The Dead Sea Mud and Salt: A Review of Its Characterization, Contaminants, and Beneficial Effects

IOP Conf. Series: Materials Science and Engineering **305** (2018) 012003 doi:10.1088/1757-899X/305/1/012003

The Dead Sea Mud and Salt: A Review of Its Characterization, Contaminants, and Beneficial Effects

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Abstract The Dead Sea has been known for its therapeutic and cosmetic properties. The unique climatic conditions in the Dead Sea area make it a renowned site worldwide for the field of climatotherapy, which is a natural approach for the provision of medications for many human diseases including unusual exclusive salt composition of the water, a special natural mud, thermal mineral springs, solar irradiation, oxygen-rich and bromine-rich haze. This review focuses on the physical, chemical, and biological characteristics of the Dead Sea mud and salts, in addition to their contaminants, allowing this review to serve as a guide to interested researchers to their risks and the importance of treatment. Beneficial effects of Dead Sea mud and salts are discussed in terms of therapy and cosmetics. Additional benefits of both Dead Sea mud and salts are also discussed, such as antimicrobial action of the mud in relation to its therapeutic properties, and the potency of mud and salts to be a good medium for the growth of a halophilic unicellular algae, used for the commercial production of β-carotene; Dunaliella.

Keywords: Dead Sea mud, Dead Sea salts, Therapeutic properties, Cosmetic properties, Climatotherapy

1. Introduction:

The Dead Sea (DS), the lowest geographical location on earth, is considered to be the biggest natural saline reserve in the world. The sea's salt content, approximated to be (348 g/L), makes its salinity 10 times the typical salinity of oceans [1]. The Dead Sea is located in the Syrian - East African rift valley and surrounded by the Moab Mountains to the east and the Judean Mountains to the West [2,3].

The atmosphere of the DS is rich in oxygen by 10% more than any other typical sea, which might be attributed to its exceptionally low altitude [4], approximated to be 396 meter below sea level [5]. However, the unparalleled salinity is not the only extraordinary characteristic of the DS, as it contains natural thermo-mineral waters, mineral muds, higher bromine content in the air, as well as high selenium content of local drinking water [6].

Due to the rarity of its atmospheric and climatic features, the DS is considered to be an attractive destination for patients who seek a medication for diseases such as psoriasis [3,7], rheumatic disorders [6, 8], and atopic dermatitis [6]. Treatments are mainly based on: (a) bathing in the DS water while exposing the skin to filtered UV radiation, and (b) mud packs prepared from highly saline black mineral mud that is rich in sulfide, which is found abundantly in the area [8, 9].

Furthermore, the distinctive combination of photobiologic characteristics and elemental properties of the DS gives this area the uniqueness that cannot be found elsewhere. The sunburn spectrum of ultraviolet light (UV) is very weak at the DS [10], because of a continuous mist that is established above water level. This mist results from remarkably high rates of water

evaporation estimated at $2*10^9$ m^3/year. Consequently, most UVB sun-burning rays (290-320nm) are filtered out, which allows a better exposure to the longer wavelength UVB and penetrating natural UVA rays (320-400nm) [11]. The sun and the sea are two factors that have played a main role in the management of many different medical illnesses, especially dermatological diseases [12, 13].

Besides the essential health purposes that the DS can serve, cosmetics is a field that has not been overlooked. Over the past years, many units of DS related cosmetic products have been marketed. These natural beauty products are made from natural pure components and extracts in addition to the DS mud, salts and minerals which are extracted directly from the DS area.

Despite the great benefits associated with the dead sea products, it is important to note that risks or side effects may be associated with these products dues to the possibility of the presence of contaminants such as heavy metals, microorganisms, or radioactive elements. We believe that treatment is required to avoid risks of such contaminants, and it is considered a challenge to find a suitable technique to detect the presence of those contaminants and to remove them without affecting the benefit of DS products. Yet, barely any research is found in the literature concerning the treatment of the DS products. Only lately one study was published by our group, [14], in which we assessed some heavy metals in the DS mud and optimized a treatment methodology using chelating agent.

On these basis, this review aims to provide details regarding the characteristic of the DS natural mud and salts, as well as their contaminants. Additionally, it aims to give an overview of their beneficial effects. This work might be a valuable reference that guides interested researchers into the importance of treatment of DS mud and salts, as it is an area that is under-studied in current research, especially that the DS products are currently considered a largely emerging industry in Jordan. The wide variety of these products and the versatile importation worldwide necessitate considering a high standard of their purity and a minimum harmfulness to the end user.

2. Dead Sea Mud:

The DS mud is derived from older sediments or the red-brown soils that are usually swept back into the sea during the winter time [15]. It is well known for its therapeutic properties for skin diseases, as it contains a unique composition of minerals.

Khlaifat *et al*., 2010 focused on studying the chemical and physical properties of DS mud samples collected from three different locations (north, middle, and south collection points). The results indicated that the chemical analysis of mud samples has revealed high CaO concentrations (20.61 - 27.86 wt.%), high CO_2 concentrations (15.47 - 25.01 wt.%) and high SiO_2 concentrations (23.74 - 33.66 wt.%) while the total soluble salts (T.S.S), chlorides and sulfates were 10.19, 4.48 and 0.056 wt.% respectively. Regarding physical properties, it was found that in individual grain size characteristic, most the samples are classified as fine grained, the liquid limit values range from 7 to 23, plasticity index range from 5 to 18, and the specific gravity ranges from 2.257 to 2.386. The variation in DS mud samples prosperities depends on the collection locations and this due to the different processes taking place at the different location [16]. Physical properties of DS mud were also studied by Arab and Alshikh, 2012 who found that the liquid limit value was about 44, plasticity index was about 15 and Plastic limit value was about 29 [17].

3. Dead Sea Salts:

The Dead Sea is the most hypersaline waterbody on earth. Its water has pH value of about 6 and contains about 348 g/L mineral salts [1].
When compared with other oceans and seas, the DS is more abundant in many elements, including chloride (212.4 g/l), magnesium (40.65 g/l), sodium (39.15 g/l), calcium (16.86 g/l), potassium (7.26 g/l), and bromide (5.12 g/l). Conversely, it has a lower concentration of sulfate (0.47 g/l), and bicarbonate (0.22 g/l) [2, 18-20].
In the period between 1959 and 1960, the DS had approximately 290 g in total of dissolved salts per liter. However, with time and due to high evaporation rates, water level decreased dramatically. This led to an increase in the salinity to become approximately 340 g/L in 1979 [21]. Since that time, the overall concentration of salts in DS has not changed significantly, with a value of 348 g/L in 2010 [1]. Despite the continuing decrease in water level and the supersaturation of DS with salts, especially sodium chloride (NaCl), the actual concentration of sodium (Na) has decreased due to the huge quantities of halite (rock salt) that precipitated in the bottom of the DS [22-24]. However, the concentrations of other soluble ions increased significantly, such as magnesium; the most prevalent divalent cation, leading to a belief that the DS is principally a magnesium chloride lake [25].
Furthermore, the DS minerals consist of specific elements that participate in regulatory activities of skin metabolism. Magnesium, potassium, and calcium are the most substantial elements present. It was proved that magnesium (Mg^{+2}) is a co-factor for phosphate transferring enzymes, and participates in balancing the regulation between cyclic adenosine monophosphate (c-AMP) and cyclic guanosine monophosphate (c-GMP). Potassium (K+) promotes CO_2 transport, and calcium is the inducer of lamellar secretion and the regulator of cell membrane permeability [26, 27].
It is also important to note that minerals have the capability in restoring moisture and enhancing intracellular water capacity due to their hygroscopic characteristics. Therefore, if absorbed into skin, they can contribute to the skin's natural moisturizing factor (NMF) [28].

4. Contaminants of Dead Sea mud and salts:

Contamination in the DS mud and salts represents a potential risk to the local population and for cosmetics producers who usually use the black sea mud which they claim to impart a relaxed feeling, nourishing the skin, activating the circulatory system and ease rheumatic discomfort [8, 29, 30]. This section will provide an overview of the most important contamination sources and how they can influence the current uses of the DS mud and salts.

4.1. Heavy metals:

Heavy metals comprise a well-known group of inorganic chemical hazards. Furthermore, it was proved that chromium (Cr), cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), mercury (Hg), nickel (Ni), and arsenic (As) are usually found at contaminated areas [31]. The abnormal accumulation of heavy metals in soils of both urban and rural environments comes because of a slow occurring geochemical cycle of heavy metals, therefore causing risks to human, animals, plants, and other ecosystems [32] .
Comparing the DS water and mud for the presence of heavy metals, DS water is found to be rich in heavy metals while the mud is found to contain very low levels of trace elements. Studies in literature show that it is more appropriate for heavy metals is to join to soluble salts in the acidic water rather than precipitating in mud [33]. These studies also revealed that the black mud usually has low content of heavy metals, thus low toxicity. Moreover, the results of sequential

extraction showed that Ni and Co were found in the carbonate fraction, Mn was joined up with iron oxide, and the residual phase contained Cr, Cu, Fe and Pb.

Abdel-Fattah and Pingitore, 2009, investigated the composition of the DS mud samples (from 3 spots in the Jordanian side of the DS) and found that toxic heavy metals present in concentrations below standard levels. In the same investigation, 16 commercial DS mud-based and mud-enhanced cosmetic products, which were marketed in Jordan and in the USA, were analyzed. Generally, cosmetic products have diluted minerals, except for cadmium, which was found in levels exceeding those in the plain DS mud samples in several of the commercial muds and in one facial mask. It was concluded that there is risk regarding mineral toxicity from DS mud or DS mud-based products [34].

Similarly, Khlaifat *et al*., 2010, determined physical and chemical properties of 24 different DS mud samples collected from three different locations on the eastern seaside of the DS. Their results showed that the mud samples were rich in some elements (Barium, Vanadium, Strontium, lead, cadmium and zinc), although there were significant differences between mud samples collected from different locations, there was no strong correlation between the location and the elements content. The most abundant element was strontium followed by barium, vanadium and lead, with the concentration ranges of 410–810, 155–380 , 209–264 , 108–114 part per million (ppm) respectively [16].

Arab and Alshikh, 2012, conducted another investigation to measure the concentrations of trace elements in DS mud using Atomic Absorption Spectra and Polargraph instrument. The results of atomic absorption spectra approved that iron has the highest concentration 964.036 ppm, followed by Selenium 6.4 ppm, zinc 5.72 ppm, and lead 3.64 ppm. On other hand, Copper concentration were very low, with a value of 0.58 ppm, while Cadmium concentration was as low as 0 ppm. Similar results were obtained by using polagraph instrumental, confirming their validity [17].

Such studies that reveal the presence of heavy metals caused the development of numerous processes that were developed to remove high concentrations of dissolved heavy metals. These include, but not limited to, ion exchange, oxidation-reduction, precipitation-filtration, membrane separation, solvent extraction, as well as reverse osmosis [35, 36].

Moreover, much attention has been paid to applying biotechnological methods for controlling and removing heavy metal pollution in recent years. Despite this, alternative processes are available, including biosorption (metals sequestering), which utilizes various natural materials derived from bacteria, fungi, yeast, and algae. These biosorbents can decrease the concentration of dissolved heavy metal from part per million (ppm) to part per billion (ppb) level. This technique is considered to be a natural and an applicable technique to treat waste water with both low and high levels of metals due to the potency of biosorbents to sequester metal ions from diluted solutions [37].

4.2. Microorganisms:

The domestic microbial flora of DS mainly involves a limited number of microorganisms which can be divided into two main groups, obligate halophilic bacterial strains (such as Sarcina-like coccus *Halobacterium sp*.) and facultative halophytic algae (such as Dunaliella). The recorded number of microorganisms' species at DS is reported to be very low, whereas the total biomass is relatively high (about 10^5 bacteria/ml and 10^4 algal cells/ml). Two different antagonistic mechanisms are reported at DS, which are developed by both bacteria and algae. The bacteria adjust their internal inorganic ionic strength to that of the medium. On the other hand, the algae

developing a mechanism for salts exclusion from the intracellular fluid using osmotic regulation and glycerol [38].
In addition to bacteria and algae, six different genera of fungi were isolated from DS water, suggesting that the DS water may have health hazard. This was concluded from a study conducted by Mbata, 2008. The study involved 100 water samples collected from DS, 68% of these samples showed fungi contamination. The recovered fungi genera included *Aspergillus versicolor* (44.1%), *Chactomium globosum* (20.6%), *Hortaea werneckii* (13.2%), *Aureobasidium pullulans* (11.8%), *Eurotium spp* (8.8%) and *Gymnascella spp* (1.5%). It was concluded that *Aspergillus versicolor* and *Chactomium globosum* are the most prevalent genera [39].
During the twentieth century, biological monitoring for the microorganisms in the DS revealed the presence of pathogenic non-halophilic *Sporohalobacter lortetii* [40]. *Haloferax volcanii*, *Haloarcula marismortui*, *Halorubrum sodomense, Halobaculum gomorrense* [1]. These are present alongside the different types of cyanobacteria, and several Dunaliella species which could grow in DS water such as *Dunaliella viridis* and *Dunaliella parva* [41, 42]. On the other hand, protozoa were not found at all due to the extreme salinity of the water [1].
Throughout the years, there was a negative balance between DS water level and salinity. On one hand, this created an environment for salt-tolerant algal genus. On the other hand, Dunaliella cells cannot survive in DS water due to this negative balance [43].
Recent studies in the literature directed their focus towards the metabolic potentials of halophilic archaea and bacteria, as well as the possibilities to use them in bioremediation applications [44]. Other studies focused on the potential of halophilic bacteria in biotechnological applications such as PHA production, extracellular protease production, halocin production and bioemulsifier production [45].

5. Beneficial effects of Dead Sea products:

5.1. Therapy

Since ancient times, DS mud has been used for treatment of various skin disorders, as it contains high concentration of minerals, allowing it to retain heat for hours and be highly absorbent [6, 46-48]. Thus, DS mud can stimulate blood circulation, enhance lymphatic flow, cleanse the skin from dead cells, and help in wounds healing and soothing irritation [47, 49].
DS salt solution, which is rich in magnesium, has many therapeutic uses. It was proved that bathing in this salt solution improves skin hydration, enhances functions of skin barriers, and reduces dry skin inflammation [50]. In addition to magnesium, other elements are present. This includes zinc, which plays a role in wound healing and epidermal regeneration [51].
Wound healing potential of natural and compounded facial masks prepared from DS black mud was tested on wounds created on the dorsum region of BALB/c mice by Abu-Al-Basal, 2012. Test mice were treated once a day for two consecutive days with 0.1% natural or compounded DS black mud or 0.2% nitrofurazone, in addition to untreated mice group used as a control. Wound healing was evaluated at day 3, 7, 14 and 21 from wounding day, by measuring weight and percentage of tissue granulation. The results showed that wound healing process (which includes wound contraction, granulation, epithelialization, angiogenesis, and collagen deposition) were accelerated when DS black mud was used compared with nitrofurazone, with note that compounded facial masks have healing property greater than that of natural black mud [52].

In addition, other medicinal properties of DS have been known for thousands of years. The major diseases that are frequently treated by DS balneotherapy are musculoskeletal and dermatologic diseases, such as rheumatoid arthritis, osteoarthritis, ankylosing spondylitis, low back pain, psoriasis, atopic dermatitis, and other joint diseases [2, 53-54]. This success in treatment comes due to the high mineral content in the DS [1, 10], and to the UVB radiation which is an attenuated radiation that leads to elevate the concentration of atmospheric oxygen and other relaxation factor [29].

Furthermore, Psoriasis is considered to be one of the most important diseases that are often treated by DS spa therapy. Several studies have proved that DS mud is efficient in Psoriasis treatment [2, 12, 29, 55-66], in addition to DS salt which also help in Psoriasis treatment due to the effects of magnesium bromide or magnesium chloride [19, 67, 68].

Psoriasis is highly affected by exposure to the sun, which acts as the main factor in the treatment process. However, the effect of solar radiation could be enhanced by bathing in DS water. This was concluded from a study conducted by Even-Paz *et al*., 1996, when eighty-one patients with Psoriasis (plaque type) underwent treatment at the DS for four weeks. They were divided into three groups: DS water bathing only; sun exposure only; and sun exposure combined with DS water bathing. Psoriasis area and severity index (PASI) was used to measure the reduction percentage in the psoriasis area, which was scored 28.4% for the first group (when patients only bathed in DS water), 72.8% for the second group (when patients exposed only to sunbathing), and 83.4% for the third group (for patients who bathed in DS water and exposed to sunbathing). This study was also found that there were no significant seasonal differences in the results related to the sun-exposure groups [69].

Similarly, Elkayam *et al.*, 2000 used balenotherapy (treatment of diseases by bathing) and phototherapy (treatment of diseases by radiation) to treat forty-two psoriatic arthritis patients at DS area. From these forty-two, twenty-three patients were receiving additional treatment with mud packs and sulfur baths, while nineteen patients did not receive any type of additional treatment. The results revealed that both groups showed significant improvement in right and left grip, patient self assessment, morning stiffness and axial skeleton movements. Over the time, better results were observed in the group that received mud packs and sulfur baths [70].

Furthermore, Fibromyalgia (musculoskeletal disorder) is another disease that can be treated with balneotherapy at the DS. This has been extensively studied by Sukenik *et al*., 2001 when twenty eight patients with fibromyalgia and psoriatic arthritis were treated with balneotherapy at the DS area, and were followed-up by assessment of several clinical indices such as number of active joints, duration of morning stiffness, a point count of eighteen fibrositic tender points, and determination of tenderness threshold in nine fibrositic and in four control points using a dolorimeter. The results revealed a reduction in both number of active joints and number of tender points which was reduced from 18.4 to 9 for active joints, and from 12.6 to 7.1 for tender points in men, while there was also a decrease from 13.1 to 7.5 for tender points in women [71].

A clinical trial optimized the use of combined mud bath treatment to treat fibromyalgia patients who have a poor response to drugs. This study was performed by Fioravanti *et al*., 2007. Forty patients were submitted to a cycle of twelve mud packs and thermal baths, while forty other patients were employed as a control group. Then, patients were evaluated by FIQ (fibromyalgia impact questionnaire), tender points count, VAS (visual analogue scale) for minor symptoms, HAQ (health assessment questionnaire), and AIMSI (arthritis impact measurement scales). After sixteen weeks of treatment, the results proved the efficiency of mud bath treatment of all evaluation parameters [72].

DS spa has a therapeutic potential in atopic dermatitis, which was evidenced by Shani *et al*., 1997 and Giryes *et al.,* 1997 when they reported 90% clearance of lesions in a study sample (n=1408) after 4-6 weeks of therapy at the DS area [65, 66].
Mud packs and sulfur baths (each separate or in combination) can be used as an effective treatment for rheumatoid arthritis patients, which was evidenced through randomized controlled trials for two weeks therapy at the DS area [8]. On the other hand, employment of mud compresses on the hands of patients suffered from swollen and tender joints could relives pain [73].
Osteoarthritis is a joint disease that affects the articular cartilage. This may cause bone to grow at the margins of joints, and leads to changes in the synovial membrane. Over the time, joints loss its normal motion which later causes swollen and pain [30]. Osteoarthritis is one of arthritis and occurs equally in men and women, and could be treated by pharmacological mediations, physiotherapy treatments or balneotherapy.
Flusser *et al.,* 2002 reported a comparison between compresses prepared from unaltered DS mud and mineral-poor DS mud. Fifty-eight knee osteoarthritis patients were selected randomly and treated as follow: forty patients were treated with compresses prepared from unaltered DS mud, and eighteen patients were treated with compresses prepared from mineral-poor DS mud. Using Lequesne index, the results indicated that knee pain can be reduced. Data suggested a better outcome for patients treated with unaltered DS mud packs compared to those treated with mineral-poor mud packs [74].
Ma'or *et. al.,* 2003 prepared compresses, bandages, warps, and dressings from small magnetic particles added to Nano-powders of DS salts. Magnetic particles were absorbed to epidermal layer of skin and provided a magnetic field that helps in pain relief when those compresses, bandages, warps, or dressings placed in a direct contact with the patient's skin, above painful region [75].
Additionally, it is important to finally note that one of the main therapeutic uses of the DS is the role of DS minerals in anti-aging. The effect of minerals on keratinocytes cultures and human skin were investigated by Soroka *et al.,* 2008. The obtained results revealed that DS minerals can decrease the expression of some aging markers, enhance proliferation, stimulate mitochondrial activity and limit apoptotic damage after UVB irradiation [76].

5.2. Cosmetics

Cosmetics products that contain either DS mud or salts have been used for long years and many companies offer product lines that feature DS minerals. Such products include bath salts, mineral mud soaps, mineral peeling soaps, hand and body lotions, eye cream, cleansing mud masks, body butter, body exfoliates, acne lotions, sunscreens, lightening cream with sun protection factor (SPF), collagen firming creams with SPF, firming night creams, scalp masks, antidandruff and numerous other shampoos, and products that have an 'anti-wrinkle effect'.
DS water is widely used in cosmetics, because of its moisturizing and smoothing properties. This is ultimately due to the high magnesium content that enhances water retaining in the skin [77, 78], and $CaCl_2$ which provides the DS water its oily feel [2, 18-20].
To prove the efficiency of DS water in skin smoothing, Ma'or et al., 1997 tested three liquid gels prepared from DS products. Those gels were applied on twenty women twice daily over four weeks. Computer-aided laser profilometry, in accordance with standard testDIN 4768 ff (German Institute of Standardisation (Deutsches Institut für Normung)) were used to determine skin roughness parameter for women at the beginning and at the end of the study. By the end of

this study, it was found that skin roughness parameter could be reduced by 40.7% when using liquid gel containing 1% of a DS mineral solution, 27.8% when using liquid gel without mineral additives, and 10.4% when using control gel without anti-wrinkle agents or the additives [77].
Zeng et. al., 2004 prepared a skin caring product that contained DS mud and salts, hydrolyzing collagen, Ginseng Radix, and optionally one or more materials selected from soybean isoflavone, sea snake bile and bamboo charcoal. The resulting product has proven improvement in skin cleansing, supplying skin with necessary nutritional ingredients and removing dead skin [79].
Fleischmann, 2004 prepared bathing solutions that contained DS salt, silica, and bicarbonate; those preparations showed effectiveness in dehydration, weight loss, improving bowel movement [80]. Another bathing product contains DS salts prepared by Hasunuma et. al., 2000, this product has the property to form bubbles when components were mixed and have an influence on skin moisturizing and conditioning [81].
Moreover, an invention was recorded in 2005 by Braun et. al. This invention concerned the preparation of skin formulations containing urea and DS mud or salts that helps in reducing skin irritation and skin damage [82].
A cosmetic preparation (formulated as cream, paste, milk or face mask) comprises mainly of DS salt, coenzyme Q10 and natural active ingredients was prepared by Beckermann 2001 as anti-wrinkling products that reduce skin wrinkles without causing irritation. The composition also comprised colloid former(s), with high molecular weight organic thickener, and was present as a stable colloidal formulation. The preparation contained also other additives such as organic solvent, inorganic thickener, surface active agent, antioxidant, antibacterial agent, gelling agent, fat, polysaccharide, oil, colorant and/or odorant [83].
Beckermann 2004 prepared face and body oil that composed of two phases; phase A (water, allantoin, DS salt, pentylene glycol) and phase B (soy oil, octyl decanol, perfume, jojoba oil), in addition to other cosmetic and dermatological formulations prepared from aqueous phase and oily phase (vicinal diol with 3-6 carbon atoms) without using of surfactants or emulsifiers [84].
Furthermore, and with regards to hair cosmetics, Robert et. al., 1997 focuses on alopecia patients and used the DS mud to prepare formulation that helps in retardation of hair loss and restoration of hair growth [85].
For aesthetic characteristics, Hwang et. al., 1998 prepared formulation containing DS mud which have an excellent impact on the prevention of dandruff, excluding itching, increase hair gloss and conditioning [86].

5.3. Additional benefits:

In addition to previously mentioned therapeutic properties of DS mud, antimicrobiocidal action is another property which is probably attributed to the combination of high salt and sulfide concentrations in plus low pH. This anitimicrobiocidal efficiency may explain the antiacne effect of facial DS mud masks because of the inhibitory effect on skin (Ma'or, unpublished observations, 1998). This was proved by Ma'or. et al., 2006 when suspensions of *P. acnes*, *E. coli*, and *C. albicans* were mixed with DS mud, then it found that the number of colonies that could be recovered declined rapidly [87].
There are also beneficial eukaryotic algae exist in the DS area, such as Dunaliella, which was reported for the first time at DS in 1940 by Elzari-Volcani. Dunaliella, is a unicellular biflagellate alga, and considered as the richest natural source of the β-carotene, the most widely used and commercially important carotenoid. β-carotene is generally used as an antioxidant, food coloring agent and source of pro-vitamin A. Thus, there is a global trend to develop anticancer

medicine from β-carotene based on its antioxidation feature. The halophilic species of Dunaliella could be also used as a source of glycerol, since it can accumulate high concentrations of glycerol [88]
In 2013 Emeish S. performed a study in Jordan aimed to investigate the probability of β-carotene production from Dunaliella isolated from the at the laboratory scale cultures, followed by subjecting the produced β-carotene to enzymatic oxidation to produce tretinoin (vitamin A). The amount of β-carotene produced during this study was 3-6% of the dry weight of cultured Dunaliella [89].

6. Conclusion:

The Dead Sea is the biggest natural saline reserve in the world. Characterization of DS mud and salts showed high concentrations of sulfates and mineral salts, which cause low pH value (approximately 6.0) of its water. DS mud and salts have been used for a long time for treatment of various disorders such as wound healing, rheumatoid arthritis, joint diseases, skin disorders and aging effects. In addition, it has been used as a constituent of several cosmetic products.
Despite the wide uses of DS mud and salts, it was found that they contain some contaminants which adversely affect the efficiency of their use such as heavy metals and microorganisms. Literature revealed that heavy metals are concentrated more in DS water, whereas microorganisms are found both mud and salts.
Thus, for safety purposes we recommended that care must be taken for the treatment of DS mud and salts before use in any therapeutic or cosmetic product.

Acknowledgement

The authors of this study would like to thank The Arab Potash Company in Jordan for their support in initiation the idea of this review and their interest in research. We also extend our gratitude to Hamdi Mango Center for Scientific Research (HMCSR) and the Deanship of Academic Research (DAR), both located in the University of Jordan (UJ). The authors would also like to thank Yazan A. Al-Ajlouni for contributing to this manuscript.

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