

Challenges and Oral Health Protocols in Extreme Antarctic Environments: A Policy Proposal for Sustainable Scientific Operations

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Desafíos y protocolos de salud bucal en entornos antárticos extremos: una propuesta de política para operaciones científicas sostenibles

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RESUMEN

La salud oral de los investigadores en la Antártida ha recibido históricamente una atención limitada, a pesar de que las afecciones dentales representan un aproximado de entre el 10 % y el 15 % de las emergencias médicas durante las misiones polares. La exposición a condiciones ambientales extremas, el aislamiento geográfico y el consumo de agua desmineralizada producida mediante ósmosis inversa pueden alterar el microbioma oral e incrementar el riesgo de enfermedades bucales incapacitantes. Este documento de política analiza la evidencia disponible sobre el deterioro sistémico acelerado de la salud oral durante estancias antárticas de corta duración y propone la institucionalización de un estándar de salud oral de «Cero Riesgo» previo a la expedición. Las medidas recomendadas incluyen la provisión de kits técnicos con dentífricos de alta concentración de flúor (5000 ppm), la implementación de sistemas de teleodontología y la integración de estrategias de soporte bioquímico destinadas a preservar la capacidad operativa y reducir la carga económica asociada a las evacuaciones aeromédicas. Asimismo, estas medidas podrían fortalecer la sostenibilidad y resiliencia a largo plazo de las misiones de investigación antártica, al favorecer el bienestar de los investigadores y la continuidad de las actividades científicas en entornos extremos.

Palabras clave: salud oral, Antártida, medicina polar, protocolos de prevención, estrés adaptativo

ABSTRACT

Historically, oral health among Antarctic researchers has received limited attention, despite dental conditions accounting for approximately 10-15% of medical emergencies during polar missions. Extreme environmental exposure, geographic isolation and the consumption of demineralized water produced through reverse osmosis may alter the oral microbiome and increase the risk of disabling oral diseases. In this policy brief, we examine current evidence regarding the accelerated systemic deterioration of oral health during short-term Antarctic stays and propose the institutionalization of a pre-expedition «zero-risk» oral health standard. Recommended measures include the provision of high-fluoride technical kits (5000 ppm), the implementation of tele-dentistry systems, and the integration of biochemical support strategies, in order to preserve operational readiness and reduce the financial burden associated with aeromedical evacuations. These measures also have the potential to strengthen the long-term sustainability and resilience of Antarctic research missions.

Keywords: Oral health, Antarctica, polar medicine, preventive protocols, adaptive stress



Introduction

The Antarctic region is one of the most hostile and physiologically demanding environments on Earth (Scientific Committee on Antarctic Research [SCAR], n.d.). The combination of extremely low temperatures, intense ultraviolet radiation and profound geographic isolation imposes continuous stress on human physiology. Although the effects of these conditions on immune function and metabolism have been extensively investigated, historically oral health has remained a secondary concern, despite being intrinsically linked to systemic health and recognized as an early indicator of chronic disease processes (Adams and Stanmeyer, 1960; Araujo-Muro *et al.*, 2026; Crowther *et al.*, 2024; Moraes *et al.*, 2023).

Due to transportation constraints and the operational conditions associated with polar travel, researchers assigned to Antarctic scientific stations commonly remain in the field for prolonged periods. Consequently, expedition personnel must transport and manage all the essential resources required throughout their stay (Burki, 2025; British Antarctic Survey, n. d.). Polar expeditions involve profound physical, psychological and social changes. Under Antarctic conditions, daily routines, dietary patterns, sleep habits and interpersonal interactions are significantly altered (Bartáková *et al.*, 2025). Collectively, these factors may negatively affect oral health status and, consequently, overall systemic health (Bhushan *et al.*, 2019; Cherry *et al.*, 2024).

Although oral health has traditionally received less attention in Antarctic medicine than other medical conditions, recent evidence suggests that exposure to extreme environmental conditions can affect several parameters of oral health. Studies conducted in Antarctica and other isolated environments have reported changes in salivary flow, periodontal indicators, inflammatory biomarkers and oral microbial composition that may increase susceptibility to oral disease during prolonged periods in the field. A previous study conducted in 2026 by Araujo-Muro *et al.* identified that a two-month Antarctic deployment was associated with significant deterioration in periodontal health and reduced salivary flow among military personnel, underscoring the critical need for rigorous pre-expedition dental screening and targeted preventive protocols. However, the available evidence remains limited and heterogeneous, due to population and expedition differences, emphasizing the need for further investigation and cautious interpretation of potential preventive strategies.

In this context, the purpose of this policy brief was to discuss current evidence regarding changes in oral health markers among researchers deployed to Antarctic scientific stations, and to identify possible preventive approaches that warrant consideration and further evaluation in future Antarctic missions.

Approach and discussion

For this study, a literature search was conducted in PubMed, Scopus and Google Scholar databases for articles published up to 2026. The search strategy used combinations of MeSH terms and keywords including: «oral health», «Antarctica», «polar medicine», «extreme environments» and «microbiome». The manuscript selection was limited to peer-reviewed original studies, systematic reviews and institutional reports. Fact sheets and opinion articles unsupported by empirical data were excluded.

Reports indicate that dental conditions account for approximately 10-15% of medical consultations during prolonged polar expeditions, whereas the incidence during short summer campaigns is generally below 5% (Peřina *et al.*, 2023). These findings suggest that duration of exposure constitutes a major determinant of oral deterioration, and that differentiated preventive strategies may be warranted, in accordance with the length of stay at Antarctic stations. In this context, these findings may justify consideration of standardized oral health criteria prior to deployment, aimed at ensuring that deployed personnel are free from any active oral diseases susceptible to exacerbation during periods of extreme isolation (Donoff *et al.*, 2022). Furthermore, preventive oral health strategies are consistent with broader sustainability goals within Antarctic programs. A reduction in preventable dental emergencies may decrease the need for costly evacuations, thereby facilitating the optimal use of limited healthcare resources, and supporting the physical and psychological well-being of researchers.

The oral microbiome is considered a sensitive indicator of systemic health. Microbiological studies have demonstrated that prolonged isolation modulates bacterial composition, reducing protective taxa while increasing inflammatory biomarkers such as interleukin-8 and leptin, both associated with oxidative stress and intense workload demands. In addition, summer expeditions have shown fluctuations in dominant bacterial phyla, including a reduction in Pseudomonadota, which has been proposed as a «microbial signature» associated with health deterioration (Moraes *et al.*, 2023).

Due to its close association with systemic inflammatory processes and periodontal disease progression, the presence of interleukin-6 (IL-6) within the oral cavity is particularly concerning (Adams and Stanmeyer, 1960; Bartáková *et al.*, 2025). These findings have been documented previously and could constitute a microbial indicator of declining oral health status, suggesting that biochemical support interventions could be explored in future studies and as part of continuous preventive monitoring, particularly in settings where oral inflammation may function as an early biomarker of systemic adaptive stress (Kerr *et al.*, 2021; Zare *et al.*,

2024; Mazurek-Mochol *et al.*, 2024, cited in Bartáková *et al.*, 2025).

Water supply constitutes another critical factor in polar expeditions. Most Antarctic stations produce potable water through reverse osmosis systems, a process that removes naturally occurring fluoride. The absence of fluoride limits the selective inhibition of acidogenic bacterial taxa such as *Streptococcus mutans* and *Lactobacillus* spp. (Bartáková *et al.*, 2025). These microorganisms metabolize dietary sugars into lactic acid, thereby promoting enamel demineralization and dental caries development.

Dietary practices in Antarctica, frequently characterized by reliance on processed and preserved foods, limited availability of fresh produce, frequent snacking and alcohol consumption, may substantially increase oral disease risk. Logistical constraints often favor shelf-stable foods rich in refined carbohydrates and added sugars, which can prolong oral acid exposure and promote cariogenic activity. In addition, dehydration associated with cold environments, low humidity and intense physical workload may further reduce salivary flow and compromise natural oral defense mechanisms. Consumption of these products has been identified as a predictor of tooth pain and gingival disorders across Antarctic stations (Mi *et al.*, 2023). Therefore, dietary practices constitute one of the most readily modifiable determinants of oral health during Antarctic deployment and should be considered alongside microbiological and inflammatory mechanisms when designing preventive strategies (Last *et al.*, 2024; Lowe and Warner, 2023; Bartáková *et al.*, 2025).

In addition to bacterial disease, three major categories of oral problems have been reported in Antarctic settings: traumatic injuries, restorative failures and biological diseases, including caries, gingivitis and periodontitis, exacerbated by microbiome alterations (Peřina *et al.*, 2023; Bartáková *et al.*, 2025; Mi *et al.*, 2023). A particularly critical issue is the fact that many oral emergencies are addressed by non-dental healthcare personnel operating under significant structural limitations. Consequently, telemedicine and tele-dentistry emerge as strategic tools to improve diagnostic and therapeutic capacity in remote Antarctic stations (Chen *et al.*, 2023; Peřina *et al.*, 2023; Mi *et al.*, 2023; Walker *et al.*, 2022). These structural limitations underscore the necessity of strengthening training programs. At the same time, operational protocols should formally incorporate protected time for oral hygiene practices and ensure access to the minimum environmental conditions that facilitate self-care.

Conclusions and recommendations

Based on the available evidence, the following measures may be considered as part of a broader sustainability strategy for Antarctic scientific programs. Protecting oral

health not only contributes to disease prevention, but also to researcher well-being, mission continuity, efficient resource management and the long-term resilience of scientific operations in remote environments.

Institutionalization of a pre-expedition «zero-risk» oral health standard: All incipient carious lesions and periodontal pockets greater than 3 mm should be treated before deployment. The rationale is both operational and financial: under extreme isolation, conditions such as pulpitis or periodontal abscesses may incapacitate expedition personnel and require costly aeromedical evacuations that far exceed the cost of preventive treatment performed prior to deployment.

Potential use of enhanced preventive supplies: Institutions should provide mandatory technical kits including high-fluoride toothpaste formulations, salivary substitutes in gel form to mitigate xerostomia, and alcohol-free remineralizing mouth rinses, to compensate for the reduced protective function of saliva under Antarctic conditions.

Exploration of biochemical support approaches: Antarctic diets are often characterized by increased consumption of shelf-stable carbohydrate-rich foods and caffeinated beverages used to counteract cold exposure and fatigue. These factors contribute to sustained oral acidification. Accordingly, field supplies should include xylitol-containing chewing gum and bicarbonate solutions to neutralize oral acidity immediately after meals, particularly during prolonged fieldwork when the brushing of teeth may not be feasible.

Training in tele-dentistry and remote diagnosis: Healthcare personnel assigned to Antarctic stations should receive training in plaque-disclosing techniques and standardized intraoral photography protocols. These strategies would facilitate teleconsultations with specialists located on the mainland, enabling early identification of inflammatory signs such as bleeding on probing (BOP) and facilitating guided interventions before minor conditions evolve into disabling infections capable of compromising mission continuity.

Consideration of structured oral hygiene protocols: This approach should include the allocation of protected hygiene periods and guaranteed access to tempered water for brushing teeth. By reducing cold-induced dental sensitivity and minimizing neglect associated with extreme fatigue, oral hygiene may be reframed as a critical preventive maintenance task necessary for preserving the long-term functionality of expedition personnel (Figure 1).

Despite the potential benefits of the preventive measures discussed, their implementation may present logistical and operational challenges. Different Antarctic programs differ considerably in terms of mission duration, healthcare infrastructure, resource availability and evacuation capacity. Consequently, any preventive



strategy should be adapted to local operational realities and prioritized according to the specific risk profile and capabilities of each program. Future Antarctic policies should recognize oral health as an integral component of sustainable scientific practice, where the protecting of researchers supports both individual well-being and the continuity of scientific knowledge generation in extreme environments.

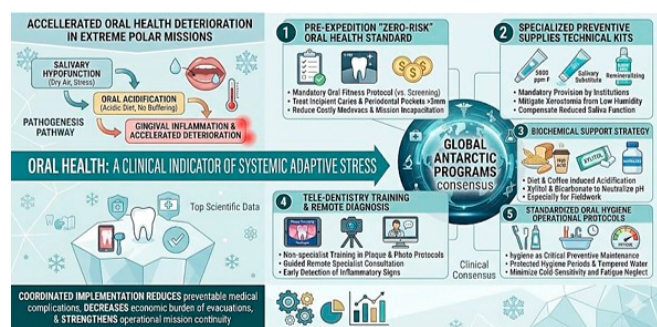


Figure 1. Recommendations for integrated operational polar oral medicine

Authors' contributions statement

Claudio Peña-Soto: Conceptualization, methodology, investigation, data curation, writing (original draft).

Guillermo Cano-Verdugo: methodology, formal analysis, validation, writing (revision and editing), visualization.

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Conflicts of interest

The authors declare no conflicts of interest.

Artificial Intelligence disclosure

During the preparation of this manuscript, the authors used ChatGPT-5 (OpenAI) only for the purposes of translation of the manuscript from Spanish to English, and Gemini (Google DeepMind) for image creation. The authors carefully reviewed, edited and approved the final English version and take full responsibility for the content, interpretation and accuracy of the manuscript.

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