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Physicochemical Parameters and Their Toxicity Level for Recreational Activity and Plaque Psoriasis Healing Effects of Hot Spring Water of Kharapani, Pokhara, Nepal

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Abstract

The current study involved the determination of water quality parameters, inclusively the dissolved mineral levels, to assess the therapeutic and toxicity states of the hot spring water of Kharapani, Pokhara, Nepal. People have widely used the hot spring for taking baths and soaking in to heal from allergic and fungal ailments, musculoskeletal disorders, arthritis, and different diseases. The high values of alkalinity (700 ppm), total suspended solids with the size of at least 2 µm (TSS) (50 ppm), total dissolved solids (TDS) (650 ppm), turbidity (13 NTU), soluble carbonate (150 ppm), soluble chloride (250 ppm), surface tension (72.98 Dynes cm^{-1}) and total hardness (880 ppm) showed the spring water was unsuitable for drinking, swimming and soaking in. The mineral levels at nitrate (undetectable), iron(II) (<0.3 ppm, undetectable), iron (II) (<0.3 ppm, undetectable), aluminum (III) (<0.3, undetectable) corresponded to safe utility levels, and the high sulphate content at 400 ppm showed that the spring was a sulphate rich hot spring with the properties of healing the fungal ailments and respiratory and musculoskeletal disorders. The hot spring water soakers reported healing and relief from itchy skin allergic rashes, and persisting skin disorders like acne, eczema, psoriasis, and joint pain, while the adverse effects such as skin blister,ooze and crust, dry and inflamed skin, dandruff, etc. were also found common among the prolonged soakers of the hot spring. The study showed an excellent healing effect of hot spring baths against psoriasis but associated with mild skin burn and dandruff. The study showed the necessity of technical moderation and maintenance of the minerals and water quality parameters at the acceptable range for swimming purposes.

Keywords: *Healing Effect; Physicochemical Parameter; Plaque Psoriasis; Recreation; Toxicity Level*

1. Introduction

Water is a significant compound that moderates the climate and has a greater impact on life processes [1]. The hot springs originate when the underground natural sources of water become hot due to a geothermal gradient and come up to the surface of the earth through the fissures of the rocks. The hot springs in Nepal have been distributed in the regions of geologically active tectonic plates [2]. The origin of hot spring water has been reported to involve the stages of meteoric or surface water dripping through the discontinuities in the rocks to the depth at the thrust zones, heat absorption from the crust, and rising up of the hot water from the rock fractures or thrust faults [2].

The levels of dissolved minerals and the respective ions in the spring water are mainly determined by the amount of minerals in the soil and sedimentary rocks, and in addition, the minerals may also get transferred to the spring water from connate water, sewage wastes [1], aquifer, or underground reservoir [3]. The hot spring under study at Kharapani (84.100 longitude and 28.400 latitude) lies at the Seti River bank in the region of live mountains under the influence of active tectonics [2, 4].

The Chemical composition of dissolved minerals and water quality parameters are greatly dependent on the natural source of water, and are also affected by domestic and industrial activities [5]. The deviation in dissolved mineral levels and physicochemical parameters beyond the acceptable range brings about the detrimental effects in health and ecosystem. It is essential to monitor the seasonal variations in composition and

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physicochemical parameters arising from natural processes and human activities, and these water quality levels have to be essentially maintained at the permissible limits for the given purposes [6]. The current study comprised determination of water quality parameters, inclusively the dissolved mineral levels, to look for the therapeutic and toxicity profiles of the hot spring water of Kharapani, Pokhara, Nepal. People have been using the hot spring water for recreational swimming, bathing and soaking in to get healed from allergic and fungal ailments, musculoskeletal disorders, arthritis, and different diseases [2].

Balneotherapy is the treatment of diseases by taking mineral water bath. It is an alternative dermatological treatment model commonly accepted and found as helpful against psoriasis and other skin disorders [7-8]. It could be a significant approach of wellness and spa tourism for the sustainable economic development of the communities [2]. The geochemical studies have shown the presence of high amount of sulphate along with other minerals in the hot springs of Nepal [9-14], and sulphur-rich mineral water bath, as studied in Dead Sea, has been found to be especially effective in the treatment of psoriasis [15]. The sulphur minerals inside the skin have been found to bring about an analgesic influence in pain receptors, immune-inhibition and vasodilation in favour of microcirculation. Daily bath in sulphur-rich water and exposure to the solar UV rays have been found to be effective against psoriasis [16]. The long-term use of skin ointments and topical corticosteroids is limited by their dermatological cumulative toxicity, and balneotherapy is a natural alternative in the treatment of psoriasis [7, 17].

Water quality parameters must be analysed to assess if the properties or constituents do not interfere with the intended utility with the toxicity effects owing to their levels above the standard. The present study comprised the determination of the levels of relevant physicochemical parameters *viz.* pH, temperature, turbidity, soluble carbonate, soluble sulphate, total hardness, nitrate, soluble chloride, iron(II), iron(III), aluminium(III), calcium(II), surface tension, total dissolved solid(TDS), total suspended solid(TSS), and total alkalinity. The toxicity levels of the hot spring water for bathing purposes were analyzed by comparing with the secondary maximum contaminant level (SMCL), Indian Standard Drinking Water specification IS: 10500-2012, and world health organization (WHO) guidelines as standard.

The primary data of healing effects of hot spring water bath (for 20 days with 10 minutes bath twice a day in an interval of six hours) against plaque psoriasis were collected from a fifty-four old male patient with the lesions on his chest area. The study showed a healing effect of hot spring bath against the plaque psoriasis, with the side effects such as mild skin burn, dandruffs, dryness, and inflamed skin. In addition, the reports from the users showed the healing and reliefs from itchy skin rashes, joint pain, and musculoskeletal disorders, but the adverse effects such as inflamed skin, dandruff, mild blisters, crust and ooze etc. were also commonly found in the prolonged users of the hot spring.

2. Experimental

2.1 Materials and Measurements

The water samples from the hot spring water of Kharapani (84.100 longitude and 28.400 latitude), Pokhara, Nepal were collected in clean polypropylene bottles and stored at ambient temperature in laboratory. The apparatus and chemicals of specific uses were pH meter ((HI-98129, HANNA, Romania) calibrated with standard acidic buffer (pH 4.2) and basic buffer (pH 9.0), turbidity meter (HACH2100AN model), sample cells, standard flasks etc. and hexamethylene tetramine, hydrazine sulphate (Fisher-scientific), barium chloride (SD fine), hydrochloric acid (Fisher-scientific), G4 sintered crucible pore size 2 µm, stalagmometer, silver nitrate (SD fine), ethylenediaminetetraacetic acid (EDTA) (Fisher-scientific), Eriochrome Black T (EBT) indicator (Sigma Aldrich), caustic soda, ammonium hydroxide, potassium ferrocyanide (Fisher-scientific), methyl orange, phenolphthalein, etc. The experiments were carried out in research laboratories of the Research Centre for Applied Science and Technology (RECAST), Tribhuvan University, Kirtipur, Kathmandu, Nepal and the Institute of Engineering, Pashchimanchal Campus, Pokhara, Nepal. The data in triplicate were taken in titrimetric and gravimetric analyses. The reports on healing effects of skin diseases were taken from Kharapani hot spring water users. The healing effect of hot spring water bath against psoriasis was periodically assessed by a dermatologist.

2.2 Methods

2.2.1 Determination of Physicochemical Parameters of Water

i. ***pH value:*** Hydrogen ions (pH) potential was measured using a microprocessor pH meter. The pH meter was plugged in and warmed up for 10

minutes. The glass electrode filled with saturated KCl solution was washed with distilled water and cleaned with soft tissue paper. The temperature of water was noted and the same temperature was set in the pH meter. The pH meter was calibrated with the calibrated knob using the standard buffer solutions with a pH of 4.2 and 9.0. The Slope switch adjusted the pH value of each buffer solution during the process of calibration. The selector switch was kept at standby mode while moving and cleansing the electrode, and the switch was turned to pH mode for recording the pH [18].

ii. ***Turbidity:*** Turbidity, a parameter used to identify the optical clarity of the water sample [19], was measured using a turbidity meter. The turbidity meter was switched on 30 minutes before the test. A 4000 NTU solution was prepared by adding 5 mL of hydrazine sulphate solution (obtained by dissolution of 1 g of solute in 100 mL of distilled water) and 5 mL of hexamethylenetetramine solution (obtained by dissolution of 10 g of solute in 100 mL of distilled water) in 90 mL of distilled water. This solution was diluted to get 400 NTU solution, and the turbidity meter with the diluted solution was calibrated to 400 NTU by adjusting the calibration knob. The turbidity meter was calibrated at 0 NTU using distilled water. Then, the turbidity meter reading was taken by inserting the water test sample [20-22].

iii. ***Total hardness***

Total hardness as $CaCO_3$ equivalent of water sample was quantified with minor modifications in the method given by Pal and co-workers [23]. 50 mL of water sample with 10 mL of basic buffer solution and 3 drops of eriochrome black T (EBT) indicator in a flask were titrated against 0.01 M EDTA solution until the wine-red color of the EBT complex turned blue due to liberation of the indicator in the basic medium.

iv. ***Surface tension***

The surface tension of the water sample concerning distilled water as a reference liquid was determined by the drop count in the same volume of both liquids using Traube's stalagmometer [24]. The method involved quantifying lowering of surface tension of distilled water by the sample under study.

v. ***Total dissolved solid (TDS)***

Total dissolved solids as a parameter to show anything else dissolved in water was gravimetrically quantified as the constant weight of the residue obtained after evaporation of water. The steps involved were based on repeatedly boiling water to drive it off, cooling it down, and taking the weight of residue until the constant weight, with facile modifications in the method reported [25].

vi. ***Total suspended solid (TSS)***

Total suspended solid with a size of at least 2 µm was gravimetrically determined with minor alterations in the given laboratory procedures [26-27]. The water sample was filtered under pressure using a pre-weighed G4 sintered crucible with a pore size of 2 µm till dryness. The crucible was left overnight at 40 °C and weighed to get the suspended solid content.

vii. ***Total alkalinity***

viii. Total alkalinity (as mg/L $CaCO_3$) owing to carbonate, bicarbonate, and hydroxide ions in water was measured as phenolphthalein alkalinity in terms of the amount of 0.1 N sulphuric acid required to lower the pH of the water sample to 4.2. The titration process against acid was followed with minor modifications [28].

ix. ***Dissolved minerals level***

The presence of dissolved minerals of basic radical species (Ca^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}) and acid radical species (SO_4^{2-}, CO_3^{2-}, NO_3^-, Cl^-) were detected by the methods of qualitative analysis by wet ways [29]. The complete precipitation of the respective salts followed by filtration under pressure with sintered glass crucible and their recovery in dry state, and the gravimetric quantification steps were used to determine the dissolved mineral levels in the hot spring water sample. The nitrate level was undetectable by the brown ring test.

2.2.2 Study of Toxicity Level of Physicochemical Parameters

The suitability of hot spring water for the purpose of bathing and swimming purposes was assessed by comparing the physicochemical parameters, inclusively the dissolved mineral levels, of the hot spring water with the secondary maximum contaminant level (SMCL), Indian standard drinking water specification IS: 10500-2012, and world health organization (WHO) guidelines as standard.

2.2.3 Study of Healing Effects Against Psoriasis and Other Diseases

The primary data of healing effects of hot spring water bath (for 20 days with 10 minutes bath twice a day in an interval of six hours) against

psoriasis were collected from a fifty-four-year-old male patient with psoriasis on his chest. The healing effects were tested by a dermatologist on day 1, day 10 and day 20. In addition, the reports from the regular users (for 10 minutes every day) with itchy skin rashes, joint pain, and musculoskeletal disorders were taken in the beginning, on days 10 and 20 during the study.

3. Results and Discussion

3.1 Physicochemical Parameters and Their Toxicity Level for Recreational Activity

The physicochemical parameters, inclusively the dissolved mineral levels in the Kharapani hot spring water samples S_1, S_{10}, and S_{20} collected respectively on day 1, day 10, and day 20 of the course of study (from July 10-30, 2023) with the acceptable and standard range for bathing and swimming purposes have been presented in table 1. The acceptable or tolerance ranges of the physicochemical parameters have been based on IS 3328 (1993): Indian standard [30], secondary maximum concentration level (SMCL) fixed by US Environmental Protection Agency [31], world health organization (WHO) guidelines [32]. The individual discussion on the physicochemical parameters with their variation over the twenty days of the study and comparing these parameters with the maximum tolerance shown in the bar graphical distribution in Figure 1 convey the status of hot spring water usability for bathing and recreational activities.

Table 1: The physicochemical parameters of the Kharapani hot spring water with their acceptable ranges for bathing and swimming purposes

Physicochemical parameters	**Sample S_1 (Day 1)**	**Sample S_{10} (Day 10)**	**Sample S_{20} (Day 30)**	**Acceptable ranges and references**
Temperature (°C)	49	50	49	-
pH	8.3	8.0	8.2	7-8 [32]
Turbidity (NTU)	13	15	13	5-10 [30, 32]
Soluble sulphate (ppm)	400	456	446	250-400 [31, 32]
Soluble carbonate (ppm)	150	150	152	SMCL 10-40 [31]
Total hardness (ppm)	880	889	874	500 [32]
Nitrate (ppm)	undetectable	undetectable	undetectable	<5 [32]
Soluble chloride (ppm)	250	252	245	250-500 [30, 32]
Iron(II) (ppm)	<0.3, undetectable	<0.3, undetectable	<0.3, undetectable	<0.3 [30, 31, 32]
Iron(III) (ppm)	<0.3, undetectable	<0.3, undetectable	<0.3, undetectable	<0.3 [30, 31, 32]
Aluminum(III) (ppm)	<0.3, undetectable	<0.3, undetectable	<0.3, undetectable	0.05-0.2, Ref. 30, 31
Calcium(II) (ppm)	354	360	348	75 [32]
Surface tension (Dynes cm^{-1})	72.98	72.26	72.40	70.40 for distilled water at 25 °C
TDS (ppm)	650	665	638	<500 [30, 31]
TSS (ppm) Pore size 2 µm	50	56	50	<10 for drinking, <30 for swimming [30, 32]
Total alkalinity (ppm)	700	700	706	<500 [30]

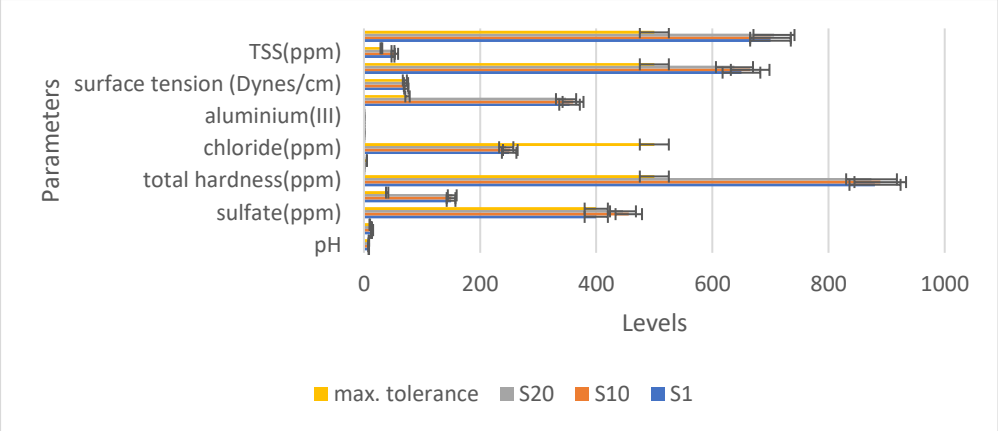

Figure 1: Variation of water quality parameters and their comparison with maximum tolerance level (with % error bars)

i. ***Temperature***

The temperature of the hot spring water samples was 49-50 °C at the collection time (10 AM, July 10, 20, and 30, 2023, cloudy weather with atmospheric temperature at 25-28 °C). The external factors such as industrial effluents affecting the spring water temperature were minimal [33]. However, the high temperature in the spring water is associated with geothermal and hydrogeological factors such as geothermal reservoirs and their permeable pathways to the surfaces [34].

ii. ***The pH and alkalinity***

The pH with variations from 8 to 8.3 lies within the tolerance range [30, 32], but a better pH range for a swimming pool has been suggested as 7.2 to 8, especially for regular swimmers [35]. The observed pH range is indicative of alkalinity strength, the hot spring water may not bring a corrosive effect on skin as this is possible only below a pH of 6.5, and the scaling effect is also minimal as this takes place above 8.5 pH value [6]. However, the high alkalinity values indicate more bicarbonate and soluble carbonate levels, and such alkaline water (pH 9) has been reported to reduce sebum on the surface of the epidermis, lower the skin eruption, and impart an anti-inflammatory effect [36, 37]. The swimming pool water alkalinity tolerance level is < 500 ppm [30], but the Kharapani hot spring water alkalinity (700-706 ppm) is higher than the recommended level.

iii. ***Turbidity***

Turbidity refers to cloudiness that appears due to interference with light transmittance by fine and colloidal particles suspended in the liquid. It indicates the amount of suspended solids such as clay, organic matter, algae, silt etc [6]. The turbidity of the water samples (13-15 NTU) was found higher than the accepted level (5-10 NTU). This may be indicative of a higher level of partially soluble minerals in the spring water.

iv. ***Total hardness and calcium(II)***

The hardness of water shows mainly the concentration of calcium and magnesium ions that have a higher tendency to combine with anions to give stable salts [38]. A greater hardness of groundwater is attributed to minerals such as limestone which supplies calcium ions, and dolomite which supplies calcium and magnesium ions to water that percolates through these minerals [39]. The higher level of calcium ions (348-360 ppm) corresponds to higher hardness in the samples. The greater hardness of the samples (874-889 ppm) was indicative of the higher concentration of calcium and magnesium ions in union with bicarbonate and chloride ions in water. These minerals react with soap to form scum that may cause clogging of skin pores and the disorders such as dry skin, damaged hair, dandruff and eczema [40].

v. ***Surface tension***

Surface tension refers to the intricate property of a liquid that is expressed as a force acting perpendicularly per unit length of the liquid surface from the interior part of the liquid. It can be expressed as surface-free energy [41]. Surface tension has been reported to be affected by variables such as dissolved constituents, impurities, temperature, and time of measurement [42, 43], and the higher surface tension could have been attributed to these conditions.

vi. ***Total dissolved solid (TDS)***

Total dissolved solid (TDS) in water usually shows the concentration of mineral ions [44, 45] and contamination by anthropogenic activities such as animal grazing, agricultural run-offs and chemical fertilizers [46]. Water from natural springs and ground well sources contain high dissolved mineral concentrations [47]. The TDS in the hot spring water samples above the standard shows the necessity of regulating the discharge of contaminants near the hot spring [30-32]. The high TDS in the bath water may cause skin breakouts, dry skin and eczema [32].

vii. ***Total suspended solid (TSS)***

Total suspended solids (TSS) in water refers to the insoluble particles of pollutant matter such as organic waste and heavy metals. These toxic pollutants in water bring about the deterioration in the natural ecology and harmful effects on living beings [48-50]. The current study involved the determination of TSS with a particle size of at least 2 µm, and the TSS level (50-56 ppm) was found to be more than acceptable level (<30 for swimming) [30, 32]. The hazardous suspended solids cause itching, skin inflammation and different disorders [32]. The results indicate the necessity of maintaining proper hygiene with minimal disposal of pollutants in the hot spring water.

viii. ***Dissolved minerals***

The dissolved mineral calcium(II) in combination with chloride, sulphate, and bicarbonate contributes towards the major constituents of the total hardness of water. The contributing ions of alkalinity are carbonate and bicarbonate. The observed levels of these mineral ions are higher in agreement with high values of hardness and alkalinity. The undetectable mineral level of nitrate ions shows no contamination of inorganic nitrate compounds or nitrogen fertilizers. The undetectable levels of aluminum (III), iron (II), and iron(III) are indicators of no anthropogenic discharge of metallic materials and very low supply of these metal ions from the natural rock and soil environment of the spring water.

3.2 ***Plaque Psoriasis Healing Effects of Hot Spring Water***

The skin lesions under the study were characterized by distinctly demarcated, scaly and erythematous, itchy, painful, irregular and symmetric plaques, and the fine bleeding points were observable upon the scraping of xerotic scales. So, the lesions were recognized as plaque psoriasis [51]. Further, the psoriasis lesions were diagnosed by a dermatologist. The balneotherapy treatment with a hot spring bath for 20 days (with 10 minutes of soaking in the spring water twice a day for an interval of six hours) showed progressive healing of the plaque psoriasis lesions as shown in Figure 2a, b & C.

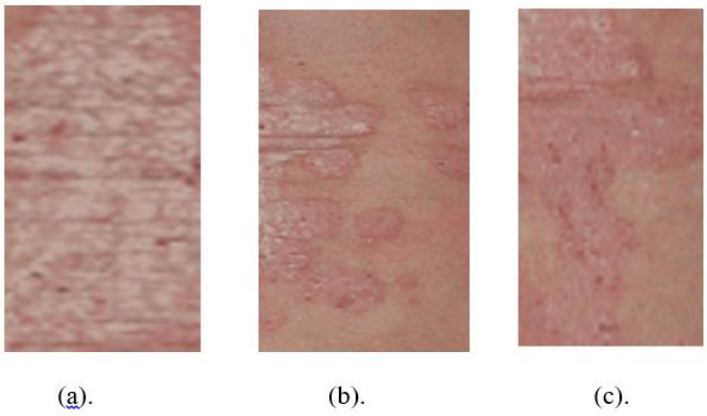

Figure 2: Progressive healing of plaque psoriasis lesions on (a). Day 1 (b). Day 10 and (C). Day 20 of the hot spring water bath

In addition to the visual observation of conspicuous partial healing of the lesions, the progress on recovery was also assessed by the subjective symptoms and the patient's personal experience towards the relief of pain and lowering of itchiness. Further, the study showed a healing effect with side effects such as dryness and inflammation of the skin, mild skin burns, and dandruff. Other hot spring swimmers reported healing and relief from itchy skin rashes, joint pain, and musculoskeletal disorders. Still, side effects such as skin inflammation, dandruff, and mild blisters were also observed among the prolonged swimmers in the hot spring.

4. Conclusion

The study showed that the physicochemical parameters pH, total alkalinity, turbidity, hardness, TDS, TSS and surface tension of the hot spring water were above the permissible range for recreational and swimming activities. The spring was found to have excess levels of soluble carbonate and calcium(II), moderately high sulphate and chloride minerals as the factors contributing towards hardness, alkalinity and TDS. The nitrate, aluminum (III), and iron (II & III) levels were found to be normal and non-interfering. The higher surface tension and TSS values were indicators of deterioration in the natural ecology and the unsuitability of the spring water for recreational activity. The study revealed the necessity of stopping the pollution by the upstream surface run-offs. The spring cleanliness through proper drainage, filtration of suspended impurities, circulation system to replace the old water flow, and protection of the geological environment, etc. must be maintained by municipal regulation. The hot spring water bath imparts a conspicuous time-dependent healing effect against plaque psoriasis. The healing effects and relief from itchy skin rashes, joint pain, and musculoskeletal disorders were also reported. Still, the side effects such as dryness and inflammation of the skin, mild skin burn and dandruff were commonly observed among the prolonged users of the hot spring.

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Conflict of interest

The authors have no conflicts of interest to declare regarding the publication of this article.

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