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THERAPEUTIC—CLIMATOLOGY
The Blue Lagoon in Iceland and Psoriasis

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The Reykjanes peninsula in Iceland is the landward extension of the Reykjanes ridge, which in turn is a section of the Mid-Atlantic Ridge, where the two continental plates meet. The peninsula consists mainly of porous volcanic lava, making it permeable to water. Therefore, seawater slowly seeps deep into the aquifers. The geothermal area on the peninsula is called "Svartsengi" (meaning Black Meadows in Icelandic), and it is highly active in that regard. A geothermal power plant was built 1976 in Svartsengi, and a lagoon called the Blue Lagoon was formed close to the plant when warm saline fluid was discharged to the lava field (Fig 1). An employee in the geothermal plant suffering from psoriasis gradually improved when he rubbed the white mud onto his psoriasis plaques while bathing in the comfortably warm lagoon. In the following years, several people tried to cure their skin diseases by bathing in the lagoon, and many of them claimed some beneficial effect from the bathing. In 1986 the government of Iceland appointed a committee to supervise and finance research in order to investigate these claims and to make suggestions as to the use of the area. Three clinical studies have been completed concerning the effect bathing in the lagoon has on psoriasis. The biology of the lagoon has also been studied extensively. We have not found in the literature any biological studies showing the existence of similar biological phenomena. Geothermal brines are widely used in the world for energy production. They often contain toxic substances like heavy metals.[1] This, however, is not the case in the Blue Lagoon. The lagoon and its surroundings have become a popular tourist attraction, with over 100,000 bathers visiting each year in addition to hundreds of patients with skin diseases.

The Blue Lagoon

The Svartsengi power plant draws fluid from wells drilled deep into a geothermal reservoir.[2] The fluid in the reservoir has a temperature of 240°C; it is a mixture of 65% seawater and 35% freshwater. The chemical composition of the saline fluid (brine) deep in the aquifers is, however, altered by interaction with the rock formation. Precipitation of magnesium silicates has reduced the magnesium concentration by a factor of thousand; and dissolution of the rock has raised the concentration of silica (SiO) roughly hundredfold, to approximately 430 mg/kg. The fluid is separated into a steam phase and liquid phase at the surface. The steam phase is used to produce electricity, and the liquid phase is used to warm up freshwater, which in turn is used to heat the houses in the neighboring communities.[3,4] After the fluid has gone through steam separators and heat exchangers, it is discharged into the lava field close to the plant at a rate of 900 m^3/hour and at a temperature of 70°C. Most of the fluid seeps down into the ground through fissures in the lava; but some evaporates, reducing the temperature further; however, enough water remains on the surface to form a pond or lagoon. The average retention time of the salt water in the lagoon is 40 hours. On cooling, the liquid becomes supersaturated with respect to silica, which then precipitates to form a white mud. This seals the fissures in the lava, which has caused the lagoon to spread to its present size, approximately 0.2 km wide, a few kilometers long, with a depth of 1–3 m. The silica concentration in the lagoon water is about 135–140 mg/kg. Some of the silica in the water polymerizes and forms colloidal particles that precipitate on the bottom of the lagoon to form a layer of white soft mud. The liquid in the lagoon has a white-bluish color. These silica particles scatter light intensely, giving the pond its name, The Blue Lagoon.

The Biology of the Lagoon

The chemical composition of the fluid in the lagoon is given in Table 1.[5] The mean temperature in the lagoon is 37°C; but strong winds can cause some fluctuations, while rain and air temperature have only a marginal effect. The mean pH is 7.5, and the salt content is 2.5%.[6] These conditions might provide a favorable environment for a number of organisms; however, this is not so,[6] and the only organisms found are some *cyanobac-*

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0738-081X/96/$32.00
PII S0738-081X(96)00099-6

Figure 1. *The Blue Lagoon, on the Reykjanes peninsula in Iceland.*

teria and a few species of *prokaryotes*. The dominating algae are the blue green algae known as *Leptolyngbya erebi var. thermalis*, belonging to the *Cyanobacteria* species. These algae grow very rapidly in the warm natural surroundings of the lagoon, and they are not found under similar conditions anywhere else in the world.[6] Due to the presence of many visiting bathers and, in addition, the lack of artificial disinfectants, it might be expected that enteric bacteria would be found in the lagoon; however, the only type of bacteria isolated from the lagoon is a Gram-negative rod belonging to the *Roseobacter* species. This bacteria has not yet been typed further as of now. No human coliform bacteria or environmental bacteria have been isolated from the lagoon and do not grow in water from the lagoon. This has also been confirmed by the bacterial monitoring regularly done by the health authorities. No fungi or plants have been found or isolated from the lagoon[6]; however the few organisms that have adapted to this harsh environment can proliferate to high numbers. The reason for the paucity of the flora may involve a number of coexisting factors, such as the high salt content, high temperature, and silica particles, which may increase the sensitivity of the bacteria to UV-light.[7]

Table 1. The chemical composition (mg/kg of fluid) of the fluid in the Blue Lagoon

	7.7
SiO	137
Na	9280
K	1560
Ca	1450
Mg	1.41
CO_2	16.5
SO_4	38.6
H_2S	0.0
Cl	18500
F	0.14
Total dissolved solids	31900 mg/kg fluid

Note: pH = 7.7; Temperature = 24°C.

The Bathing Facilities

A more controlled situation was required for studying the effect bathing has on various diseases; therefore a new bathing facility was developed for this purpose. This facility is situated beside the original lagoon, measuring 25 × 6 m. The bottom of the new lagoon was made even by covering it with 10–20-cm layer of soft silica mud having an abundance of blue green algae.

The temperature was controlled by adjusting the inflow of hot water. No difference was found between the two lagoons regarding salts, silicates, algae, bacteria, or pH.[8]

Effect on Healthy Skin and Psoriasis

Effect of Bathing on Healthy Skin

Like all prolonged hot baths, bathing in this lagoon can make normal skin dry. The silicate particles which precipitate to form a very soft white mud on the bottom are often rubbed on the skin. The abrasive effect of the fine silicate particles make the skin quite soft but at the same time dry. Therefore it is necessary to compensate with emollients after bathing. Should the head be dipped into the water the hair shafts will be covered with silicates. This makes the hair dry and uncontrollable for a few days after bathing. To prevent this bathers are advised to use hair conditioner before immersing their heads in the water. Like all hot baths, prolonged bathing can cause dizziness upon emerging from the water. Alcohol ingestion increases the dizziness.

Effects on Psoriasis, the First Study

Two preliminary studies were conducted on the effect of the bathing in the lagoon on psoriasis.[9,10] Both studies indicated some beneficial effect on psoriasis, which led to more thorough studies. The first serious study was done in 1992. Twenty-eight psoriatics aged 16–75, from different parts of Germany, selected by German dermatologists, were treated in the lagoon.[11] All were treated at the same time. No other skin treatment but application of moisturizers was allowed. Patients with plaque psoriasis or extensive guttate psoriasis of more than one-year duration and with more than 10% of the body surface involved were included. All psoriasis treatments were stopped 4 weeks prior to the study. The patients bathed three times a day for one hour at a time for three weeks. The study was carried out in August–September, to minimize the effect of UV-radiation. They were advised to rub the silica mud on the skin while bathing. A quick shower was taken afterwards. The skin was examined upon arrival, after one, two, and finally after 3 weeks. The severity of the disease was determined by the Psoriasis Area and Severity Index score (PASI) as described by Frederikson and Pettersson[12] and by photographs. Twenty-seven patients, 15 men and 12 women, 25 to 62 years of age (mean age 46.1 years) entered the study. The mean duration of their psoriasis was 25.5 years. All had received psoriasis treatment in the previous year. The mean PASI score fell significantly the first week of treatment, from an average value of 16.1 to 10.8 ($p = 0.01$). At three weeks 5 of the 26 patients had an improvement rate of at least 75%. At that time, psoriasis improved by less than 35% or deteriorated in only 4 of the 26 patients. A few patients described mild stinging, itching or burning during, or shortly after, bathing. Many patients noticed dry skin that was easily remedied with emollients. These results showed that bathing in the Blue Lagoon for only three weeks had a favorable effect on psoriasis, although in some cases it was not sufficient as a single treatment. The algae *Leptolyngbya erebi var. thermalis*, which is found in the lagoon, has been grown in a greenhouse under controlled conditions. It has been freeze-dried and minced and thereafter applied to the lesions of 12 psoriasis patients in lotion and in cream form, but until this time without an effect on psoriasis (unpublished results from the author).

Adding UVB Treatment to the Bathing, the Second Study

From these results, it was evident that further studies were needed. The scaling decreased very rapidly and the lesions became thinner after only two weeks, but thereafter things slowed down. To take advantage of this, adding UVB would be a good choice. Twenty-three psoriasis patients (aged 17–64, with a median age of 46 years; 10 women and 13 men) were treated all at the same time.[13] The mean duration of their psoriasis was 23 years (range 4–43 years). All of them had been treated for psoriasis in the previous year. The control group consisted of 17 Icelandic psoriatics (aged 17–81, with a median age of 43 years; 8 women and 9 men). The psoriasis duration was 21 years (range 2–60 years). All had received psoriasis treatment in the previous year. The treatment schedule in the Blue Lagoon was the same as in the first study, but instead of 3 weeks they were treated for 4 weeks. UVB treatment was given daily 5 times a week at the treatment facility. The control group was treated only with UVB 5 times weekly for 4 weeks with the same UVB source (Philips TL 100W/01) but did not bathe in the lagoon. Moisturizers and emollients were permitted. The patients were evaluated with the PASI score weekly. The PASI values from both studies are shown in Table 2 and Fig 2. The mean PASI score fell significantly in all groups during the study. The difference between the groups was substantial and significant at all points. At four weeks 20 of the 21 patients had an improvement rate of at least 75% in the combination group, but in the UVB group 4 of the 17 patients improved by at least 75%. At the same time

Table 2. Total PASI scoring of psoriasis patients being treated in the Blue lagoon during treatment in the Blue Lagoon alone and from the two studies

Week	*Bathing*	*Bathing + UVB*	*UVB-treatment*
0	16,1	20,3	16,7
1	10,8	13,3	14,4
2	8,5	10,0	12,1
3	8,2	5,6	9,5
4		2,8	6,9

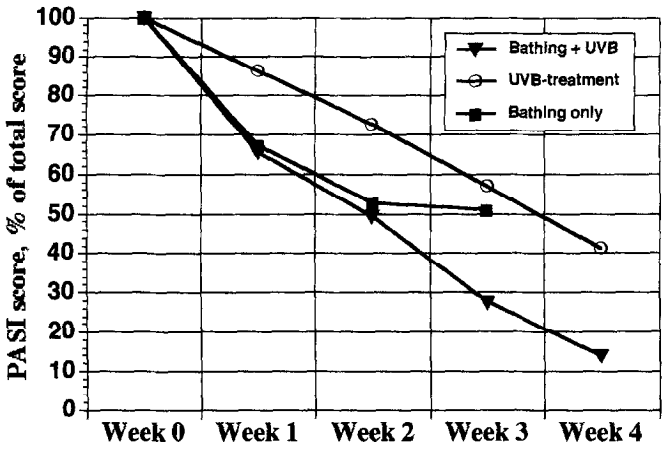

Figure 2. The PASI scoring during treatment in the Blue Lagoon, when combined with UVB and when treatment is given with UVB alone, presented as percentage of the original PASI score.

psoriasis improved by less than 35% or in only 1 of the 21 patients in the combination group, but 12 of the 17 patients in the UVB group. Approximately 50% of those in the combination group reported mild stinging or itching during, or shortly after, bathing. None was withdrawn due to side effects.

Discussion

The first controlled study on the "Blue Lagoon" showed that the bathing has a beneficial effect on psoriasis,[11] but it was not efficient enough when used alone. The second study[13] showed that combination with UVB increased the efficacy of the treatment significantly, and that it was better than UVB alone at all evaluation points. As the scaling decreased very quickly along with rapid thinning of the lesions in the first 2 weeks of bathing in the first study, it was not surprising to see that adding UVB had such a good effect. In the second study the mean PASI score decreased from 20.3 to 2.8, or by 86%, in 4 weeks. It seems evident from our results that bathing in the Blue Lagoon combined with UVB for 4 weeks has a very favorable effect on psoriasis, and this effect is greater than in our UVB control group. The skin type of the two groups was similar, even if the mean PASI score before the treatment started was slightly lower in the control group than the bathing group. This should not have any effect on the results. Natural UV phototherapy and bathing in salt water has been shown to have beneficial effect on psoriasis.[14–16] In the Blue Lagoon, there are some noticeable differences compared to the usual UV-thalassotherapy. The silica brine and the minerals of the Lagoon are different and not found in other areas in the world.[6] The algae *Lyngbya estuaria var. thermalis* is unique in this context and not found under similar conditions anywhere else. The third difference is the period of natural sunlight in Iceland, which is not reliable for treating psoriasis except for a short period of the summer. Hot baths are very common in Iceland as in many other countries, but reports of improvement of psoriasis in hot baths are not well documented. The silica mud has an abrasive effect when rubbed on the psoriasis plaques. This probably causes the early desquamation that is observed;[10] however, the erythema decreased with the desquamation; but it did not increase as might be expected when the scaling decreases and the inflamed lesion becomes evident.[16] In spite of the many treatment modalities available for psoriasis, there is no treatment suitable for all patients. Some patients are generally opposed to the use of drugs, or they may not tolerate the sunlight, so other treatment modalities have to be explored. Psoriasis patients from many countries, seeking alternative treatment modalities and balneotherapy, are already being treated in the Blue Lagoon. In Iceland it is frequently used to treat psoriasis and other disorders of keratinization when other treatments, like UVB, have failed.

Conclusions

Bathing in the Blue Lagoon, with the addition of UVB light, is a useful alternative treatment of psoriasis, and better than UVB treatment given alone.

References

1. Premuzig ET, Lin MS. In: Farmer JG, editor. Geothermal waste treatment biotechnology. International Conference, Heavy Metals in the Environment. CEP Consultants, Edinburgh, UK. 1991;2:95–8.
2. Ragnarsdottir KV, Walter JW, Arnorsson S. Description and interpretation of the composition of fluid and alteration mineralogy in the geothermal system at Svartsengi, Iceland. Geochim Cosmochim Acta 1984;84:1535–53.
3. Bjarnason JO. Svartsengi. Chemical Monitoring 1980–1987. Orkustofnun (National Energy Authority of Iceland). Report OS-88001/JHD-01, 1988:1–98 (In Icelandic with English abstract).
4. Hauksson T. Svartsengi. The chemical composition of thermal ground water and heated freshwater. Orkustofnun (National Energy Authority of Iceland). Report OS-80023/JHD-12, 1980:1–38 (In Icelandic).
5. Bjarnason JO. On the chemical composition of the fluid in the Blue lagoon, Svartsengi. Orkustofnun (National Energy Authority of Iceland). Report JOB-92/03. 1991:1–3 (In Icelandic with English abstract).
6. Petursdottir S, Kristjansson J. The relationship between physical and chemical conditions and low microbial diversity in the Blue lagoon geothermal lake in Iceland. FEMS Microbiology Ecology 1995; In press.
7. Anagnostidis K, Komarek J. Modern approach to the classification system of cyanophytes. 3-Oscillatoriales. Arch Hydrobiol 1988;80:1–4.
8. Kristjánsson JK, Pétursdóttir SK. Studies on the Biological Ecosystem in a new Lagoon adjacent to the Blue Lagoon. A report to the Blue Lagoon committee. (Icelandic) 1992: 27–30.

9. Ingolfsdottir V, Beck HJ, Sigurdsson G, et al. The Effect of Bathing in the Blue Lagoon on the Skin Disease Psoriasis. (Icelandic). The Icelandic Medical J 1987;19:15.
10. Olafsson JH, Gudgeirsson J. The Blue Lagoon and Psoriasis. A Comparative Study. 1991:1–5. Unpublished report. The University of Iceland, Department of Dermatology.
11. Olafsson JH, Sigurgeirsson B, Palsdottir R. The effect bathing in a thermal lagoon in Iceland has on psoriasis. A preliminary study. J Eur Acad Dermatol Venereol 1994;3: 460–4.
12. Frederiksson T, Pettersson U. Severe psoriasis—oral therapy with a new retinoid. Dermatologica 1978;157:238–44.
13. Olafsson JH, Sigurgeirsson B, Palsdottir R. Psoriasis treatment: Bathing in a thermal lagoon combined with UVB, versus UVB-treatment only. Acta Derm-Venereol. (Stockh); In press.
14. Molin L. Climate therapy for Swedish psoriatics on Hvar, Yugoslavia. Acta Derm Venereol (Stockh) 1972;52:155–60.
15. Abels DJ, Kattan-Byron J. Psoriasis treatment at the Dead Sea: A natural selective ultraviolet phototherapy. J Am Acad Dermatol 1985;12:639–43.
16. Snellman E, Lauharanta J, Reunanen A, et al. Effect of heliotherapy on skin and joint symptoms in psoriasis: A 6-month follow-up study. Br J Dermatol 1993;128:172–7.