The impact of environmental air pollution on the prevalence of molar incisor hypomineralization in schoolchildren: A cross-sectional study

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Conflict of interest

None declared

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Abstract

Background. Molar incisor hypomineralization (MIH) is a common condition that causes considerable pain to children and distress to their parents. Clinically it is manifested by demarcated opacities of tooth enamel with reduced mineralization. The mean global incidence of this disorder has been estimated at around 13–14%. Environmental pollution is one of the suspected etiological factors, but the impact of air pollutant components on MIH has yet to be studied.

Objectives. To assess whether the level of air pollution components has an impact on the prevalence of MIH.

Material and methods. This cross-sectional study included 2354 children, aged 6–12 years, attending schools in 2 voivodeships (regions) of Poland with best and worst air quality. Smog alarms are announced more than 50 times a year in the Silesian voivodeship, while in the Pomeranian voivodeship, consistently low levels of air pollution are observed. Our air quality assessment was carried out on the basis of average annual results from measuring stations located in the 2 voivodeships. Dental examinations of teeth were conducted using the European Academy of Paediatric Dentistry (EAPD) criteria for the diagnosis of MIH.

Results. Levels of air pollution components over time were notably higher in the Silesian voivodeship, especially sulfur dioxide (SO₂), particulate matter (PM₁₀) and polycyclic aromatic hydrocarbons (PAH). The MIH was diagnosed more often in children in the Silesian voivodeship (13.7%) than in the Pomeranian (6.4%). In the Pomeranian voivodeship, MIH was most often diagnosed in children aged 6 (14.53%).

Conclusions. This study shows a correlation between higher concentrations of air pollutants and the occurrence of enamel developmental disorder in the form of MIH. Future research is required to assess whether this is related to the presence of a specific component or to the more frequent occurrence and treatment of air pollution-related general diseases, such as respiratory illnesses.

Key words: children, air pollution, prevalence, enamel defects, molar incisor hypomineralization

Introduction

Due to increasing awareness as well as a decline in the incidence of dental caries, researchers have been focusing on developmental disorders of the teeth. One developmental disorder of enamel, first described in 2001, is molar incisor hypomineralization (MIH).¹ It involves reduced mineralization and increased porosity of the tooth enamel, and involves the first permanent molars (FPM) and often the permanent incisors (PI).¹ Clinically the changes are manifested as white, cream-yellow or brown opacities, clearly demarcated from healthy enamel (Fig. 1). The affected enamel has a disturbed structure and, due to the effects of chewing forces, it may break down soon

Fig. 1. Demarcated opacities on first permanent molar

Fig. 2. Post-eruptive breakdown (PEB) of first permanent molar

Fig. 3. Demarcated opacities on permanent incisors

after eruption, resulting in a significant loss of mineralized tooth structure (Fig. 2).²

The MIH is a public health problem whose consequences are not only health-related but also economic. For the patient, these teeth are the cause of discomfort and sometimes pain (even during brushing), and often require advanced treatment at a very young age. Furthermore, when the disorder also includes incisors – visible when smiling – it can create a major esthetic problem (Fig. 3). Visible patches can negatively affect the patient's well-being and their contact with peers.³

For a dentist, treating children with MIH represents a significant challenge.⁴ The affected teeth cause pain and hypersensitivity, and often do not undergo sufficient anesthesia, compromising the child's cooperation. Children with MIH are more prone to suffer from dental phobia than healthy ones. Furthermore, the incorrect enamel structure does not allow for the effective adhesion of materials, and fillings often chip off, necessitating repeated treatment. Studies show that children with MIH require more frequent treatment than children without MIH.⁵ Treatment mainly concentrates on prevention of post-eruptive enamel fractures and reduction of tooth sensitivity. However, in more advanced cases – where there is a loss of hard tooth tissues – tooth reconstruction is required; sometimes it is even necessary to extract teeth at a very young age. The MIH is considered to be the second biggest cause of permanent molar loss after caries, emphasizing the need for deeper understanding of this disorder and the possibility of its prevention.⁶

In the last few years, several papers have been published on the prevalence of MIH.⁷ In 2 recent meta-analyses, the average prevalence was estimated at 14.2% and 13.1% (range: 2–40%), with statistically significant differences between macroregions, regions and countries.^{8–10} These studies confirm that the number of MIH cases is still growing, with the highest prevalence being in high-income countries.⁹

Despite many attempts to establish the etiology of this disorder, no single specific factor responsible for the occurrence of MIH has been identified. Determining a specific etiological factor is difficult because the research conducted is often retrospective. First permanent molar

disorders can be diagnosed only following their eruption, i.e., around 6–7 years of age, while the amelogenesis of these teeth occurs much earlier, i.e., in the perinatal period and the first years of a child's life, so the causative factor must work at that time. Parents often do not remember the history of illnesses and the medicines taken a few years ago.¹⁰ In the literature, the following suspected factors are presented, among the others: childhood illness, prematurity, fevers, otitis media, hypoxia at birth, pneumonia, and drugs taken, including antibiotics.^{11–15} Scientists are also trying to find a genetic predisposition for this disorder, but there is still no clear evidence of one.^{15,16} At present, the etiology is considered multifactorial, without indicating any single specific causal factor.¹⁷

Researchers' hypotheses also increasingly point to environmental pollution as a predisposing factor for MIH. Due to the toxic effects on human health even many years after exposure, dioxins have been considered a predisposing factor for dental development disorders. They belong to the group of persistent organic pollutants (POPs) that are still a considerable component of environmental pollution.¹⁸ Studies have shown a correlation between exposure to dioxins (mainly due to their excretion in breast milk), prolonged breastfeeding and the occurrence of MIH,¹⁹ although other researchers have rejected this hypothesis.²⁰ In the literature, one can also find a link between exposure to polychlorinated biphenyls (PCBs) and their impact on enamel development, including hypomineralization.²¹ Other contaminants, such as polycyclic aromatic hydrocarbons and respirable particulate matter with a diameter of up to 10 µm (PM10), also pose a threat to human health.

There is still little evidence that can unequivocally confirm or rule out a link between environmental pollution and the occurrence of MIH. To our knowledge, the relationship between MIH and the level of common air pollutant components other than PCBs has yet to be studied. The aim of this study is thus to determine the prevalence of MIH in 2 different regions of Poland – the Pomeranian and Silesian voivodeships – which, due to their location and industrialization, differ substantially in the intensity of air pollutants. Based on previous research, it can be hypothesized that air quality influences the prevalence of MIH.

Methods

Study design and sampling procedures

The study was conducted in primary schools in 2 voivodeships in Poland: Pomeranian and Silesian. The research group was made up of children residing in the Silesian voivodeship, while children from Pomeranian voivodeship were assigned to the negative control group. There are 719 primary schools in the Pomeranian voivodeship and 1454 in the Silesian. Special care schools, penal institutions,

correctional schools, and schools in hospitals were excluded, leaving 553 schools in the Pomeranian voivodeship and 1324 in the Silesian voivodeship qualified for the study. According to the latest data, 150,372 children aged 6–12 attend primary schools in the Pomeranian voivodeship and 260,789 in the Silesian voivodeship, so assuming a 95% confidence level, 383 children in Pomerania and 384 in Silesia should be examined for the group to be representative. According to recommendations from Elfrink et al.,⁷ for assessing the prevalence of MIH estimated at 5%, a minimum group of 300 children is required, and a minimum number of 1000 children is recommended to evaluate a possible MIH etiological factor.

We selected 30 schools from the Pomeranian voivodeship and 15 from the Silesian voivodeship, and sent letters to the school heads inviting them to participate in the study.

Ethical considerations

The Independent Bioethics Committee for Scientific Research at the Medical University of Gdańsk gave their approval (No. NKBBN/182/2013) to conduct the study. Permission was obtained to conduct the study in 15 schools in the Pomeranian voivodeship and 7 in the Silesian. Information regarding the study and consent forms for participation in the study was sent to the parents or legal guardians of children aged 6–12. On the day of the study, children without a parent's or guardian's permission, children with general medical diseases, and children who were uncooperative or did not assent to the examination were excluded from the study.

Study location and air pollution measurement methods

The Pomeranian voivodeship is located in the north of the country, on the Baltic Sea coast, while Silesia is located in the south of the country, about 600 km away. Smog alarms are announced more than 50 times a year in the Silesian voivodeship; in the Pomeranian voivodeship, constantly low levels of air pollution are observed. In both voivodeships, stations measuring the level of air pollution are located in various cities. The number of stations has changed over time; there are currently 20 in the Pomeranian voivodeship and 30 in Silesian. The stations perform hourly or 24-hour tests. The archived results are posted on the website of the Chief Inspectorate for Environmental Protection in Poland at <http://powietrze.gios.gov.pl/pjp/current>.

The enamel mineralization of FPM and PI starts in the perinatal period and ends at the age of about 3 years. Given that the study was conducted in the years 2016–2019, studied children aged 6–12 were born between 2004 and 2012. Therefore, the air pollution levels from 2004 to 2013 were taken into account for the study. In order to assess air quality in those years, archive data on the level of pollution

were averaged for each year. The available measurements for air pollutant components comprise:

- inorganic gas pollutants: sulfur dioxide (SO₂), nitrogen dioxide (NO₂), nitrogen oxides (NO_x), ozone (O₃), and carbon monoxide (CO);
- particulate matter (PM₁₀);
- heavy metals in PM₁₀: lead (Pb; PM₁₀), arsenic (As; PM₁₀), cadmium (Cd; PM₁₀) and nickel (Ni; PM₁₀);
- volatile organic compounds: benzene (C₆H₆);
- polycyclic aromatic hydrocarbons (PAHs) in PM₁₀: benzo(a)pyrene (BaP; PM₁₀), benzo(a)anthracene (BaA; PM₁₀), benzo(b)fluorantene (BbF; PM₁₀), benzo(k)fluorantene (BkF; PM₁₀), and benzo(j)fluorantene (BjF; PM₁₀).

Study settings

Each child's dental examination was carried out at school using a dental probe, an oral mirror and a head lamp. The teeth were not cleaned or dried before examination. When necessary, cotton rolls were used to remove food debris. All the surfaces of the index teeth were examined, and MIH was diagnosed according to the criteria published by Weerheijm et al.²² (Table 1). Only defects greater than 1 mm in diameter were reported. All the examinations of all the children were performed by the same investigator (NG), who was trained and calibrated before the process commenced. The reliability of that examiner was also assessed by re-examination of every 10th child.

Statistical analyses

Descriptive statistics of the data were generated using standard statistical parameters: percentage, mean (M) and standard deviation (SD), median, and minimum and maximum (min and max). Correlations between pairs of numerical parameters were studied using the χ^2 test. The air quality was compared using Student's t-test for independent samples. A p-value <0.05 was considered statistically significant for all tests. The data were organized into files (Microsoft Excel 2013; Microsoft Inc., Redmond, USA) and statistically processed using STATISTICA v. 13.1 software (StatSoft Inc., Tulsa, USA).

Results

Characteristics of the surveyed population

The study involved 2354 children (a response rate of 67.3%) aged 6–12 (M = 8.80, SD = 1.89), of whom 50% were girls and 50% were boys. Most of the children (61%) came from the Pomeranian voivodeship, while over a third (39%) were from the Silesian voivodeship. Over 75% lived in cities, while 23% lived in rural areas. We excluded 79 children from the study because they had no erupted permanent molars. A total of 96.7% (n = 2275) of the examined children had at least 1 erupted FPM and were included in the study, so assuming a 95% confidence level, the statistical error can be assessed as 2% for the entire population.

Characteristics of air pollution

The annual average air pollutants for both voivodeships are presented in Table 2. The statistical analysis of the data showed significantly higher levels of most of the pollutants measured in the Silesian voivodeship than in the Pomeranian. The greatest differences were observed in the cases of SO₂ and PAH, especially BaP (PM₁₀). The concentrations of these substances in the south of Poland were almost 4 times higher than in the north of the country. In terms of PM₁₀, C₆H₆, NO₂ and CO the levels were almost double in Silesian voivodeship than in Pomeranian. In the group of heavy metals in PM₁₀, the mean values of lead, cadmium and arsenic were also significantly higher in the Silesian voivodeship. The level of Ni (PM₁₀) turned out to be higher in the Pomeranian voivodeship, but the difference was not statistically significant. The only statistically significant higher level in the Pomeranian voivodeship was the O₃ concentration.

Distribution and dissemination of MIH depending on the voivodeship

The MIH was diagnosed in 212 children, representing 9.32% of the study population. The χ^2 analysis revealed statistically significant differences between the prevalence

Table 1. MIH diagnostic criteria according to Weerheijm et al.²²

Demarcated opacity	A demarcated defect involving an alteration in the translucency of the enamel, variable in degree. The defective enamel is of normal thickness with a smooth surface and can be white, yellow or brown in color.
Post-eruptive enamel breakdown (PEB)	A defect that indicates deficiency of the surface after eruption of the tooth. Loss of initially formed surface enamel after tooth eruption. The loss is often associated with a pre-existing demarcated opacity.
Atypical restoration	The size and shape of restoration do not conform to the temporary caries picture. In most cases, in molars these are restorations extended to the buccal or palatal smooth surface. At the border of the restorations frequently opacity can be noticed. In incisors, a buccal restoration can be noticed not related to a trauma.
Extracted molar due to MIH	The absence of a first permanent molar should be assessed in relation to other teeth. Reasons for considering extraction due to MIH are: Opacities or atypical restorations in the other first permanent molars combined with absence of a first permanent molar. The absence of first permanent molars in sound dentition in combination with demarcated opacities on the incisors is likely to be due to MIH. It is not likely that incisors will be extracted due to MIH.
Un erupted	The first permanent molar or the incisor to be examined are not yet erupted.

Table 2. Annual average air pollutants for both voivodeships

Year	Voivode-ship	SO ₂ [μg/m ³]		NO ₂ [μg/m ³]		NO _x [μg/m ³]		O ₃ [μg/m ³]		CO [mg/m ³]		PM10 [μg/m ³]		Pb (PM10) [μg/m ³]		As (PM10) [ng/m ³]	
		Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
2013	Silesian	13.595	15.654	24.407	17.822	42.987	59.033	48.352	31.393	0.52	0.367	44.183	31.877	0.039	0.035	1.719	1.058
	Pomeranian	5.009	4.573	14.581	11.766	22.229	26.469	53.094	24.611	0.394	0.241	24.057	15.318	0.009	0.006	1.027	0.202
2012	Silesian	11.959	15.074	21.343	11.161	48.806	73.254	50.644	33.394	0.632	0.646	45.318	43.757	0.038	0.034	1.866	1.828
	Pomeranian	5.113	9.678	7.611	7.763	24.351	28.666	47.903	24.183	0.377	0.257	25.032	19.437	0.013	0.015	1.358	1.479
2011	Silesian	11.052	12.61	25.241	12.032	57.017	87.628	48.153	31.581	0.614	0.584	48.526	41.945	0.036	0.031	2.214	2.326
	Pomeranian	3.838	6.795	8.646	9.461	28.472	41.571	49.674	25.972	0.381	0.305	25.61	20.758	0.026	0.105	1.174	0.519
2010	Silesian	17.087	19.671	22.836	13.413	50.082	64.894	43.266	30.438	0.648	0.619	51.888	47.679	0.04	0.047	4.845	5.341
	Pomeranian	3.746	5.274	8.841	8.378	30.646	39.695	51.617	24.521	0.429	0.354	28.223	22.643	0.015	0.015	1.076	0.471
2009	Silesian	14.548	12.381	24.176	18.807	43.651	58.273	46.133	32.278	0.553	0.483	41.974	36.845	0.037	0.033	3.348	2.329
	Pomeranian	3.878	4.482	18.042	15.303	27.96	35.716	47.42	26.024	0.39	0.306	25.611	19.903	0.044	0.081	2.927	2.789
2008	Silesian	11.421	9.186	26.002	18.696	45.282	57.854	45.0	32.375	0.561	0.456	38.43	34.091	n/d	n/d	n/d	n/d
	Pomeranian	3.413	4.707	17.134	13.611	23.692	27.544	53.077	19.064	0.367	0.238	22.923	16.689	0.031	0.039	1.46	1.976
2007	Silesian	11.444	10.769	24.092	11.34	19.484	14.662	45.196	31.646	0.601	0.498	35.457	33.874	n/d	n/d	n/d	n/d
	Pomeranian	2.105	1.813	5.259	3.604	19.358	22.223	55.77	24.474	0.327	0.197	23.684	15.387	0.016	0.022	n/d	n/d
2006	Silesian	22.45	34.733	31.134	23.624	18.339	14.786	47.389	32.877	0.815	0.767	48.567	60.14	n/d	n/d	n/d	n/d
	Pomeranian	6.009	10.599	17.8	14.079	25.216	28.504	58.937	28.38	0.399	0.287	28.831	25.126	n/d	n/d	n/d	n/d
2005	Silesian	19.767	15.432	27.289	19.84	18.658	12.382	50.467	32.708	0.683	0.519	45.932	40.154	n/d	n/d	n/d	n/d
	Pomeranian	2.473	2.571	15.77	12.403	23.77	24.626	51.379	25.598	0.364	0.201	26.667	18.859	n/d	n/d	n/d	n/d
2004	Silesian	31.349	24.51	24.803	14.518	17.274	8.218	43.96	30.924	0.76	0.567	39.413	36.524	0.093	0.099	n/d	n/d
	Pomeranian	5.088	5.603	14.71	13.852	20.215	20.501	53.206	23.52	0.375	0.268	26.542	23.06	n/d	n/d	n/d	n/d
Mean 2004–2013	Silesian	16.467	6.505	25.132	2.660	36.158	15.753	46.856	2.573	0.639	0.093	43.969	5.145	0.047	0.022	2.798	1.310
	Pomeranian	4.067	1.238	12.839	4.756	24.591	3.607	52.208	3.487	0.38	0.027	25.718	1.908	0.022	0.012	1.504	0.717
t		3.8891		7.1329		2.2634		3.9053		8.4723		10.5185		2.5554		2.0884	
p-value		<0.05*		<0.05*		<0.05*		<0.05*		<0.05*		<0.05*		<0.05*		>0.05	

Avg. – average; SD – standard deviation; t – Student's t-test result; * statistically significant; n/d – no data.

of MIH in the 2 voivodeships. The MIH was observed more than twice as often in children in the Silesian voivodeship (13.7%) than in the Pomeranian (6.4%). Furthermore, in children from the Silesian voivodeship, MIH was significantly more often diagnosed on PIs than in their counterparts from the Pomeranian voivodeship (4.9% compared to 3.2%). The results are presented in Table 3.

Distribution and prevalence of MIH depending on gender, age and year of birth

The MIH was diagnosed more often in boys than in girls (54.2% compared to 45.8%), but the gender difference was not statistically significant in either of the voivodeships; nor did the genders differ in terms of the presence of lesions on incisors. In the Pomeranian voivodeship, MIH was diagnosed more often in children aged 6 (14.53%) than in older children, which was statistically significant. In the Silesian voivodeship, there were no significant differences between the age groups. A comparison of the occurrence of MIH in children born in different years is shown

in Table 4. There was a gradual increase in the incidence of MIH in children born in later years, but none of the differences were statistically significant (Fig. 4).

Discussion

According to reports from the European Environment Agency (EEA),²³ air quality in many cities in Poland falls below European Union (EU) pollution standards. The reports also show differences in the intensity of pollution depending on the region of Poland, with higher concentrations of hazardous substances observed in the south of the country, including the Silesian voivodeship. As many as 3 cities in this voivodeship are in the top 10 European cities with the largest number of days per year in which the permissible concentration of 24-hour PM10 was exceeded. The problem of pollution increases significantly during the heating season. Adverse meteorological conditions (low rainfall or wind) in this area are also contributing factors. The components of air pollution analyzed in this study are those commonly used to assess air quality in EU countries.²³

Table 2, cont. Annual average air pollutants for both voivodeships

Year	Voivode-ship	Cd (PM10) [ng/m ³]		Ni (PM10) [ng/m ³]		C ₆ H ₆ [μg/m ³]		BaP (PM10) [ng/m ³]		BaA (PM10) [ng/m ³]		BbF (PM10) [ng/m ³]		BkF (PM10) [ng/m ³]		BjF (PM10) [ng/m ³]	
		Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
2013	Silesian	1.171	1.32	2.54	3.399	2.006	1.961	6.77	7.074	5.376	5.682	4.97	4.494	2.542	2.332	4.25	3.873
	Pomeranian	0.249	0.165	2.293	2.308	0.658	0.951	2.589	3.956	2.101	3.573	2.82	3.92	1.126	1.553	0.728	1.177
2012	Silesian	0.976	1.319	1.619	1.276	2.444	3.287	8.314	11.692	8.911	14.527	7.748	10.643	4.136	6.065	5.224	7.422
	Pomeranian	0.421	0.609	6.146	8.847	0.689	1.159	3.038	5.194	2.799	7.164	2.263	3.563	0.848	1.313	3.218	8.36
2011	Silesian	1.351	1.448	1.775	1.414	2.047	3.02	8.908	11.069	7.012	7.972	7.763	7.515	3.849	3.779	4.746	4.485
	Pomeranian	0.45	0.523	5.429	5.581	0.782	1.175	2.75	4.999	2.45	4.94	1.929	3.3	0.801	1.606	6.513	13.764
2010	Silesian	1.183	1.274	2.583	2.756	1.867	3.225	9.272	11.121	10.289	12.84	9.168	10.283	3.995	4.088	5.104	5.121
	Pomeranian	0.446	0.492	4.194	4.342	0.684	1.272	4.683	6.91	8.885	14.144	3.856	5.121	2.63	3.655	13.285	18.491
2009	Silesian	1.246	0.882	5.436	7.108	1.894	2.547	8.685	10.812	8.024	12.003	8.476	11.466	3.775	4.383	7.545	8.954
	Pomeranian	0.74	0.774	3.628	5.248	1.762	2.19	3.111	3.893	3.035	3.599	2.006	2.315	1.594	1.579	5.032	5.902
2008	Silesian	n/d	n/d	n/d	n/d	2.31	3.141	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Pomeranian	0.703	0.755	3.397	5.081	1.401	1.625	2.152	3.179	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
2007	Silesian	n/d	n/d	n/d	n/d	2.918	3.838	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Pomeranian	n/d	n/d	n/d	n/d	2.402	1.652	0.925	1.574	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
2006	Silesian	n/d	n/d	n/d	n/d	2.679	4.951	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Pomeranian	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
2005	Silesian	n/d	n/d	n/d	n/d	3.572	4.004	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Pomeranian	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
2004	Silesian	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Pomeranian	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Mean 2004–2013	Silesian	1.185	0.137	2.791	1.542	2.373	0.587	8.390	0.970	7.922	1.864	7.625	1.596	3.659	0.640	5.373	1.271
	Pomeranian	0.502	0.186	4.181	1.407	1.197	0.683	2.750	1.130	3.854	2.835	2.575	0.797	1.4	0.756	5.755	4.730
t		6.7955		1.5637		3.7051		9.0107		2.6814		6.3307		5.0995		0.1741	
p-value		<0.05*		>0.05		<0.05*		<0.05*		<0.05*		<0.05*		<0.05*		>0.05	

Avg. – average; SD – standard deviation; t – Student's t-test result; * statistically significant; n/d – no data.

Table 3. Occurrence of MIH in Pomeranian and Silesian voivodeships

Children	Voivodeship		Total n (%)	χ ²	p-value
	Pomeranian n (%)	Silesian n (%)			
With MIH diagnosis; FPM and PI affected	88 (6.43)	124 (13.69)	212 (9.32)		
Without MIH	1281 (93.57)	782 (86.31)	2063 (90.68)	33.99	<0.001*
PI affected	44 (3.21)	44 (4.86)	88 (3.87)		
Non-PI affected	1325 (96.79)	862 (95.14)	2187 (96.13)	3.96	0.047*
Total	1369 (100)	906 (100)	2275 (100)	–	–

* statistically significant; FPM – first permanent molars; PI – permanent incisors; MIH – molar incisor hypomineralization.

This study has attempted to assess whether environmental air quality has an impact on the prevalence of MIH in a given population. It has been shown that in the Silesian voivodeship, where it can be objectively concluded that air quality is inferior, based on measurements of pollution levels and data published by the EEA, the prevalence of MIH was over twice as high as in the Pomeranian voivodeship. Particular differences pertained to the concentration of SO₂, the level of which in the south of Poland was 4 times higher than in the north. Concentrations about

twice as high were also observed for PM10 NO₂, lead and cadmium.

A study assessing the prevalence of MIH in children from 2 regions of Turkey that significantly differ in terms of industrialization showed no association between MIH prevalence and the levels of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in the environment. The measurements of the concentration of the substances were carried out on the basis of soil samples in a given region.²⁴ However, other air-polluting

Table 4. Occurrence of MIH depending on the age of the respondents

Voivodeship	Children	Age [years]							χ^2	p-value
		6 n (%)	7 n (%)	8 n (%)	9 n (%)	10 n (%)	11 n (%)	12 n (%)		
Pomeranian	with MIH	17 (14.53)*	21 (7.95)	21 (7.17)	12 (5.58)	5 (2.73)	8 (5.33)	3 (2.65)	21.15*	0.002*
	without MIH	100 (85.47)	243 (92.05)	272 (92.83)	203 (94.42)	178 (97.27)	142 (94.67)	110 (97.35)		
	total	117 (100)	264 (100)	293 (100)	215 (100)	183 (100)	150 (100)	113 (100)		
Silesian	with MIH	4 (16)	35 (19.13)	28 (15.3)	17 (9.77)	22 (15.94)	7 (8.33)	8 (8.70)	11.77	0.06
	without MIH	21 (84)	148 (80.87)	155 (84.70)	157 (90.23)	116 (84.06)	77 (91.67)	84 (91.30)		
	total	25 (100)	183 (100)	183 (100)	174 (100)	138 (100)	84 (100)	92 (100)		

* statistically significant; MIH – molar incisor hypomineralization.

Fig. 4. The prevalence of MIH in various birth years in the Pomeranian and Silesian voivodeships

Pomeranian – (χ^2 (8, n = 1369) = 12.94; ni), p = 0.095; Silesian – (χ^2 (8, n = 906) = 10.47; ni), p = 0.202

substances were not taken into account, and given their negative impact on health, they can undoubtedly have an equally negative effect on tooth development. Apart from the worst effects of pollution described in the literature, such as premature mortality and shortened life expectancy,²⁵ air-polluting substances are also responsible for the occurrence of diseases considered in the etiology of MIH, such as otitis media and respiratory diseases, which in children are mainly manifested as irritations, acute infections and asthma attacks.^{26,27} Acute or chronic action of the air polluting substances depends on the time of exposure to a given factor and its concentration and accumulation in the human body. Undoubtedly, the negative impact of pollution on children, in both the prenatal and postnatal periods, is more dangerous and cannot be compared with the effects on adults. The lungs develop throughout childhood and their sensitivity to airborne contaminants at different stages of puberty can vary.²⁸ Even if air pollution is not directly responsible for the occurrence of MIH, it can act indirectly, leading to disease and therefore a need to take various medications. Recently, evidence of a relationship between prenatal exposure to air pollution and autism spectrum disorders and cognitive dysfunction has also been identified.²⁹

In our study, six-year-old children in the Pomeranian voivodeship displayed a significantly more frequent occurrence of MIH than did children from other age groups. Research in the Pomeranian voivodeship was carried out in 2016 and 2017, so six-year-old children were born in 2010 and 2011. Interestingly, in these years, the highest concentrations of NO₂ and CO in the Pomeranian voivodeship were recorded in the years being analyzed. However, the largest difference and clearly higher concentrations in these years were observed in the case of PAHs, mainly benzo(a)anthracene BaA (PM10) and benzo(j)fluoranthene BbF (PM10). The PAHs are organic compounds consisting of 2 or more fused benzene rings arranged in different configurations. The literature has highlighted their mutagenic and carcinogenic effects.³⁰ They are also thought to be detrimental to the nervous system, heart, brain vessels, and respiratory system.³¹ In addition, exposure during the prenatal period is harmful to the developing brain and may thus instigate cognitive dysfunction.³² The PAHs arise as a result of incomplete combustion of organic materials (e.g., coal, wood, oil), mainly related to anthropogenic activities but also from natural sources, such as open combustion or volcanic eruptions. Moreover, their presence in the environment leads to their presence in numerous types of food. Processed food

is considered to be their main source, because cooking processes and techniques such as baking, smoking or drying contribute to their formation. Their presence can be detected in dairy products, nuts, drinks, and meat products (mainly pork), among others.³³ The PAHs are highly soluble in fats, so they are easily absorbed from the digestive tract and mostly accumulate in adipose tissue.³⁰ Further research is certainly needed, but based on the results obtained in this study, a link between PAHs exposure during the prenatal period as well as during the first years of life cannot be excluded from the etiology of the occurrence of MIH.

Recently, bisphenol A and its analogs, used worldwide in plastic containers, have been mentioned among the potential etiological factors of enamel disorders.³⁴ Researchers who have found evidence of the presence of MIH in ancient populations are questioning the impact of modern factors such as antibiotics, bisphenol A or dioxin on the occurrence of MIH. These factors were not present in ancient times because they relate to industries that only appeared in the 20th century. Therefore, it has been suggested that MIH etiologies can be found among factors that have been present for centuries.³⁵ Still, many components of air pollution have existed since the emergence of human beings and the use of open fire. There is evidence of the presence of, for example, lead, soot and PAHs in ancient times.³⁶

The importance of air quality in the etiology of MIH can additionally be demonstrated by the difference in occurrence in different regions of the country. Problems during pregnancy, childhood diseases and other medical factors occur in children around the world, so MIH etiology should be researched comprehensively in specific local environmental conditions. In line with global trends, another study has found that the number of MIH cases is increasing.⁹

Given the difficulties associated with treatment, MIH is a challenge for both dentists and patients. It is important to establish the etiology of the disorder to discover possible interventions, highlight risk groups and prevent severe complications.⁵

Conclusions

The results of this study suggest the impact of air pollution on the higher incidence of MIH in a given population. Further research is necessary to determine the specific pollutant. Therefore, although our research points in a specific direction, further research in various regions of different countries is required to confirm these findings.

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