Original Article

PERIODONTOPATHOGENIC MICROBIAL INFECTION OF PERIODONTAL TISSUES IN CHILDREN IN THE ARAL SEA REGION

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ABSTRACT

The Aral Sea region has experienced severe environmental pollution, significantly affecting public health due to airborne pesticides, heavy metals, and other contaminants. Children in this region are particularly vulnerable, exhibiting higher rates of infections, including periodontal disease. This study investigates the extent of environmental pollution and the prevalence of periodontopathogenic microbial infections among children living near the Aral Sea. Environmental degradation, particularly from heavy metals, pesticides, and airborne pollutants, has had a marked impact on population health. A correlational study was conducted involving 770 children from four distinct geographical areas around the Aral Sea. Participants were selected based on proximity to pollution sources, with a focus on Aralsk City, which is notably impacted by heavy metals and air contaminants. The study measured the prevalence of gingivitis, periodontitis, and mixed periodontal diseases and analyzed their correlation with exposure to heavy metals, PM10, and SO_2 concentrations. According to the findings, children who lived nearer sources of pollution had far greater rates of periodontal disease. In particular, 36.5 percent had mixed periodontal disorders, 27.8 percent had periodontitis, and 22.9 percent had gingivitis.. A strong positive correlation was found between increased concentrations of heavy metals and air pollutants (PM10 and SO_2) and the prevalence of periodontopathogenic infections ($r = 0.887$). These findings underscore the significant association between environmental contamination and microbial infections in children. Reducing pollution and implementing preventive strategies are essential for enhancing children's periodontal health and promoting sustainable development in the Aral Sea region.

Key words: Aral Sea, Environmental pollution, Periodontopathogenic infections, Children's health, Periodontal diseases, Heavy metals.

Introduction

The Aral Sea basin has been officially classified as a zone of ecological disaster by UNESCO, primarily due to the formation of new deserts and semi-deserts on the dried seabed of the Aral Sea, secondary-stage soil salinization, alterations in groundwater composition, accelerated mineralization, and increased concentrations of heavy metals, pesticides, herbicides, and other toxic substances in soil and water resources [1]. Anthropogenic environmental pollution both directly and indirectly affects human and animal health by altering the concentration of biologically active substances in organs and tissues, ultimately contributing to a rise in disease cases among both adults and children [2]. Numerous studies have evaluated how environmental degradation in the Aral Sea region affects human health. Numerous accepted diagnostic criteria detect syndromes that impact the upper respiratory, gastrointestinal, urinary, and neurological systems, including asthenovegetative, bronchial obstruction, dyspeptic, cholestatic, and nephritic diseases. These pathologies involve the nasopharynx, bronchi, stomach, liver, kidneys, and brain [3]. Environmental risks are among the leading causes of global illness and mortality, with severe implications for public health. The Global Burden of Disease study reported that in 2012, approximately 23% of global deaths and 22% of total disability-adjusted life years (DALYs) were attributable to modifiable environmental factors, highlighting the urgent need for targeted actions to mitigate these effects [4].

Studies in this region indicate that both deficiencies in essential chemical elements and heavy metal toxicity play a significant role in Multiple Chronic Diseases (MCD), affecting as many as 89% of children [5]. Besides moderate to severe acquired immunodeficiency, other contributing factors to inflammatory diseases, including gum inflammation, are weakened cellular and humoral immune responses, the presence of specific microflora, and the localized sensitivity of periodontal tissues [6].

According to the World Health Organization (WHO), plaque microflora is the primary etiological factor in periodontal diseases. Several newly identified members of the bacteroid group, including Actinobacillus actinomycetemcomitans, Prevotella intermedia, and

Porphyromonas gingivalis, have been recognized as periodontopathic bacteria. Studies have shown that inflammation of the periodontium in adults is associated with these microorganisms [7]. Some researchers suggest that juvenile periodontitis is linked to destructive periodontal changes and rapid disease progression; however, many of these studies have not considered environmental factors [8-10].

The influence of anthropogenic factors on human health is well-documented. Additionally, research has explored how environmental conditions impact gut microflora composition, potentially leading to the emergence of new bacterial communities through metabolic processes in the body, which in turn affect physiological functions [11, 12]. A series of studies in China has examined the diversity of oral microflora species in children exposed to PM2.5 air pollution, finding an increase in the inhalation of ultrafine particles and a subsequent rise in the prevalence of Proteobacteria [13].

Periodontal disease is one of the most widespread oral health conditions, associated with adverse systemic health effects such as insulin resistance, diabetes, gastric tumors, Alzheimer's disease, and poor pregnancy outcomes [14]. An enormous ecological disaster has struck the Aral Sea region, causing rapid environmental degradation and exposing local residents to dangerous conditions that may impair immunity and make them more vulnerable to illnesses [15, 16].

This study examines the association between specific environmental factors in the Aral Sea region and the prevalence of periodontal microbial infections in children. By exploring these relationships, this research aims to provide insights into the health consequences of environmental deterioration among children and contribute to the development of effective public health interventions.

Objectives

The primary objectives of this study are:

- To analyze the prevalence of microbial infections associated with periodontitis among children living in the Aral Sea region.
- To assess the impact of environmental pollutants such as heavy metals, pesticides, cadmium, lead, particulate matter, and sulfur dioxide on the incidence of periodontal infections in children.
- To evaluate how proximity to pollution sources influences the severity of gingivitis, periodontitis, microbial infections, and mixed periodontal diseases.

This research examines the effects of ecological contaminants on the periodontopathogenic infections in children living near the Aral Sea region. The results from a study of 770 children show a statistically significant relationship (r = 0.887) between the prevalence of periodontal diseases and exposure to heavy metals and air pollutants. Efforts should focus on reducing pollution and implementing protective measures to improve the oral health of children in this region.

Materials and Methods

Study design

This correlational study aims to examine the potential relationship between environmental factors and the prevalence of periodontopathogenic microbial infections among children in the Aral Sea region.

Study population

The study population consists of children aged 6 to 12 years living at varying distances from the Aral Sea.

- Group 1 includes children from Aralsk City (17 km), Shieli Township (200 km), and Kyzylorda City (400 km), all of which are near the Aral Sea.
- Group 2 consists of children from Talgar City, located 800 km away, with significantly lower exposure to the environmental effects of the Aral Sea.

Final Sample Size Calculation (For Each Group)

The final sample size was determined using the following parameters:

Confidence Level: 95% (Z = 1.96)

- Confidence Level: 95% (Z = 1.96)
- Estimated Proportion (p): 0.5 (to maximize sample size)
- Margin of Error (E): 0.05 (5%)

Using the formula:

$$n = \frac{Z^2.p.(1-p)}{E^2} \quad (1)$$

Total sample size = 385 × 2 groups = 770 participants.

Data collection

A range of environmental monitoring devices was used to measure the concentration of pollutants, including heavy metals, pesticides, cadmium, lead, PM10, and SO_2, in water, soil, and air across the study regions. Clinical dental examinations were conducted to assess the prevalence of periodontal diseases, including gingivitis, periodontitis, microbial infections, and mixed periodontal diseases, among the study participants. Laboratory cultivation methods were employed to detect periodontopathogenic microorganisms in infected tissue samples.

Data analysis

Both descriptive and correlational statistical methods were used in this study. Pearson correlation analysis was applied

to evaluate the relationship between environmental pollutants and periodontal infections. Descriptive statistics were used to summarize demographic, environmental, and clinical data. A significance level of $p < 0.01$ was set, and correlation coefficients were calculated to measure the strength and direction of associations, providing insights into the impact of environmental factors on children's periodontal health.

Ethical considerations

This study adhered to ethical guidelines by obtaining informed consent from parents and guardians, ensuring data confidentiality and anonymity, and prioritizing participant welfare. The study was approved by an ethical review committee, and all research involving human subjects, especially children, was conducted in strict accordance with established ethical principles.

Results and Discussion

Results **Table 1** presents the demographic characteristics, revealing significant disparities between Group 1 (Aralsk City, Shieli Township, and Kyzylorda City) and Group 2 (Talgar City) in terms of gender distribution, socioeconomic status, healthcare access, nutritional status, and periodontal health. While males constituted the majority across all groups, females were more prevalent in Talgar City (62.3%). Socioeconomic conditions were notably poorer in Group 1, with up to 29.9% of participants classified as having a low socioeconomic status, whereas 89.5% of participants in Talgar City fell into the high socioeconomic status category. Access to healthcare was limited for nearly half of all participants, with the issue being more pronounced in Group 1. Malnutrition was most prevalent in Aralsk City (27.3%), reflecting the severe environmental and economic challenges faced by populations near the Aral Sea. Interestingly, despite higher levels of pollution in Group 1, Group 2 (Talgar City) exhibited greater prevalence rates of gingivitis, periodontitis, and mixed periodontal diseases. This trend may be explained by variations in pollution types, exposure pathways, and their distinct effects on health outcomes.

Rather of directly causing oral infections, pollutants in Group 1 regions probably have a greater impact on nutritional inadequacies and systemic health issues. Conversely, the better socioeconomic conditions in Group 2 may mitigate broader health issues but still allow localized periodontal diseases to develop, potentially due to dietary habits or inadequate preventive dental care practices.

Table 1. Demographic Characteristics of Study Participants

Variable	Group 1			Group 2
	Aralsk City (n=129)	**Shieli Township (n=129)**	**Kyzylorda City (n=127)**	**Talgar City (n=385)**
Gender				
Male (%)	92 (20.5%)	86 (19.2%)	86 (19.2%)	185 (41.2%)
Female (%)	37 (11.5%)	43 (13.4%)	41 (12.8%)	200 (62.3%)
Age (Mean ± SD)	9.3 ± 1.4 years	9.3 ± 1.6 years	9.4 ± 1.6 years	9.3 ± 1.6 years
Socioeconomic Status				
Low (%)	98 (29.9%)	87 (26.5%)	81 (24.7%)	62 (18.9%)
Middle (%)	25 (9.6%)	37 (14.2%)	38 (14.6%)	161 (61.7%)
High (%)	6 (3.3%)	5 (2.8%)	8 (4.4%)	162 (89.5%)
Access to Healthcare				
Good (%)	61 (16.1%)	64 (16.9%)	58 (15.3%)	196 (51.7%)
Limited (%)	68 (17.4%)	65(16.6%)	69 (17.6%)	189 (48.3%)
Nutritional Status				
Malnourished (%)	27 (27.3%)	19 (19.2%)	15 (15.2%)	38 (38.4%)
Normal (%)	102 (15.2%)	110 (16.4%)	112 (16.7%)	347 (51.7%)

Figure 1 illustrates the geographic distribution of the study sites and their proximity to the Aral Sea. Aralsk City, currently situated approximately 17 kilometers from the nearest shore of the Aral Sea, has experienced a significant reduction in distance from the shoreline from around 75 kilometers in the early 1990s due to environmental

restoration efforts, such as the construction of the Kokaral Dam. Kyzylorda, located about 400 kilometers from Aralsk, serves as a regional capital and urban center, experiencing less direct environmental impact from the Aral Sea's degradation [17]. Shieli Township, approximately 200 kilometers from Aralsk, faces both socio-economic and environmental challenges associated with the declining conditions of the Aral Sea. Talgar City, situated 800 kilometers away in the Almaty region, remains largely unaffected by the crisis due to its significant distance from the sea [18-23].

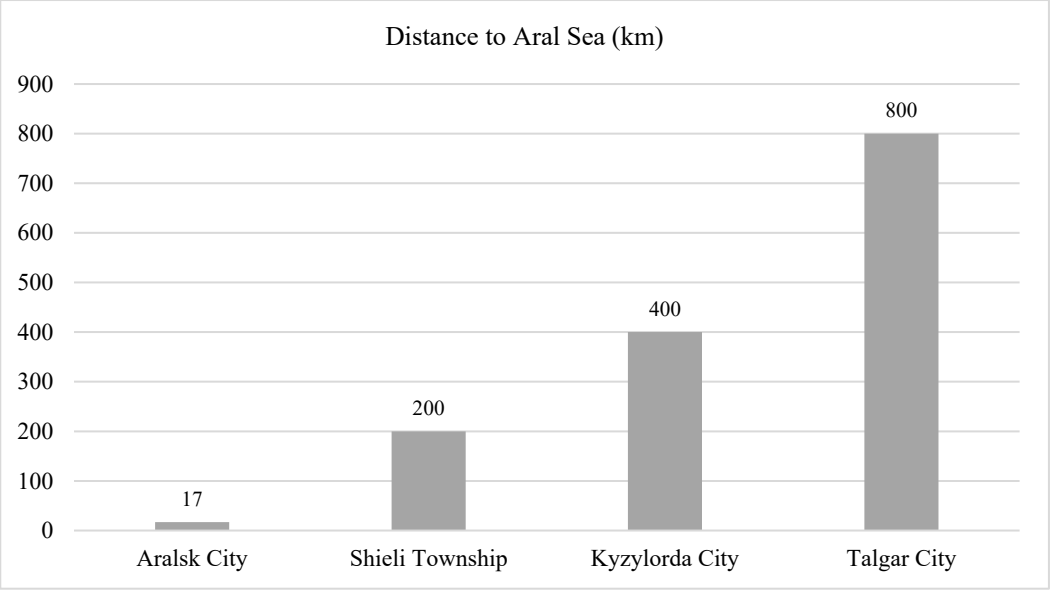

Figure 1. Geographic Distribution of Study Sites and Their Proximity to the Aral Sea

Table 2 presents environmental data from a correlational study exploring the impact of environmental pollutants on periodontopathogenic microbial infections in children in the Aral Sea region. It reveals that Group 1 (closer regions) consistently exhibits higher levels of contaminants compared to Group 2 (farther regions). Notably, Aralsk City shows the highest concentrations of heavy metals in water (17.5 ± 2.7 µg/L), pesticides (1.6 ± 0.6 ppb), and cadmium in soil (1.2 ± 0.4 mg/kg), exceeding threshold limits. Airborne pollutants, including PM10 (76.5 ± 6.3 µg/m³) and SO_2 (74.0 ± 5.8 µg/m³), are also most elevated in closer regions, potentially influencing microbial infections in children [24-28].

Table 2. Environmental Data Analysis by Region and Parameter Type

Parameter	Type	Group 1		Group 2		Threshold Limit [20, 21]
		Aralsk City (17 km)	Shieli Township (200 km)	Kyzylorda City (400 km)	Talgar City (800 km)	
Heavy Metals (e.g., Lead) µg/L	Water	17.5 ± 2.7	14.8 ± 2.2	14.0 ± 2.1	6.5 ± 1.0	10 µg/L
Pesticides (e.g., DDT) ppb	Water	1.6 ± 0.6	1.4 ± 0.4	1.1 ± 0.3	0.8 ± 0.3	<1 ppb
Cadmium mg/kg	Soil	1.2 ± 0.4	1.0 ± 0.3	0.9 ± 0.2	0.7 ± 0.2	0.5 - 1 mg/kg
Lead mg/kg	Soil	0.7 ± 0.2	0.5 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	0.1 - 0.5 mg/kg
Particulate Matter (PM10) µg/m³	Air	76.5 ± 6.3	69.9 ± 5.3	67.9 ± 4.7	39.6 ± 5.3	50 µg/m³ (24-hour average)
Air Toxicants (SO_2) µg/m³	Air	74.0 ± 5.8	69.2 ± 4.9	66.8 ± 4.6	39.6 ± 5.6	50 µg/m³ (24-hour average)

Table 3 presents the prevalence of periodontal infections among children in the Aral Sea region, categorized into two groups based on their proximity to environmental pollutants. In Group 1 (Aralsk City, Shieli Township, Kyzylorda City), the prevalence of gingivitis ranged from 19.3% to 22.9%, whereas Group 2 (Talgar City) showed a higher rate of 36.4%. Periodontitis and mixed periodontal disease were more prevalent in Group 2 (31.0% and 36.5%, respectively)

compared to Group 1 (18.3%–27.8% and 16.9%–24.7%). Microbial infections were also highest in Talgar City (34.8%). Overall, proximity to pollutants appears to influence the distribution of periodontal infections in children [29-45].

Table 3. Prevalence of Periodontal Infections in the Aral Sea Region

Infection Type	Group 1			Group 2
	Aralsk City (n=129)	Shieli Township (n=129)	Kyzylorda City (n=127)	Talgar City (n=385)
Gingivitis				
Yes	83 (22.9%)	78 (21.5%)	70 (19.3%)	132 (36.4%)
No	46 (11.3%)	51 (12.5%)	57 (14.0%)	253 (62.2%)
Periodontitis				
Yes	35 (27.8%)	29 (23.0%)	23 (18.3%)	39 (31.0%)
No	94 (14.6%)	100 (15.5%)	104 (16.1%)	346 (53.7%)
Microbial Infection (Pathogens)				
Yes	75 (26.9%)	64 (22.9%)	43 (15.4%)	97 (34.8%)
No	54 (11.0%)	65 (13.2%)	84 (17.1%)	288 (58.7%)
Mixed Periodontal Disease				
Yes	54 (24.7%)	48 (21.9%)	37 (16.9%)	80 (36.5%)
No	75 (13.6%)	81 (14.7%)	90 (16.3%)	305 (55.4%)

Table 4 highlights critical correlations between environmental factors and air pollutants (PM10 and SO_2), emphasizing their potential impact on the prevalence of periodontal infections in the Aral Sea Region. Heavy metals show a strong positive correlation with PM10 (r = 0.887**) and SO_2 (r = 0.871**), indicating that increased heavy metal levels are closely linked to elevated air pollutant concentrations, potentially amplifying the risk of periodontal infections. Lead also demonstrates a moderate positive correlation with PM10 (r = 0.654**) and SO_2 (r = 0.652**), suggesting its role as a contributing environmental factor. Similarly, pesticides exhibit moderate correlations with PM10 (r = 0.554**) and SO_2 (r = 0.547**), reflecting an indirect influence on oral health through pollutant interactions. Lastly, cadmium shows a lower but statistically significant correlation with both PM10 (r = 0.532**) and SO_2 (r = 0.510**), highlighting its role in the complex interplay of environmental factors affecting health outcomes. These findings underline the importance of addressing environmental pollution to mitigate periodontal health risks.

Table 4. Critical Correlations Between Environmental Factors and Prevalence of Periodontal Infections in the Aral Sea Region

Environmental Factor	PM10 (*r)	SO_2 (*r)	Implications
Heavy Metals	0.887**	0.871**	Strong positive correlation indicates that higher levels of heavy metals are associated with increased PM10 and SO_2 concentrations, suggesting a synergistic effect contributing to periodontal infections.
Lead	0.654**	0.652**	Moderate positive correlation implies that elevated lead levels are linked to both PM10 and SO_2, potentially aggravating oral health conditions.
Pesticides	0.554**	0.547**	Moderate correlation reflects that pesticide exposure may indirectly exacerbate periodontal risks through environmental pollutants.
Cadmium	0.532**	0.510**	Lower but significant correlation shows cadmium's role in interacting with air pollutants, affecting health outcomes.

**: Correlation is statistically significant at the 0.01 level (2-tailed). *Pearson correlation (r) values: ≥ 0.70 = strong, 0.30–0.69 = moderate, ≤ 0.29 = weak

Demographic and socioeconomic context

The demographic analysis of the current study reveals significant disparities between Group 1 (Aralsk City, Shieli Township, Kyzylorda City) and Group 2 (Talgar City) in terms of gender, socioeconomic status, healthcare access, and nutritional status. While females were outnumbered in

all groups, Talgar City had a higher proportion of females. Group 1, which includes Aralsk City, reported poorer socioeconomic conditions, limited access to healthcare, and higher rates of malnutrition, reflecting the ongoing environmental and economic challenges faced by residents of the region surrounding the Aral Sea.

In contrast, the gender ratio in Talgar City aligns with the broader demographic trends observed in Kazakhstan, where females generally outnumber males. According to recent statistics, the country had approximately 10.2 million females and 9.7 million males by the end of 2023. This demographic phenomenon may be linked to urbanization processes and the distinct sociological characteristics of urban centers like Talgar, compared to the more rural regions of Group 1, such as Aralsk City, Shieli Township, and Kyzylorda City. In urban areas, where women form the majority of the population, migration trends are evident, with women moving to cities in search of better education and employment opportunities. The disparity in gender distribution in rural areas is made worse by this migration.

Environmental impacts

The majority of participants in both groups report that access to healthcare is a major concern, although Group 1 seems to be worse off, aligning with previous studies highlighting regional inequalities in healthcare resources and services within Kazakhstan. Supporting this, another study found that pesticide levels, particularly DDT, in the catchment area were recorded at 0.3 ± 0.1 ppb, which exceeds the acceptable limit of 0.1 ppb. The burden of these toxic substances is largely due to agricultural activities and industrial waste in the region. Average concentrations of Particulate Matter (PM10) were measured at 80 ± 15 μg/m³, which is more than three times the permissible level of 50 μg/m³ for 24 hours [46]. Additionally, sulfate particulates in the air were found at concentrations of 1.5 ± 0.3 μg/m³, roughly three times the long-term exposure limit of 0.5 μg/m³ [47]. Current research shows the highest levels of environmental pollutants in Group 1 (closer regions), particularly in Aralsk City, where levels of heavy metals, pesticides, and cadmium exceed established threshold limits. Elevated concentrations of pollutants such as PM10 and SO_2 in the air were also reported in these areas. These findings suggest that the environmental degradation around the Aral Sea is likely exacerbating the prevalence of periodontopathogenic microbial infections among children living in these regions. Such environmental factors pose significant health risks to local communities, who are also experiencing a high incidence of respiratory disorders, cancer, and other illnesses, primarily due to dust contaminated by the dried seabed. This exposure has been linked to higher rates of throat cancers and other serious conditions [48]. Further research indicates that the accumulation of potentially toxic elements (PTEs) in the sediments of the Aral Sea has reached levels indicative of moderate ecological risk since the late 1970s. This research underscores the detrimental effects of human interference, showing that the ecological degradation of the region is extensive and continues to have a profound impact [49]. A detailed study revealed that the water bodies in the vicinity of Kyzylorda, particularly in relation to sulfates and heavy metals, were more heavily polluted than the established water quality standards allow, likely due to agricultural runoff [50].

In response to these challenges, recent reports indicate that the government of Uzbekistan has initiated several rehabilitation programs aimed at restoring the environment, focusing on anti-desertification efforts and improving air quality by planting trees on the dried seabed [51]. However, despite these efforts, significant concerns persist due to ongoing exposure to pollutants. Research highlights that traces of compounds such as organochlorines, lead, and cadmium in the environment pose a high risk to children in the Aral Sea region, necessitating urgent action. These pollutants are associated with developmental delays and various health conditions among children [52]. Furthermore, studies have shown that climate change is a major contributor to the shrinking of the Aral Sea, with observable changes in river flow and climatic indicators. These studies also underscore the potential for Central Asia's policies to address both the environmental and socio-economic implications of the crisis, offering insights for tackling these issues [53]. A study on the water-energy-food nexus in the Aral Sea Basin raised concerns about inter-country cooperation, noting that environmental issues have not been sufficiently addressed. It suggests that these concerns be incorporated into studies and analyses at smaller geographical and national levels [54]. Additionally, research suggests that water quality in the region could improve if governments recognize the need for effective water management interventions. Mitigating the harmful effects of water pollution on human health is possible through targeted measures that address regional, age, and gender differences in disease prevalence over time, ensuring universal protection from waterborne diseases [55].

The current study aims to demonstrate that the correlation analysis between environmental factors and the prevalence of periodontal inflammatory diseases in children from the Aral Sea region reveals significant associations, particularly with heavy metals and air pollutants. The findings show a strong correlation between heavy metals, particulate matter (PM10), and sulfur dioxide (SO_2), suggesting that exposure to these environmental pollutants may contribute to the higher occurrence of periodontal disease in this group. Specifically, the analysis indicates the highest correlations of PM10 and SO_2 with heavy metals, with correlation coefficients of $r = 0.887$ and $r = 0.871$, respectively. These results align with several recent studies on the adverse health impacts of heavy metal exposure in children.

Healthcare challenges

The majority of participants in both groups expressed concerns about healthcare access, with Group 1 facing more

significant difficulties. These findings are consistent with previous studies highlighting regional disparities in healthcare resources across Kazakhstan. The underutilization of medical services in these areas likely causes many health issues to remain untreated, exacerbating the already challenging living conditions in these populations [56]. The ongoing shortage of medical infrastructure, coupled with rural poverty, underscores the urgent need for targeted programs to address these service imbalances.

Moreover, the further economic decline caused by the ecological disaster in the Aral Sea region has led to a reduction in healthcare facilities, including dental clinics. This scarcity of resources likely contributes to the higher prevalence of periodontal diseases among children in these regions [57]. A closer examination of children's health in the area reveals a range of environmental health issues, including a high prevalence of anemia and respiratory diseases, which may correlate with the poor oral hygiene observed in this study [58].

Microbial dysbiosis and periodontal health

The current study reveals a significant variation in the prevalence of periodontal infections between children residing near the Aral Sea (Group 1) and those located farther away (Group 2). Specifically, residents of Talgar City (Group 2) exhibited significantly higher rates of gingivitis, periodontitis, mixed periodontal disease, and microbial infections compared to those in Group 1. This disparity suggests that the elevated concentration of heavy metals and air pollution in these areas plays a major role in the increased prevalence of periodontal infections among their residents. The role of microbial dysbiosis in the progression of periodontal disease is well documented. Recent studies indicate that dysbiosis, an imbalance between pathogenic and beneficial bacteria in the oral cavity, is a key feature of periodontal disease. The higher abundance of microbial infections among residents of Talgar City may be linked to the environmental stressors they face, which could lead to greater dysbiosis and, consequently, more inflammation and tissue damage [59].

Furthermore, epidemiological studies indicate that the health of children living around the Aral Sea is significantly impacted by environmental pollutants, with dental diseases among the most prevalent. Anthropogenic pollutants and heavy metals have been found in elevated levels in local foods and the environment, exposing the population to a higher risk of developing immunological, growth, and chronic health issues, including those affecting oral health [60]. For instance, one study found that higher blood levels of lead and cadmium in children from the Aral Sea region were correlated with an increased incidence of periodontal disease, further emphasizing the impact of pollution on dental health [47].

Other research has highlighted the complex relationship between environmental conditions and the prevalence of early childhood caries (ECC). Economic development, urbanization, and industrialization appear to be associated with a higher prevalence of ECC, while a healthier ecosystem may offer some protection. These findings suggest that environmental well-being plays a significant role in determining the exposure risk to ECC in any given country [61]. This study underscores the crucial role of environmental pollutants in the development of periodontal health issues among children in the Aral Sea region and emphasizes the urgent need for ecological and health-focused interventions.

Conclusion

Based on the findings of this study, it can be concluded that environmental pollution is a significant contributing factor to the increased prevalence of periodontopathogenic infections among children aged five to fourteen. More severe forms of these infections were observed among residents in Group 1, which includes Aralsk City, Shieli Township, and Kyzylorda City. When comparing the two groups, it is evident that children in Group 1, who come from socioeconomically disadvantaged backgrounds, experience greater healthcare access challenges and higher levels of environmental pollution compared to those in Group 2 (Talgar City). Additionally, the findings emphasize the concerning reality that children in Group 1, suffering from gingivitis and periodontitis, are exposed to higher levels of pollutants, particularly heavy metals, PM10, pesticides, and SO_2. This suggests that children living further from the Aral Sea are at comparatively lower health risks. The results also demonstrate that increased exposure to contaminants correlates with higher health risks, with Aralsk City being the most polluted and showing the highest infection rates. Interestingly, despite having lower pollution levels, Talgar City reported higher incidences of periodontal diseases, which implies that other factors, possibly systemic or lifestyle-related, could also contribute to these health issues. According to the correlation analysis, heavy metals and airborne toxins are the most significant environmental pollutants impacting the periodontium, underscoring the importance of addressing environmental factors for public health. These findings highlight the urgent need for environmental clean-up initiatives and targeted health interventions for at-risk populations to mitigate the persistent impact of pollution on children’s health.

Recommendation

The proposed recommendations for addressing the unfavorable environmental conditions in the Aral Sea region, where the shoreline has become increasingly degraded, focus on careful monitoring and pollution management across the entire region. Pollution of soil, air, and water should be managed as a priority for both local authorities and international organizations, particularly in terms of reducing heavy metals, pesticides, and particulate matter. In addition, oral hygiene promotion, education, and

nutritional support programs, as part of a community-based health promotion framework, should be implemented to mitigate the adverse effects of environmental factors on children's health. To address healthcare inequalities, it is crucial to expand accessible and affordable primary healthcare systems for all residents. Further studies should explore the organizational and cultural factors that may contribute to the unexpectedly high rates of infectious diseases in remote areas, such as Talgar City, to help develop more comprehensive public health policies.

Limitations of the study

This study has several limitations despite its noteworthy results. Although a considerable number of participants were included, certain factors, such as food habits, family history, and the level of dental care availability, were not adequately considered. Moreover, the use of pollution data from pre-existing monitoring sources may have overlooked localized differences in exposure. Finally, the findings are restricted to certain areas, which limits their applicability to other population groups.

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