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REVIEW ARTICLE

On the potential use of radon waters from the Khmilnyk resort for the treatment of dental diseases

Alisa Pachevska, Iryna Simonova, Olena Popova, Tetiana Chugu

VINNYTSIA NATIONAL PIROGOV MEMORIAL MEDICAL UNIVERSITY, VINNYTSIA, UKRAINE

ABSTRACT

Aim: To explore the therapeutic potential of radon-rich waters from the Khmilnyk resort in Ukraine for the treatment and prevention of periodontal diseases.
Materials and Methods: A literature review was performed using PubMed and Google Scholar databases, covering research published between 1970 and 2023 related to radon balneotherapy, particularly in dentistry.
Conclusions: Balneotherapy, particularly with low-dose radon exposure, is known for its anti-inflammatory, analgesic, and antioxidant effects. Although radon waters have been widely used in the treatment of cardiovascular and musculoskeletal disorders, their application in dental care, especially for chronic periodontal inflammation, remains underexplored. The Khmilnyk resort, with its unique radon-mineral composition and long-standing therapeutic tradition, offers promising perspectives for integration into dental practice. Radon therapy may improve blood circulation in periodontal tissues, stimulate cellular regeneration, and enhance oral immunity.
The use of Khmilnyk radon waters could become an effective adjunct in periodontal treatment. Further clinical trials are warranted to validate optimal protocols and safety measures.

KEYWORDS: radon waters, balneotherapy, dentistry, PubMed, Google Scholar, Medline

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INTRODUCTION

Balneotherapy is a clinically effective complementary approach in the treatment of low-grade inflammation- and stress-related pathologies. The biological mechanisms by which immersion in mineral-medicinal water and the application of mud alleviate symptoms of several pathologies are still not completely understood, but it is known that neuroendocrine and immunological responses – including both humoral and cell-mediated immunity – to balneotherapy are involved in these mechanisms of effectiveness; leading to anti-inflammatory, analgesic, antioxidant, chondroprotective, and anabolic effects together with neuroendocrine-immune regulation in different conditions [1]. Hydrotherapy stimulates blood circulation and phagocytosis, helps activate the body's antioxidant system. [2-4]. In dentistry, periodontal diseases remain the most common and constantly require the search for new treatment methods. Hydrotherapy in dentistry is primarily used in the treatment of periodontal diseases. Its therapeutic effect lies in stimulating blood circulation in periodontal tissues, driven by the biochemical composition of the water (mineral, sea, or sulfuric water), water pressure (1-3 atm), and thermal influence (37-45°C). Hydrotherapy promotes inflammation reduction and exudate resorption. It is employed in cases of chronic inflammation of the gums, deeper periodontal layers, and atrophic changes. Hydrotherapy enhances blood flow and phagocytosis. Trace elements present in mineral waters particularly benefit the gingival epithelium, acting as catalysts in biochemical detoxification processes. However, scientific data on the use of radon waters in dentistry remains limited. From existing literature, it is known that radon waters are used in periodontal disease hydrotherapy in the form of rinses, drinking courses, and inhalations. For radon therapy, water is sourced from natural springs, boreholes, and less commonly, uranium mines [5].

AIM

To analyze the potential of using radon waters from the Khmilnyk resort for the treatment and prevention of periodontal diseases.

MATERIALS AND METHODS

A literature review was conducted using the PubMed and Google Scholar databases, covering studies published between 1970 and 2023 concerning radon water therapy, especially for dental diseases. The data were analyzed to identify the most common dental conditions treated with this form of physical medicine. Publications containing the following keywords were selected: balneology, dentistry, radon waters. Out of 50 articles reviewed, 25 were selected that contained relevant information directly related to the topic.

REVIEW AND DISCUSSION

According to historical records, the Khmilnyk resort is located on the northwestern edge of the Ukrainian

Crystalline Shield, which represents an outcropping of the Earth's most ancient crystalline platform.

The granites and other massive rocks of the Ukrainian Crystalline Shield, which formed in geological antiquity, have been subject to long-term weathering processes – rain, wind, heat, and cold. The resulting fractured granite, crisscrossed with numerous interconnected fissures, has created favorable conditions for the formation of underground waters through the infiltration of atmospheric precipitation, floodwaters, and meltwaters into the depths of the granite layers.

As these subterranean waters percolate through the rock, they become enriched with various salts, minerals, and gases, acquiring new chemical properties. In addition to common minerals and salts, the waters also absorb trace amounts of naturally occurring radioactive elements found in granite. These elements impart radioactive characteristics to the water. According to the Institute of Geological Sciences of the National Academy of Sciences of Ukraine, the locations of radioactive water deposits within the Ukrainian Crystalline Shield often coincide with regions rich in granite formations.

These geological features – structural composition, terrain, and climate – determine the hydrogeological profile of groundwater deposits. When drilling into granite massifs, naturally occurring fissures are encountered, facilitating the upward movement of water into the borehole. This is precisely how the therapeutic waters of Khmilnyk, enriched with health-promoting components, were first obtained from granite formations.

The Southern Bug River, which splits into two branches, creates an island-like area within the city. Historically, residents of this part of Khmilnyk faced a persistent shortage of potable water. Attempts to extract water from traditional wells consistently failed. At depths of 5-7 meters, drillers encountered dense rock layers that were impossible to penetrate manually. The small amounts of water that did emerge were yellowish in color, unpalatable, and extremely hard, rendering it unfit for drinking. Consequently, deeper aquifers had to be tapped to meet the community's needs.

In 1934, in a search for potable water within the city center, the Ukrainian Geological Exploration Trust drilled its first borehole, labeled No. 1E. At a depth of 65 meters, the water obtained was yellowish, saline in taste, and highly mineralized, making it unsuitable for either drinking or technical purposes.

From April 1935 to 1938, researchers from the Institute of Geological Sciences of the National Academy of Sciences of Ukraine conducted detailed chemical and physicochemical analyses of water from borehole No. 1E. The water appeared yellowish, odorless, with a slightly astringent, salty taste. It had a temperature of 10°C and a specific gravity of 1005-1006. Freshly collected water was clear but became cloudy upon settling, producing a precipitate composed of calcium, magnesium, iron carbonates, and other compounds.

Chemical and radiological studies of the mineral spring water revealed the presence of radon (a radium decay product), carbon dioxide, nitrogen, oxygen, potassium, sodium, calcium, magnesium, manganese, iron, bicarbonates, chloride, sulfates, and rare gases such as helium, argon, xenon, and krypton. Organic substances were also found, including bitumens, humic acids, petroleum-based acids, as well as a variety of trace elements. Some of these components form a surface film that slows the rapid volatilization of therapeutic gases during balneological procedures.

According to data from the Institute of Geological Sciences of NAS Ukraine, the gaseous composition of the water includes: carbon dioxide (92.73%), nitrogen (7.2%), helium (0.068%), and xenon and krypton (0.044%).

The chemical composition of the mineral water from borehole No. 11 is represented by the Kurlov formula:

$$\mathrm{Rn17\ nKu/л\ CO^2_{0,5}\ M_{2,5}\ \frac{HCO_3 54 SO^4_{\ 27}}{Ca51\ (Na\ +\ K)\ 45}\ t^{\circ}\ -9^{\circ}C}$$

Based on the research conducted by an expedition comprising staff from the Institute of Geological Sciences of the National Academy of Sciences of Ukraine and the Ukrainian Research Institute of Balneology, the following conclusions were drawn: the water discovered in Khmilnyk can be classified as carbonated, radon-rich, and mineralized. It contains a significant amount of manganese, which undoubtedly adds balneological value; given the described characteristics and adequate discharge rates, external therapeutic application is feasible, provided it is carried out under strict medical supervision.

Experimental and clinical studies conducted by researchers at the Ukrainian Research Institute of Balneology have confirmed the therapeutic value of the mineral water from the borehole No. 1E. The radon water-bearing area in Khmilnyk was officially recognized as a health resort by Resolution No. 1376 of the Council of People's Commissars of the Ukrainian SSR, dated October 10, 1938. The spring was put into practical use [6].

Subsequent extensive studies carried out by the Central Research Institute of Balneology and Physiotherapy, the Ukrainian Research Institute of Rehabilitation and Balneology, and Vinnytsia National Pirogov Memorial Medical University have established that both existing and newly discovered sources of mineral water possess comparatively high therapeutic properties. Based on their hydrogeological origin and ionic composition, certain mineral water sources in Khmilnyk are considered unique due to their distinctive combination of dissolved components, with no analogues among known mineral waters across the European territory of the country [3].

Between 1934 and 1960, six wells were drilled on the island part of Khmilnyk, all tapping into carbonated radon-rich mineral water. This water has since been used for therapeutic purposes by the Regional Physiotherapy Hospital, Railway Clinical Hospital No. 2, the „Southern Bug" sanatorium, and the „Radon" sanatorium. The deposit has been designated the „Khmilnyk therapeutic water deposit."

Given the high therapeutic value and proven effectiveness of these mineral waters, the Ukrainian Republican Council

for Trade Union Resort Management decided to clearly delineate the radon mineral water distribution zone in Khmilnyk, with the aim of evaluating future development prospects for the resort. Hydrogeological investigations conducted by specialists from the Ukrainian office „Ukrgeokoptazhminvod" led to the identification of new promising radon water deposits in the resort area, with substantial discharge capacity.

Drilling operations were carried out between 1952 and 1962 on the southwestern outskirts of the city and in the „Lisna dacha" area. A total of 21 wells were drilled, yielding nitrogen-radon water. These newly discovered wells were collectively named the Novo-Khmilnyk Deposit.

Research on the chemical composition and physicochemical properties of the therapeutic waters from the new deposit, conducted by the Institute of Geological Sciences of the National Academy of Sciences of Ukraine, revealed the water to be clear, odorless, fresh-tasting, slightly mineralized, with a typical color and a temperature of 9°C. Chemically, the water is radon-rich, with a bicarbonate-calcium-sodium-magnesium composition and a mineralization level of 0.7 g/L. Additionally, it contains trace amounts of iodine, bromine, copper, zinc, nickel, cobalt, silver, manganese, metaboric acid, and silicic acid.

The chemical composition formula of the therapeutic water from the Novo-Khmilnyk deposit (borehole No. 5RK):

$$Rn88nKu/\text{л}M_{0,7}\ \frac{HCO_3 95}{Ca63\ Na18\ Mg27}\qquad t^\circ\ -9^\circ C$$

The nitrogen-radon waters of the Novokhmilnyk deposit are currently used for therapeutic purposes by several health institutions, including the inter-farm sanatorium „Podillia," the „Khmilnyk" Sanatorium of the Ukrainian Trade Union Health Resort Association (AO „Ukrprofzdravnytsia"), the Military Clinical Sanatorium, and the Maternal and Child Rehabilitation Center „Berezova Roscha".

Hydrogeological and chemical-radiological studies conducted in the vicinity of the Khmilnyk resort have identified two main types of therapeutic waters: carbonated radon mineral waters with low radon content and weakly mineralized waters with low to moderate levels of radon. The concentration of radon in various boreholes ranges from 50 to 100 nCi/L.

The total reserves of carbonated radon waters at the Khmilnyk deposit are estimated at 5.5 million m^3 per day. The sanitary condition of these therapeutic waters is satisfactory. A reduced concentration of deuterium – known to stimulate biological activity – has been detected in these water types [6,7].

In 1989, the Nobuzh Geological Survey Team, while conducting additional exploration, discovered another radon water deposit in the southern part of the resort (Holodkynskyi site).

Subsequent investigations revealed that this new deposit contains weakly mineralized hydrocarbonate-calcium-magnesium water with radon concentrations ranging from 60 to 180 nCi/L. The borehole discharge reaches 1800 m^3/day.

It is important to emphasize that, prior to the discovery of borehole No. 1E in Khmilnyk, no known sources suitable for radon balneotherapy had existed in Ukraine. Currently, radon-bearing sources have been found in Zhytomyr, Kyiv, Kirovohrad, and other regions of Ukraine, where radon therapy clinics operate successfully. However, due to its long-standing practice and accumulated expertise, the Khmilnyk resort remains the leading facility in the country providing radon balneotherapy.

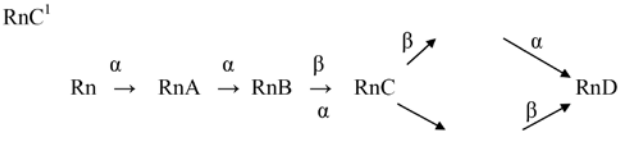
The favorable combination of therapeutic components in the radon waters, picturesque natural surroundings, mild climate, proximity to rivers and forested areas, convenient location with good transportation links, and the high efficacy of treatments have made Khmilnyk the most prominent radon health resort in Ukraine [6].

According to literature sources, radon (radon-220) is the principal therapeutic agent in radon waters. It is a primary isotope of the chemical element with atomic number 86 in the Periodic Table of Dmytro Mendeleev and is a decay product of radium. Radon was discovered in 1900 by physicists E. Rutherford and E. Dorn.

Radon belongs to the group of inert, or so-called noble gases, which are chemically non-reactive. It is widely distributed in nature – present in atmospheric air, mineral and freshwater sources, and all natural environments that contain dispersed radium.

The presence of radioactive elements in the air, water, soil, food, and the human body forms the natural background radiation, which is not only harmless but also essential for the maintenance of normal biological functions. As academician V.I. Vernadskyi wrote in 1935, a deficiency or absence of specific natural radioactive elements in the diet may disrupt metabolic processes and potentially lead to serious health disorders.

During the decay of radon, a series of new radioactive isotopes are formed – namely Radium A, Radium B, and Radium C. These are unstable daughter products that settle on surfaces, forming an active layer where further radioactive decay continues. As previously mentioned, this process results in the release of three types of radiation. Radium A decays by emitting alpha particles and produces a new radioactive atom, Radium B, which further decays by emitting beta particles and gamma rays, leading to the formation of Radium C, C^1, C^{11}, and the stable isotope Radium D (Lead-210). The decay chain of radon and its daughter products can be expressed by the following formula:



Due to their limited penetration ability, alpha and beta particles are absorbed by water, and only those alpha rays located in the immediate vicinity of the body's surface exert a therapeutic effect. Gamma radiation, on the other

hand, is not absorbed by water due to its high penetration capacity. However, the quantity of gamma particles present in radon water is so negligible that they can practically be disregarded.

The influence of natural factors, including radon water, on the human body is considerably more complex than that of pharmacotherapy.

It has been established that the primary active agent in radon therapy is alpha radiation emitted by radon and its short-lived decay products.

The mechanism of ionizing radiation at the molecular and cellular levels has been extensively studied by prominent scientists, including biologists, physiologists, and physicians. According to Professors I.I. Gusarov, P.G. Tsarfis, and A.N. Obrosov, two main types of ionizing effects on cellular molecules are distinguished: direct ionization, which occurs directly in biologically significant macromolecules such as DNA, RNA, and enzymes; indirect ionization, which involves the ionization of water molecules within cells. Irradiation of water leads to the formation of free radicals – potent oxidants such as OH^-, HO_2, H_2O_2, and O_2, as well as the powerful reducing agent atomic hydrogen. These radicals interact with vital biopolymers (e.g., proteins, nucleic acids) and other cellular structures [8-10].

Thus, ionization results in the generation of hydroxyl radicals, hydrogen peroxide, and other strong oxidants within cells, intensifying oxidative processes in the body.

At the Khmilnyk health resort, treatment traditionally involves very low doses of radon. A typical therapeutic course of 15 baths with radon concentrations of 12-15 nCi/L is equivalent to approximately one month of natural background radiation exposure. Compared to the doses used in clinical radiology for oncological treatment, the ionizing radiation doses in radon therapy might initially appear insignificant.

Nevertheless, long-term clinical practice confirms the high efficacy of low-radon-content baths, as demonstrated by both short- and long-term medical observations. Numerous scientific institutes specializing in balneology and physiotherapy also attest that, while the radiation doses administered in radon therapy are minimal, they are sufficient to exert a significant therapeutic effect on the body – not only from a dosimetric perspective but also from a clinical standpoint [11].

Over the past 20-25 years, radiobiological literature has accumulated considerable data on the favorable, stimulatory effects of low doses of ionizing radiation.

Treatment with low-radon-content baths activates the body's antioxidative defense mechanisms by generating compounds rich in "free" electrons. These compounds neutralize molecules with unpaired electrons, thereby restoring normal redox balance and yielding positive clinical outcomes.

Consequently, low-radon baths exhibit marked antioxidant, anti-inflammatory, desensitizing, and analgesic properties. They stimulate the secretion of glucocorticoid hormones from the adrenal cortex, which supports their broad application in the treatment of musculoskeletal disorders, hypertension, atherosclerosis, and other cardiovascular conditions. Additionally, they have a pronounced sedative effect, promote deeper sleep, and reduce pain symptoms. Extensive experience in treating elderly patients at radioactive health resorts demonstrates that radon therapy normalizes overall body tone, enhances work capacity, improves skin elasticity, and restores capillary circulation. Radon water will likely hold a prominent place among future therapeutic and preventive tools in gerontology for combating premature aging [12].

Radon baths, inhalations, and irrigations are employed at the Khmilnyk resort for the treatment of various diseases. Radon penetrates the body through intact skin and the respiratory tract, enters the bloodstream, and is subsequently distributed throughout the organism. The temperature of the water, along with dissolved gases (such as carbon dioxide found in certain Khmilnyk sources), facilitates more rapid absorption of radon and its decay products into bodily tissues.

When radon water is applied externally, all physicochemical stimuli, including those caused by radioactive radiation, primarily affect the skin – a large and significant receptor zone. Under the influence of ionizing radiation, the skin undergoes biophysical and biochemical changes, including alterations in metabolic processes and the formation of various vasoactive substances. These reactions result in changes in skin temperature, tactile sensitivity, and pain perception.

Due to the skin's close connection with internal organs and tissues, the biophysical and biochemical changes triggered by radon baths can influence biological and metabolic processes in different body systems.

Ionizing radiation from radon water has a specific impact on the nervous system. Radon baths most commonly induce inhibitory processes in the central nervous system, reducing pain symptoms and normalizing sleep patterns [6-7].

Clinical observations conducted at several leading medical institutions have confirmed that radon water plays a significant role in maintaining mineral homeostasis within the oral cavity. Therefore, the use of radon water for inhalations and mouth rinses is highly important [13].

The alpha radiation emitted by radon contained in water is believed to be a critical factor in regulating inflammatory processes and maintaining oral homeostasis. Researchers argue that these doses exhibit a phenomenon known as „hormesis" [1, 14-16].

Inhalations and rinsing with radon water in cases of periodontitis have been shown to reduce, and eventually eliminate, advanced inflammatory processes. A clinical trial conducted at the Tskaltubo resort involved 150 participants, including 120 patients and 30 healthy individuals (control group). The results demonstrated that radon water inhalations and rinses significantly contributed to the reduction and eventual resolution of oral inflammation in patients with periodontitis. The authors assert that the unique properties of Tskaltubo mineral water represent a valuable component in the treatment of early-stage periodontal disease [13].

Radon water's pronounced anti-inflammatory, desensitizing, and analgesic effects are widely applied in the treatment of periodontitis of various etiologies. In recent years, radon therapy has also been used in the rehabilitation of patients with maxillofacial injuries, as it promotes accelerated bone callus formation [14, 15].

The therapeutic benefits of radon baths are characterized by their mild action, sedative effect, and a broad range of applicable dosages. Notably, adverse reactions to radon therapy are rare. Radon waters are generally well tolerated by patients and can mitigate the intensity of other, more potent balneotherapeutic factors. This compatibility enables their use in combination with other forms of balneo- and physiotherapy [16-18].

In addition to reflex responses, hormonal entry into cells, dissociation of corticosteroid-protein and other protein complexes, as well as changes in homeostasis have been observed. Simultaneously, there is neurogenic mobilization of the hypothalamic-pituitary-adrenal system and the release of glucocorticoids [19, 20].

Radon baths exert a more pronounced influence on the pituitary-adrenal axis than carbon dioxide-hydrogen sulfide baths. They stimulate the secretion of ACTH and cortisone, activate the glucocorticoid and mineralocorticoid functions of the adrenal cortex, enhance intracellular steroid metabolism, and suppress autoimmune processes. These changes lead to the development of protective and compensatory mechanisms and the restoration of impaired physiological functions, which ultimately determine the therapeutic efficacy of spa treatment.

The effectiveness of radon therapy can also be attributed to the fact that stimulation of the adaptive-defense response continues beyond the treatment period, persisting for several months or even years.

Thus, radon treatment provides a prolonged analgesic, anti-inflammatory, and desensitizing effect in a wide range of conditions [21, 22].

Long-term clinical observations and specialized studies have demonstrated that, when administered in appropriate doses, radon-rich waters act as physiological stimuli. They regulate neurohumoral processes, restore intracellular metabolism, and normalize secretory, enzymatic, and trophic functions [12-14].

While the radon waters at the Khmilnyk resort are used to treat cardiovascular, musculoskeletal, and neurological disorders [22-24], there is no available literature on their application in dental disease treatment. However, at other balneological resorts, radon therapy has been successfully implemented in the management of periodontal diseases [5, 11, 13].

CONCLUSION

The use of radon-rich waters represents a promising method for the treatment of oral diseases. It may enhance the outcomes of standard endodontic disinfection of root canals and periodontal therapy. Further clinical trials are needed to determine the most effective and safe parameters for radon therapy, but current clinical outcomes are highly encouraging. We consider the application of Khmilnyk resort radon waters in dentistry to be a promising direction for future research and clinical practice.

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CONFLICT OF INTEREST

The authors declare no conflict of interest

CORRESPONDING AUTHOR

Iryna Simonova
Vinnytsia National Pirogov Memorial Medical University,
Vinnytsia, Ukraine
e-mail: arinasimonova@gmail.com

ORCID AND CONTRIBUTIONSHIP

Alisa Pachevska: 0000-0002-6041-3814 A B D E
Iryna Simonova: 0000-0002-3501-1813 D F
Olena Popova: 0000-0002-7793-021X A
Tetiana Chugu: 0000-0001-9605-6196 E

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