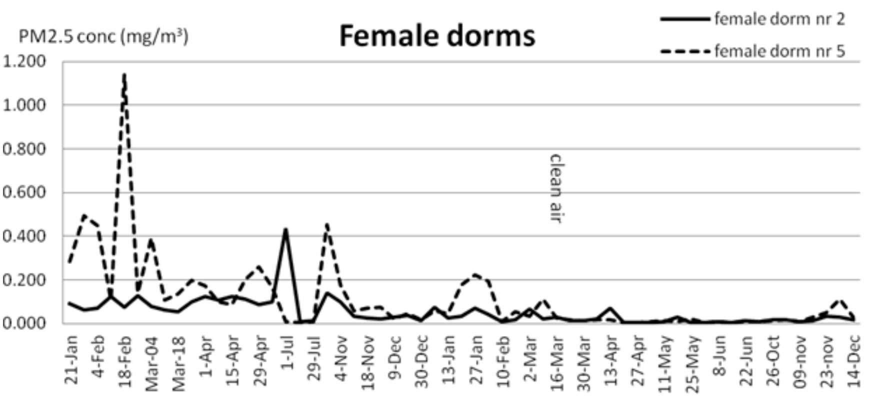

Fig. 4. Dynamics of $PM_{2.5}$ air pollution in the female student bedrooms of the UMPh Tirgu Mures before and after the national clean air law

exposure caused increased oxidation of LDL (low density lipoproteins), enlarged the thickness of the arterial wall, and promoted plaque growth and instability [16]. In humans, long-term exposure to $PM_{2.5}$ has been associated with increased carotid intima media thickness, a subclinical marker of coronary atherosclerosis [17].

The health benefits of reducing $PM_{2.5}$ exposure to the lowest possible values is of current interest. A recent research estimated the significant acute and chronic effects of $PM_{2.5}$ exposure below the current standards in the USA. According to the study conducted in New England, penalized spline models of long-term exposure indicated a larger effect for mortality in association with exposures exceeding 6 ìg/m^3 versus those under 6μg/m^3. In contrast, the association between short-term exposure to $PM_{2.5}$ and mortality appeared to be linear across the entire exposure distribution. The researchers concluded that improving air quality with even lower $PM_{2.5}$ than currently allowed by the current standards may benefit public health [18]. The most recent implementation guidelines state that effective measures require total elimination of smoking and tobacco smoke in all indoor places. Several countries adopted lately the Framework Convention on Tobacco Control to protect their citizens from exposure to tobacco smoke in workplaces, public transport and indoor public places, but still most of the world population remains exposed to secondhand smoke. As new tobacco products emerge, evaluating secondhand smoke exposure and its effects is crucial [19].

Significantly reducing $PM_{2.5}$ air pollution in the buildings of our university campus represents a major improvement in the environmental conditions for university students and faculty. Anecdotally, we observed an increase in the number of students smoking outdoors and on the perimeter of university buildings, including the main and secondary entrances to the central educational building. Thus, while the legislation may have had limited impact on smoking status of individuals, the health benefits of clean air for non-smokers should be realized by the legislation.

This is the first study to document the impact of the clean air legislation on medical universities in Romania using a validated environmental marker for air quality, where prior research has shown that smoking rates among Romanian heath professional students is high. According to a study carried out in 2010 at a medical university in Bucharest, Romania, the smoking rate among the dental students was 35% based on self-administered questionnaires [20]. Our research data showed that the overall smoking prevalence of medical students attending the University of Medicine and Pharmacy in Tîrgu Mures was 34 – 33.5 - 33.4%, respectively, evaluated in the spring of 2014-2015-2016 based on self-administered questionnaires.

Nonetheless, there are limitations of our study that should be noted. First, our data collection did not fully extend into the winter months, when one might hypothesize a lackadaisical policy enforcement period, given high rates of smoking among students and faculty. Second, we only measured the short-term effects of the new smoking ban, therefore, the long-term efficacy is unknown. Third, there may be certain places within buildings where students/ faculty smoke - such as bathrooms and private offices - which were not measured in this study. Thus, while we observed remarkable declines in $PM_{2.5}$ in public spaces and in dormitories, we acknowledge that the declines may be somewhat attenuated in private spaces where individuals may smoke and where observations were not possible.

Finally, the increasing tendency of the last few measured values during the winter period in 2016 and the intensification of outdoor smoking close to the buildings in the campus gives us caution about the long term efficacy of the new, clean air legislation and sets new objectives for the team involved in the smoke-free university project to promote local policy enforcement.

Conclusions

Decreasing evolution of $PM_{2.5}$ pollution could be observed in all the buildings of our university campus where our research team determined the fine particles' concentration. This improvement in the air quality lowers the exposure to second-hand smoking in our university campus, which was the aim of the interventions included in the smoke-free medical university project and the goal of the Romanian legislation banning smoking in public places.

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