Academy of Romanian Scientists *Volume 13, No. 2, 2024, pp. 74 - 83*
Annals Series on Biological Sciences Online ISSN 2285 – 4177

ORIGINAL PAPERS

EFFECTS OF POLLUTION ON ORAL HEALTH: TYPES OF POLLUTANTS AND IMPACT ON THE ORAL CAVITY

Malina VISTERNICU[1,2,*], Viorica RARINCA[1,2,3], Cătălina IONESCU[2,4], Vasile BURLUI[5], Gabriel CIMPOIESU[6], Alin CIOBICA[1,2,7,8]

[1] Doctoral School of Biology, Faculty of Biology, Alexandru Ioan Cuza University of Iasi, No 20A, Carol I Avenue, 700506 Iasi, Romania
[2] "Ioan Haulica" Institute of Apollonia University, Pacurari Street 11, 700511 Iasi, Romania
[3] Doctoral School of Geosciences, Faculty of Geography and Geology, "Alexandru Ioan Cuza" University of Iași, Carol I Avenue, No. 20A, 700505 Iași, Romania
[4] Department of Biology, Faculty of Biology, Alexandru Ioan Cuza University of Iasi, Bd. Carol I no. 20A, 700505 Iasi, Romania.
[5] Clinical Department, Apollonia University, Păcurari Street 11, Iasi, Romania
[6] Citadin S A, Bulevardul Tudor Vladimirescu 32, Iasi, Romania
[7] CENEMED Platform for Interdisciplinary Research, "Grigore T. Popa" University of Medicine and Pharmacy of Iasi, University Street No. 16, 700115 Iași, Romania.
[8] Academy of Romanian Scientists
* Corresponding author: malina.visternicu@yahoo.ro

Abstract. *Air pollution is known as a major problem for public health but also the health of the environment. As it increasingly affects the quality of life, it has become a topic of interest for researchers in recent years. Air pollution refers to the pollution of the environment by liquids, gases, and solids but also wastes that have negative effects on health. The pollutants with the greatest harmful potential are particulate matter (PM), sulfur dioxide (SO2), tropospheric ozone (O3), and nitrogen dioxide (NO2), but also some heavy metals. This review article aims to correlate oral health and air pollution and to analyze the types of air pollutants. We will also investigate their direct and indirect effects on the oral cavity, as these compounds can contribute to oral health problems such as periodontal diseases, oral cancer, and dental caries, through different mechanisms, including oxidative stress (OS), inflammation, and oral microbiome imbalances. By understanding these mechanisms, we want to emphasize the need for multidisciplinary approaches to reduce the negative effects of environmental pollution on oral health.*

Keywords: oral health, environmental pollution, air pollution, oral diseases, periodontitis

DOI [10.56082/annalsarscibio.2024.2.74](https://doi.org/10.56082/annalsarscibio.2024.2.74)

INTRODUCTION

In recent years, researchers have begun to investigate the correlation between oral health and air pollution [1]. Environmental pollution involves the production or release of harmful substances or contaminants in the natural environment (water, air, or soil) that can harm living organisms and the ecosystem. Air pollution is a complex mixture of particles and gases with a high risk to human health. The most harmful air pollutants consist of gaseous pollutants, including PM, O_3, NO_2, SO_2, and CO. PM is a complex mixture of solid, liquid, or solid-liquid particles suspended in the air [2]. Since pollutants enter the body through inhalation and cause various respiratory and cardiovascular problems or other serious health problems such as premature death, heart attacks, and ingestion, it is reasonable to assume that there is a strong correlation between these pollutants and their impact on the oral cavity [3].

Air pollution is one of the biggest public health challenges globally, being associated with a wide range of conditions, from respiratory and cardiovascular problems to mental health effects. In this context, the oral cavity is one of the main routes of environmental contamination associated with many chronic diseases (cancers, fertility, and behavioral disorders) through diet, drugs, and breathing [4]. These environmental factors, including, but not limited to, endocrine disruptors and excessive fluoride can disrupt dental development and thus lead to irreversible enamel defects. These defects are then treated with materials that can release molecules capable of generating these defects, leading to a vicious circle, especially in pregnant women and young children [4]. An important role in the health and disease of the oral cavity is played by the microbiota, because oral infections, caries, and periodontal diseases are mostly associated with the dysbiosis of the oral microbiota [5].

Oral diseases are among the most widespread diseases globally, hurting health by reducing the quality of life [6]. According to the World Health Organization (WHO), 45% (3.5 billion people worldwide) have dental conditions during their lifetime from early life to old age (Figure 1).

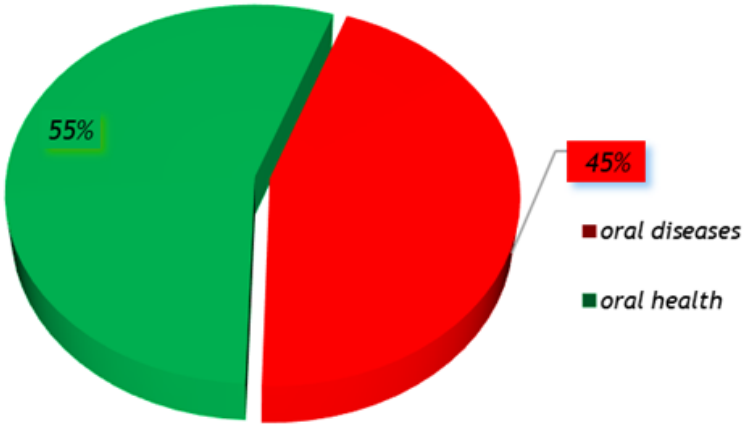

Figure 1. Global prevalence of dental conditions (according to WHO)

Among the most prevalent oral diseases are dental erosion, periodontal disease, tooth loss, and cancer in the oral cavity [7,8]. Good oral health reflects a person's ability to adapt to physiological changes throughout life but also to maintain their teeth through care. Although tooth decay is a lifelong condition, it affects very young children, so it needs to be followed up into adolescence and adulthood, even later. Moreover, oral diseases particularly affect socially disadvantaged people [8]. Although it is the most common infectious disease of humans, its prevalence varies from one population to another [9].

Periodontal disease is a type of chronic, non-communicable inflammatory disease caused by the colonization of the tooth surface, especially around the gingival margin and interdental spaces. The colonized biofilm releases a variety of biologically active products, including endotoxins, chemotactic peptides, organic acids, and protein toxins. They diffuse into the gingival epithelium and initiate the host response that ultimately leads to gingivitis [9]. Associations between periodontal disease and other systemic medical conditions may result from inflammatory mechanisms or due to a disruptive host immune response [10]. In addition to those previously mentioned, there are other environmental factors associated with periodontal disease, including drug use, methamphetamine, and smoking, the latter affecting all components of the inflammatory response, and being associated with increased tooth loss [11].

Another oral condition is oral cancer, being one of the most common types of cancer worldwide. It is defined as a malignant neoplasia that occurs in the oral cavity or on the lip, more common in men than in women. Among the major factors of this condition are alcohol consumption and smoking, reported in 90% of cases, both having a synergistic effect [12,13]. Ochoa Scussiatto et al., (2024) demonstrated that there is a clear relationship between increased levels of

exposure to polluted air and increased incidence rates of oral cavity cancer [14]. Also, Dhane et al., (2024) stated that the increase in environmental pollutants, including arsenic (As), was associated with oral cancer, which is an alarming indicator of future global health problems [15].

Through this review, we aim to investigate the influence of some atmospheric pollutants on oral health, this, being useful to dentists in informing patients about the implications of pollution on oral health, thus supporting the promotion of environmental sustainability.

MATERIALS AND METHODS

The most common scientific databases such as PubMed, Google Scholar, and Science Direct were used to write this review. The search focused on the use of the keywords "oral health", "environmental pollution", "air pollution", "oral diseases", and "periodontitis", but also the combination of these. Also, only English language data up to November 2024 were included. Searching for the combination of the words "environment pollution" and "oral diseases" were identified in PubMed (n=1677), Google Scholar (84,600), and Science Direct (n=23,228). These results demonstrate the interest of researchers in this topic which is becoming more and more problematic in global health. Finally, we selected several 35 articles relevant to achieving the purpose of the review.

Types of pollutants and their impact on oral health

Ambient air pollutants mainly come from industrial activities, forest fires, waste burning, and transport emissions [16]. Environmental pollutants have become one of the important causes of congenital malformations [17]. Air pollutants can influence local and systemic inflammation, oxidative stress, but also the microbial community. According to the WHO, air pollution is the largest environmental risk factor for human disease, and almost the entire population (99%) breathes air that exceeds WHO limits [1,18]. Air pollution, climate change, lead contamination, pesticide residues in food, and new chemicals have a significant impact on human health. However, it is important to note that 23% of environmental risk factors can be modified and prevented. In the current context, the global population is facing increasing chronic exposure to heavy metals in the environment, generated by rapid urbanization and large-scale industrial activities [19].

Major public health pollutants include PM such as inorganic gases and secondary pollutants (CO_2, NO_2, O_3, and As) released from chemical reactions in the atmosphere (Figure 2) [1]. Carbon monoxide (CO) is the third cause of poisoning. However, its harmful effects are not only limited to acute poisoning

with high concentrations but also to prolonged exposure to low doses. CO toxicity is manifested by ion channel dysregulation, reactive oxygen species (ROS) generation, cytochrome c oxidase impairment, and endothelial nitric oxide release. In this context, OS plays an essential role in the pathogenesis of many diseases, including in the oral cavity, because it is exposed to polluted air [20].

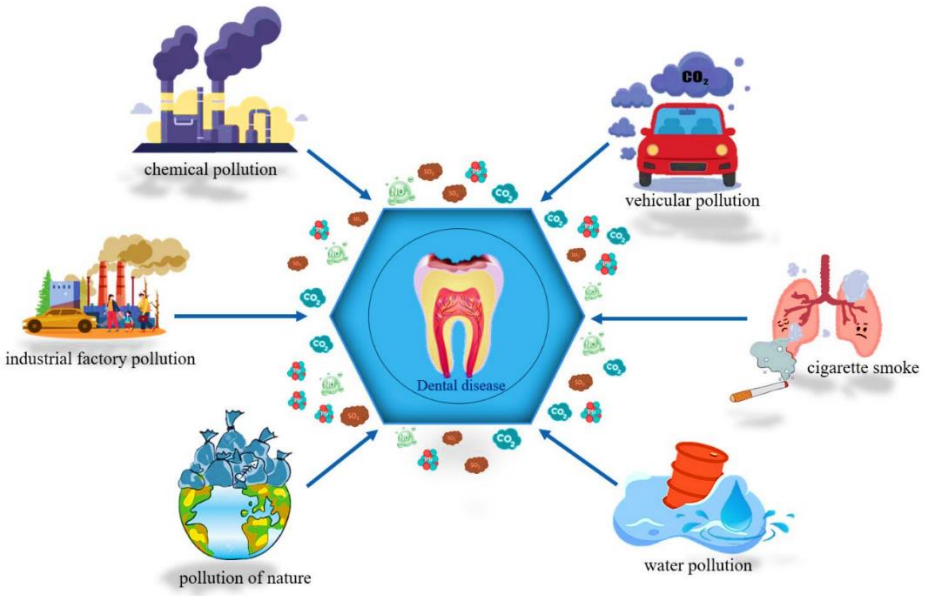

Figure 2. The impact of pollution on oral health

PM, 2.5 micrometers or less in diameter, has multiple major sources, including motor vehicles, power plants, household wood burning, forest fires, agricultural residue burning, certain industrial processes, and other types of combustion [21]. These particles are mostly composed of carbon, on the surface of which there are deposits of chemical components, microorganisms, and heavy metals. For monitoring suspended particles, PM_{10} and $PM_{2.5}$ are the most used indicators. Among them, $PM_{2.5}$ has become the main indicator of health risks associated with fine particle pollution, being integrated into air quality indices in many countries [21].

Dental erosion has a variable prevalence, being defined as the loss of dental hard tissue through a chemical process that does not involve the influence of bacteria [22]. Exposure to pollutants can have significant effects on oral health, with enamel erosion observed in individuals working in dusty environments containing a mixture of tartaric acid, sodium bicarbonate sucrose, and magnesium sulfate [23]. Moreover, studies show that children's saliva and tooth enamel contain significant levels of lead, its concentrations increasing directly

proportional to the worsening of caries, indicating a potential cariogenic effect of this chemical element (Table 1) [24].

Tabel 1. Effects of pollutant exposure on oral health

Effects	***Description***	***References***
Erosion of tooth enamel	It has been observed in people working in dusty environments containing a mixture of TTA, sucrose, $MgSO_4$, and $NaHCO_3$.	[23]
Dental caries	The children's enamel and saliva contained lead, and levels increased with caries severity, demonstrating its cariogenic potential.	[24]
Oral cancer	High concentrations of $PM_{2.5}$ in air pollution are associated with a 43% higher risk of developing cancer.	[25]
Periodontitis	Exposure to air pollutants was associated with periodontitis, even after adjustment for confounders.	[1]
	It produces ROS, causes oxidative damage, and delays mineralization.	[26]
Loss of teeth	It releases free radicals, causes oxidative damage, and interferes with mineral formation.	
Enamel defects		
Dry mouth (xerostomia)	Individuals from countries with low exposure to NO and SO showed an increased frequency of dry mouth.	[27]
Oral inflammations and infections	Pollutant exposure can weaken the immune system, making the mouth more prone to infection and inflammation.	[28]

$MgSO_4$ - magnesium sulfate; $NaHCO_3$ - sodium bicarbonate; NO - nitric oxide; $PM_{2.5}$ - fine particles 2.5; ROS - reactive oxygen species; SO_2 - sulfur dioxide; TTA – tartaric acid.

In addition, it was found that $PM_{2.5}$ pollution increases the risk of oral cancer by 43%, highlighting the link between air pollution and the development of this condition [25]. Exposure to these atmospheric pollutants has also been associated with periodontitis [1], and with the generation of ROS that cause oxidative damage and delay the mineralization process, this hurting the loss of teeth and the occurrence of dental defects [26]. Moreover, people living in countries where exposure to NO/SO is low have a higher frequency of xerostomia [27], and this exposure to pollutants can reduce the efficiency of the immune system, making the oral cavity more vulnerable to infection and inflammation [28].

Another toxic substance common in dental conditions is lead (Pb), as teeth accumulate that element during their development. Hard dental tissue can accumulate lead and other hard metals from the environment [29]. Dental Pb

levels are considered good biological indicators for exposure to this environmental element. Its levels in saliva and blood cause imbalances in the growth of oral microflora. Once the pH decreases, oral inflammatory parameters change, and ROS are generated that cause oxidative damage [26]. Both human and animal studies have shown that teeth with high levels of Pb are more prone to tooth decay [30]. The distribution of Pb in blood, bone, and saliva, with an impact on dental health, is influenced by environmental and physiological factors such as age, sex, type and position of teeth, pregnancy, lactation, eating and drinking habits, smoking and exposure to lead contaminants in residential and occupational areas. However, living and working in lead-free environments can prevent exposure to this toxic metal [26]. One of the molecules in chronic contact with the oral cavity is fluoride (F). It can (re)mineralize enamel and inhibit the community of bacteria that cause caries, so it is therefore used to prevent damage [4]. Also, excessive exposure to considerable amounts of fluoride (F) during enamel formation results in a type of enamel hypoplasia also known as fluorosis [30]. Dental fluorosis represents, like incisive-molar hypomineralization, a condition of enamel development, which, like the latter, causes opaque spots from whitish to brown, generating, in certain cases, diagnostic difficulties between the two pathologies [4]. Furthermore, antibiotics (tetracyclines) given to children or infants where the teeth are developing can have side effects such as discoloration of the tooth enamel. Children exposed to cigarette smoke are at greater risk of dental caries, this environmental factor being associated with periodontitis in adults [30]. Also, the prevalence of dental caries is lower in children living in less polluted regions [31].

Once heavy metals enter the body, through ingestion, inhalation, or skin contact, they can accumulate in various organs, including calcified tissues, bones, and teeth, presenting a significant risk to human health due to toxicity and long-term persistence. Pollution assessment can be done by physical and chemical methods and by bio-indicators [32].

Measures to protect and prevent dental disease following exposure to pollutants

To prevent and protect dental health in the context of exposure to pollutants, several aspects must be considered, including correct and frequent oral hygiene, an adequate diet, hydration, and the use of mouthwash, but also protection against atmospheric pollutants. Regular visits to the dentist for check-ups and professional cleanings should also be made. On the other hand, the harmful health effects of air pollution are largely determined by the concentration of air pollutants and the time of exposure to them. People can take many steps to reduce the amount of pollutant inhalation [21]. People can reduce the harmful effects of

ambient air pollution by reducing the time spent in outdoor activities and the level of activity when the air quality index exceeds a certain level [21]. Also, wearing a protective mask is recommended in such cases to prevent the harmful effects of ambient air pollutants, but also the adverse effects of vehicle pollution [33,34]. Another important measure is smoking cessation [35].

Although there is no direct link between the various effects of air pollution and nutrition, nutrients in the diet remain essential for maintaining health. An increased consumption of fresh fruits and vegetables brings significant health benefits. These foods are rich in valuable nutrients, such as vitamins with antioxidant properties, including vitamin C and E. Antioxidants play an important role in protecting the body by helping to reduce oxidative stress and inflammation. This protective effect could become more important in defending against the adverse effects of air pollutants [28].

CONCLUSIONS

Oral diseases are a major health problem because they have a high prevalence globally, with a major impact on society. PM, NOx, SO_2, and O_3 are the main pollutants responsible for the development of oral diseases, including gingival inflammation and xerostomia caused by reduced saliva flow due to exposure to O_3 and other pollutant gases. Moreover, air pollutants can contribute to the erosion of tooth enamel, increasing the risk of tooth decay and other oral conditions. The impact of pollution on the oral cavity is significant, requiring preventive measures but also a reduction of exposure. However, further studies are needed to also analyze the influence of other pollutants on oral conditions.

ACKNOWLEDGMENTS

Ciobica Alin is funded through The Operational Program for Competitiveness 2014-2020, Axis 1, under POC/448/1/1 Research infrastructure projects for public R&D institutions/universities, project" Multidisciplinary platform for medical research-development in N-E region, CENEMED", grant agreement no. 127606.

REFERENCES

[1] Marruganti C, Shin HS, Sim SJ, Grandini S, Laforí A, Romandini M. *Air Pollution as a Risk Indicator for Periodontitis*. Biomedicines 2023;**11**. https://doi.org/10.3390/biomedicines11020443.

[2] Vo T, Wu C, Lee I. *Potential effects of noxious chemical-containing fine particulate matter on oral health through reactive oxygen species-mediated oxidative stress: Promising clues*. Biochem Pharmacol 2020;**182**. https://doi.org/10.1016/j.bcp.2020.114286.

[3] Sinjari B, Santilli M, Di Carlo P, Aruffo E, Caputi S. *The Correlation between Oral Health and Air Pollution: A Systematic Review*. Dentistry Journal 2024; **12:215**. https://doi.org/10.3390/DJ12070215.
[4] Babajko S, Gayrard V, Houari S, Thu Bui A, Barouki R, Niederreither K, et al. *Oral cavity as a target and a marker of environmental exposures: Developmental dental defects*. Medecine/Sciences 2020;**36**. https://doi.org/10.1051/medsci/2020024.
[5] Thomas C, Minty M, Vinel A, Canceill T, Loubières P, Burcelin R, et al. *Oral microbiota: A major player in the diagnosis of systemic diseases*. Diagnostics 2021;**11**. https://doi.org/10.3390/diagnostics11081376.
[6] Abanto J, Carvalho TS, Mendes FM, Wanderley MT, Bönecker M, Raggio DP. *Impact of oral diseases and disorders on oral health-related quality of life of preschool children*. Community Dent Oral Epidemiol 2011;**39**. https://doi.org/10.1111/j.1600-0528.2010.00580.x.
[7] Kisely S. *No mental health without oral health*. Canadian Journal of Psychiatry 2016;**61**. https://doi.org/10.1177/0706743716632523.
[8] Peres MA, Macpherson LMD, Weyant RJ, Daly B, Venturelli R, Mathur MR, et al. *Oral diseases: a global public health challenge*. The Lancet 2019;394. https://doi.org/10.1016/S0140-6736(19)31146-8.
[9] Scannapieco FA. *The oral microbiome: Its role in health and in oral and systemic infections*. Clin Microbiol Newsl 2013;**35**. https://doi.org/10.1016/j.clinmicnews.2013.09.003.
[10] Loos BG. *Periodontal medicine: Work in progress*! J Clin Periodontol 2016;**43**. https://doi.org/10.1111/jcpe.12550.
[11] Chatzopoulos GS, Jiang Z, Marka N, Wolff LF. *Periodontal Disease, Tooth Loss, and Systemic Conditions: An Exploratory Study*. Int Dent J 2024;**74**. https://doi.org/10.1016/j.identj.2023.08.002.
[12] Rivera C. *Essentials of oral cancer*. Int J Clin Exp Pathol 2015;**8**.
[13] Silva DB da, Pianovski MAD, Carvalho Filho NP de. *Environmental pollution and cancer*. J Pediatr (Rio J) 2024. https://doi.org/10.1016/J.JPED.2024.09.004.
[14] Ochoa Scussiatto H, Stenson KM, Al-Khudari S, Jelinek MJ, Pinto JM, Bhayani MK. *Air pollution is associated with increased incidence-rate of head and neck cancers: A nationally representative ecological study*. Oral Oncol 2024;**150**. https://doi.org/10.1016/j.oraloncology.2024.106691.
[15] Dhane AS, Sarode SC, Sarode GS, Sharma NK. *Rise in arsenic pollution and oral cancer: A call for action*. Oral Oncology Reports 2024;**9**. https://doi.org/10.1016/j.oor.2024.100238.
[16] World Health Organization. Air Quality Guidelines. Global update 2005. 2006. https://doi.org/10.1007/BF02986808.
[17] Melody S, Wills K, Knibbs LD, Ford J, Venn A, Johnston F. *Adverse birth outcomes in Victoria, Australia in association with maternal exposure to low levels of ambient air pollution.* Environ Res 2020;**188**. https://doi.org/10.1016/j.envres.2020.109784.
[18] Clappier A, Thunis P, Beekmann M, Putaud JP, de Meij A. *Impact of SOx, NOx and NH3 emission reductions on PM2.5 concentrations across Europe: Hints for future measure development*. Environ Int 2021;156. https://doi.org/10.1016/j.envint.2021.106699.
[19] Gupta K, Muthu MS, Saikia A, Sriram S, Nirmal L, Wadgave U, et al. *Association of exposures to environmental chemicals estimated through primary teeth biomatrix and health outcomes in children and adolescents - A systematic review*. Sci Total Environ 2024;928. https://doi.org/10.1016/J.SCITOTENV.2024.172032.
[20] Gregorczyk-Maga I, Celejewska-Wojcik N, Gosiewska-Pawlica D, Darczuk D, Kesek B, Maga M, et al. *Exposure to air pollution and oxidative stress markers in patients with potentially malignant oral disorders*. Journal of Physiology and Pharmacology 2019;**70**. https://doi.org/10.26402/jpp.2019.1.09.

[21] Jiang XQ, Mei XD, Feng D. *Air pollution and chronic airway diseases: What should people know and do?* J Thorac Dis 2016;**8**. https://doi.org/10.3978/j.issn.2072-1439.2015.11.50.
[22] Johansson AK, Omar R, Carlsson GE, Johansson A. *Dental erosion and its growing importance in clinical practice: From past to present*. Int J Dent 2012. https://doi.org/10.1155/2012/632907.
[23] ELSBURY WB, BROWNE RC, BOYES J. *Erosion of teeth due to tartaric acid dust*. Br J Ind Med 1951;**8**. https://doi.org/10.1136/oem.8.3.179.
[24] Pradeep Kumar KN, Hegde AM. *Lead exposure and its relation to dental caries in children*. Journal of Clinical Pediatric Dentistry 2013;**38**. https://doi.org/10.17796/jcpd.38.1.lg8272w848644621.
[25] *Air pollution exposure may be linked to higher risk of mouth cancer*. Br Dent J 2018; 225:800. https://doi.org/10.1038/SJ.BDJ.2018.994.
[26] Khalid M, Abdollahi M. *Role of lead in dental diseases*. J Environ Sci Health C Toxicol Carcinog 2020;**38**. https://doi.org/10.1080/26896583.2020.1834313.
[27] Brito-Zerón P, Flores-Chávez A, Ng WF, Horváth IF, Rasmussen A, Priori R, et al. *Exposure to air pollution as an environmental determinant of how Sjögren's disease is expressed at diagnosis*. Clin Exp Rheumatol 2023;**41**. https://doi.org/10.55563/clinexprheumatol/p1r1j4.
[28] He QQ, Wong TW, Du L, Lin GZ, Gao Y, Jiang ZQ, et al. *Nutrition and children's respiratory health in Guangzhou, China*. Public Health 2008;**122**. https://doi.org/10.1016/j.puhe.2008.06.010.
[29] Cenic-Milosevic D, Mileusnic I, Kolak V, Pejanovic D, Ristic T, Jakovljevic A, et al. *Environmental lead pollution and its possible influence on tooth loss and hard dental tissue lesions*. Vojnosanit Pregl 2013;**70**. https://doi.org/10.2298/vsp1308751c.
[30] Billings RJ, Berkowitz RJ, Watson G. *Teeth*. Pediatrics 2004;**113**:1120–7. https://doi.org/10.1542/peds.113.s3.1120.
[31] Dautov FF, Lysenko GN, Lysenko AI. *[Impact of environmental air pollution on dental morbidity in children]*. Gig Sanit 2003.
[32] Kamberi B, Kocani F, Dragusha E. *Teeth as Indicators of Environmental Pollution with Lead*. J Environ Anal Toxicol 2012;**02**. https://doi.org/10.4172/2161-0525.1000118.
[33] Ingle ST, Pachpande BG, Wagh ND, Patel VS, Attarde SB. *Exposure to vehicular pollution and respiratory impairment of traffic policemen in Jalgaon city, India*. Ind Health 2005;**43**. https://doi.org/10.2486/indhealth.43.656.
[34] Zhao P, Yu KP, Lin CC. *Risk assessment of inhalation exposure to polycyclic aromatic hydrocarbons in Taiwanese workers at night markets*. Int Arch Occup Environ Health 2011;**84**. https://doi.org/10.1007/s00420-010-0551-1.
[35] Rigotti NA. *Smoking cessation in patients with respiratory disease: Existing treatments and future directions*. Lancet Respir Med 2013;**1**. https://doi.org/10.1016/S2213-2600(13)70063-8.