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SHORT COMMUNICATION

To treat or not to treat? Misbeliefs in spa water disinfection

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Abstract
"Spa waters should be left untreated" says the dogmatic approach. Health authorities of European countries having traditional spa culture strictly control hygienic conditions of bathing in thermal/mineral waters. These regulations are based on the assumption that chemical treatment (disinfection) of such waters impacts their healing effects. However, a slow change of paradigm has been observed in studying the mode of action of spa waters that could help overcome recent attitudes. Organic content or the role of microbiome has also been emphasized by some authors recently. The article deals with possible interactions among aquatic microorganisms and the disinfection and health effects of spa waters and tries to explain the new findings in this field.

Keywords Spa · Balneology · Balneotherapy · Disinfection · Public health

Introduction

Therapeutic bathing in thermal/mineral spa waters has been a part of cultural and medical traditions of several European (especially Central European) countries. Description of the most important healing spas started—mainly in German and Hungarian languages—in the early nineteenth century. Indeed, the first chemical analyses on the inorganic contents of hot springs registered during the reign of Queen Maria Theresia were published in the eighteenth century. Otherwise, the healing effects of waters in the Habsburg Empire were mentioned by G. Werner (in Latin language) as early as in 1549 (Balegová 2008; Kiss 2008). Based on contemporary analytical data, the therapeutic effects have been tried to explain with the significant salt content (Preysz 1892; Hintz 1901).

Curative effects and modes of action

In spite of the expansive research, we are not aware of the exact mode of action of the different medicinal waters even today. Therapeutic effects of thermal/mineral waters have been proven in comparative studies, using treated and placebo groups of patients. Its exact way would be performing a double or triple blind (experimental, interventional) epidemiological study.

The healing effects of balneotherapy in a wide range of disorders are well described; however, the exact mechanism of the healing spa cure is almost completely unknown, at least its relationship to the presence of certain chemical ingredients. Such arguments that "several studies have shown the therapeutic role of mineral elements and other chemical compounds present in thermal waters" (Valeriani et al. 2018) are false and misleading since only the effects of the water (as a whole) have been proven, not of the particular components (Szűcs et al. 1989; Kovács and Bender 2002; Nasermoaddeli and Kagamimori 2005; Varga 2011; Bender et al. 2014). Moreover, the applied methodology is otherwise entirely unsuitable for this purpose (Liang et al. 2015; Varga 2016).

The well-known physical (thermal, mechanical) features affect cardiovascular and locomotor disorders. But the same effects can also be detected using simple hot water due to similar hydrostatic and thermal circumstances.

Chromatographic analyses prove that majority of spa waters contain high amounts of dissolved organic matter (Kárpáti et al. 1999; Varga 2012). The absorption of organics takes place through the skin or, in case of volatiles, by inhalation. The classical approach tries to (unsuccessfully) explain the therapeutic efficiency with the presence of inorganic elements, apart from some exemption (e.g. colloidal sulphur, radon, CO_2). In our previous studies, direct and indirect evidences were collected for an unconventional explanation of the mode of action of spa waters used in prevention and therapy (Varga

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2012a). We also proved for the first time the real health effects of the pure organic fraction of a thermal/mineral water using similar double-blind studies (Szigetvár, South Carpathian Basin) (Hanzel et al. 2018, 2019).

Each medicinal water is an entity

As each thermal/mineral water is a unique, highly sophisticated physico-chemical, biological-ecological system indeed, one should consider this fact both in therapeutical use and water treatment technology (disinfection) of the particular water. Considering inorganic components, the effect of chemical treatments can be more or less calculated. Oxidative reagents may change the valency of inorganic ions or cause precipitation, turbidity, etc. In case of gaseous waters (CO_2, H_2S, etc.), chemical treatment might modify the volatile gas (vapour) phase above the water surface inhaled by the patients. The traditional approach (the dogma) says that inorganic components are responsible for the health effects due to the high concentration of salts in these waters. (*Ad absurdum*, osmotic concentration might also be proposed as the healing factor.) But, if it were true, most treatments would not significantly change the healing potential. The chance of finding organic compounds in the background of health effects is much bigger as they may be biologically active in very low concentrations. On the other hand, concentrations of inorganic ions are much higher within the human body as compared to the spa waters, so uptake (and the possible effect) must be very limited, if any (Varga 2012b).

In the case of diluted organic constituents and colloids, it is more difficult to forecast consequences of the chemical treatment. Formation of chlorination by-products has been the focus of drinking water analytics for decades, identifying—besides the "ordinary" trihalomethanes (chloroform, dichlorobromomethane, dibromochloromethane, etc.)—such compounds like chlorinated hydroxy-furanones (MXs). Their specific toxicity (mutagenicity, carcinogenicity) is also known (IARC 1991, 2004). Precursors of the by-products (e.g. humic substances) are also present in several thermal waters, indeed in considerably higher concentration (brownish artesian waters). However, when taking spas, the routes of exposure are quite different (dermal, inhalation) as compared to drinking water (ingestion). In other words, chlorination should not be applied in this case due to the high risk of formation of mutagenic/carcinogenic by-products.

Effects of disinfection on pathogens

The applied concentrations of chemical disinfectants are much higher in the basins as compared to drinking water. These high concentrations are mainly enough to kill pathogenic bacteria. But other non-bacterial pathogens can be highly resistant to the treatment, such as protozoa. Nowadays, *Cryptosporidium parvum* or *Giardia lamblia* often cause tap water-borne outbreaks (together with some viruses, such as calicivirus) in the developed world (OEK 2006; Castro-Hermida et al. 2015; Moreira and Bondelind 2017). In spa water, protozoal pathogens are also frequent (e.g. *Trichomonas spp*.), showing high chlorine and temperature tolerance (Dessì et al. 2019).

Another possible problem is the cyanobacterial or algal overgrowth in open-air basins. Some toxin-producing species are either thermotolerant or thermophilic. These producers are important participants of the different natural or artificial aquatic ecosystems. The eukaryotic algal species and especially the prokaryotic cyanobacteria (formerly blue-green algae) produce several types of biologically active compounds (e.g. neurotoxins) causing human health problems. Chemical killing of these organisms releases these toxins from the cells, resulting in high aquatic concentrations. Toxin overproduction in natural surface waters may act as toxic exposure to the aquatic vertebrates living in these water bodies. The originally tropical toxin-producing strains of *Cylindrospermopsis raciborskii* or *Synechocystis spp.* can nowadays be isolated in hot waters in Europe as well (Varga 2010, 2012b; Antunes et al. 2015).

Mechanical treatments (microstraining, sand filtration, etc.) may much more effectively eliminate the abovementioned species than chemical ones. Using these, the disadvantageous effects of direct action caused by the organisms themselves or their products could be avoided.

Self-preservation of microbiological quality: spa water as an ecosystem

Some kind of disinfection—either chemical or physical—is highly important to keep the proper hygienic condition of the basins in spas, but another crucial issue is their action on the spa water microbiome composed of non-pathogenic, autochthonous organisms. Their role in the healing action has not been entirely cleared yet. Nevertheless, some authors—also in the balneological literature—suggest their significant human health effects. A microbiome, however, is able to control pathobionts as it was proven in microbial colonization studies (Sevillano et al. 2018). Growth of allochthonous bacteria is limited in spa waters first by abiotic factors, such as temperature, osmotic concentration and starvation, as these waters are oligotrophic, halobic and warm. The unique environment of a particular spa water creates a highly adapted characteristic autochthonous bacterial community. This ecological system can strictly control pathogens' survival, e.g. with biocide production (bacteriocin-like compounds, siderophores, etc.) inhibiting the growth of coliforms or staphylococci (Vachee et al. 1997). This will yield significant advantages for the autochthonous bacterium populations in competence for enlarging their realized niche within the microbiome.

On the other hand, the biofilm of hot water pipes, storage tanks, drains and basin walls should be mentioned as well. This microbial community often serves as a “refuge” for pathogenic microorganisms. *Legionella* and *Mycobacterium* strains can survive and proliferate in several ameba species (such as *Vermamoeba vermiformis*) which are common members of the community. The health risk caused by surviving thermotolerant pathogenic bacteria should also be reduced (Lu et al. 2016).

In oligomineral waters (< 500 mg/L), biotic and abiotic factors can self-preserve the water quality that is subject to modulation by temperature (Sevillano et al. 2018). It should be studied how halobity (higher salt concentrations) can modify this phenomenon, if any.

Dermal microbiological studies suggest that skin microbiome can have a role in influencing infections, inflammatory illnesses, autoimmune disorders, as well as neoplasms (Antonelli and Donelli 2018). In conclusion, the microbiome of spa waters and human skin have public health significance; if disturbing, in our present knowledge, the consequences cannot be assessed.

Conclusions

Some sort of treatment is obviously necessary for maintaining the proper hygienic conditions of spa water during bathing, since microbial burden can elevate the health risk to spa users. Taking into consideration the facts, arguments and speculations mentioned above, only a few alternatives remain on theoretical basis. *Chlorination* and other oxidative chemical treatments may not be supported because of its possible chemical action on the aqueous *organic* compounds with potential healing effects. *Algaecides* kill toxin-producing algae and cyanobacteria (in open-air basins), causing high toxin levels in water. Neither, pathogenic protozoa can be eliminated with them as they tolerate high doses of these chemicals.

Use of *microstrainers* or *sand filters* might be an effective solution. Larger organisms (protozoa, algae) can be filtered out by them, considerably decreasing the risk of infection. Pathogenic bacteria, of course, will get across the filter, but the natural microbiome can control their survival. The biofilm can be effectively eliminated by mechanical cleaning.

The presence of autochthonous organic matter also limits the use of *activated carbon filtration* due to the risk of eliminating these compounds during the process. The effect of *membrane filtration* technology on the aquatic microbiota is the function of the porosity of the membrane.

Another possible physical disinfection technology is *ultraviolet (UV) treatment*. It may be highly effective but is not selective, killing majority of bacteria. Transmittance of the water is highly important in this case because colour and turbidity might considerably modify the effective distance of the irradiation. Another disadvantage is if the organic content of the water shows protective action on the effects of UV light on the microbial DNA (Varga et al. 2015).

The new era of nanoproducts has also affected water treatment technology, e.g. the antimicrobial action of nanosilver particles is well known (Valeriani et al. 2018). Judgement of carbon nanotubes, the most popular nanoproduct, is contradictory because their toxicity is a function of size distribution (Szendi and Varga 2008; Shvedova et al. 2012), and examinations have not applied standardized material (Varga 2017). Therefore, if they are used, they should be separated (such as in packed columns) to avoid human exposure.

In final conclusion, the issue of treating or not treating spa waters will be a subject of debates in the future for a long time. The exact evaluation of different technologies should be based upon exact experimental epidemiological studies comparing the effects of treated and untreated versions of spa water on healing. If the traditional theory was accepted on healing by inorganic content of spa waters, rejection of disinfection would simply be a contradiction in terms.

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