# MINERALOGY AND GEOCHEMISTRY OF MEHA SOLAR SALT POND, IRAQ

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## EXTENDED ABSTRACT

The present work deals with Meha depression pond, one of the solar saltworks ponds in the desert region of Iraq. A combined mineralogical-geochemical study is conducted using X-ray diffractometry and scanning electron microscopy for identification of the mineralogical phases of the silty mud base of the pond and of the harvested salt. Wet chemical water quality analysis and salt chemistry and bacterial investigation for Colony Forming Unit (CFU) are achieved to discuss their suitability for various industrial and domestic uses. Salt are produced in good quantities from these saline ponds but with primitive ways that reduce the quantity and quality of the produced salt. The main source of the salt is solar evaporation of water accumulated in low-relief areas mainly in spring seasons. The morphometry of the area plays a main role in the flow, leakage and accumulation of salty water. The hydrogeologic system controls the upward leakage of salty groundwater to the bottom of valley and flow to the depressions. The mineralogy and hydrochemistry of saltwater reflect the mutual effect of surface water and ground water with the halite or salt rich host rocks. Therefore, the present work focuses on these approaches for better consideration and development of the Meha solar saltwork. The study discusses also the proposed way of concrete basin construction for accumulation and monitoring of water accumulation and evaporation to reduce the unwanted materials in the harvested salt and to replace the primitive way of salt extraction by a new one to develop this saltwork pond. Generally, the mineralogy of the mud base of the pond includes; halite, gypsum, carbonates (mainly calcite with subordinate dolomite, ankerite, and siderite), silicates dominated by quartz and feldspars and clay minerals that are represented by kaolinite, illite, chlorite, illite-smectite, and palygorskite. Harvested salt is composed mostly of halite with less amounts of sylvite. The pond water is analysed for various cations and anions and hypothetical salt precipitation is estimated to be mainly of halite with few amounts of sylvite and rare magnesium and calcium salts. Chemical analysis of the harvested salt shows good quantities of Na and Cl for halite (NaCl) formation. The biological study indicates that the main bacterial phases in the hard salt produced by primitive ways contains more of bacilli and cocci bacteria than those in the constructed basin for evaporation. In general, the harvested salt is good for domestic uses and various industrial uses.

**KEYWORDS:** Solar salt pond, Mineral phases, Chemical and biological characteristics, Iraq

## 1. INTRODUCTION

Salt deposits accumulate on every continent and are distributed in two great belts, one in either hemisphere, which lie approximately between the latitudes of 15° and 35° from the equator [1]. Today, Sodium chloride (Halite) is a cheaply produced commodity extracted either from mines or saltpans. In the production of table salt, processing, packing and marketing are the major costs. Halite also is the most common industrial evaporite salt. It

is used in some form by virtually every person in the world. There are more than 14,000 reported usage of halite [1]. Halite, along with other salts, has long played a very important role in human affairs. Salt's main uses were as preservation and as a much sought for additive to flavor foodstuffs [2]. Without salt, the human metabolism cannot function.
Although rock salt exists in Iraq, it is not exploited and/or studied in details. The salt bearing formations in Iraq can be roughly grouped under bedded salt deposits from the early and middle Miocene Dhiban and Fatha formations and piercing salt bodies in the southern parts of Iraq during the upper Jurassic [3]. The main sources of salt in Iraq are playa lakes, brines and sea water. Out of 33 known salt locations, only ten are actually producing from playa ponds, brines and sea water sources (Figure, 1).

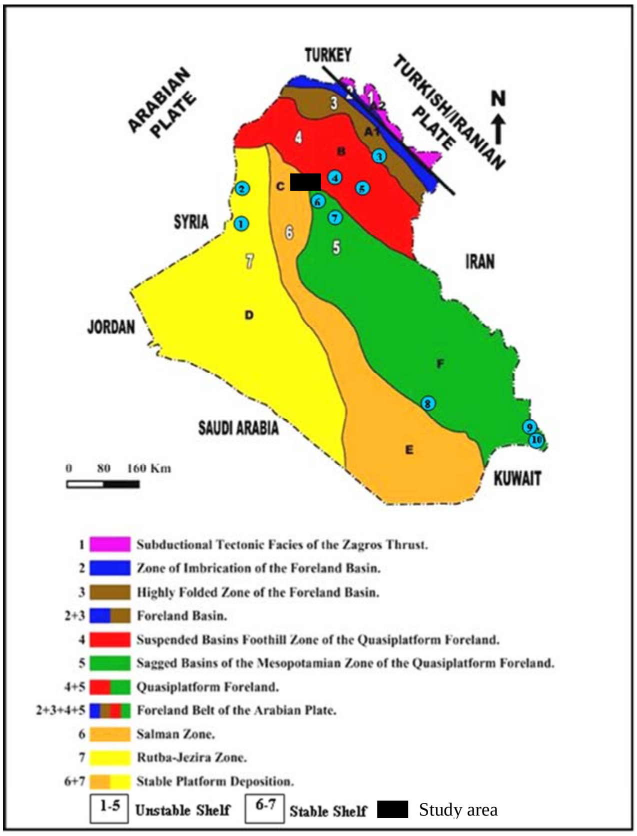


**Figure 1:** Illustrates the tectonic divisions of Iraq, modified from [4], and the physiographic provinces of Iraq with the main ten salt sites in Iraq and the location of the study area. Provinces are: Zagros mountains (A1, folded zone; A2, nappe zone), Foothills (B), Jezira (C), Northern (D) and Southern (E) deserts, and the Mesopotamian Plain (F) after [5], Slattern locations (green circles) after [6], (1- Al-Tawil, 2- Boara, 3- Chamchemal, 4- Hawija, 5- Tuz Khurmatu, 6- Al-Khalifa, 7- Shari, 8- Samawa, 9- Sanam, 10- Fao).

Peoples in the area under study working in consolidation of the muddy base of the low-relief areas before the rainy season to form impermeable base that used to store water for evaporation and salt accumulation. The consolidated muddy base is surrounded by relatively higher ridges to isolate water for evaporation. The way of consolidation of the muddy base is a primitive one that may lead to contamination from external sources if it is not completely monitored. In order to find a new method for salt harvesting, a concrete

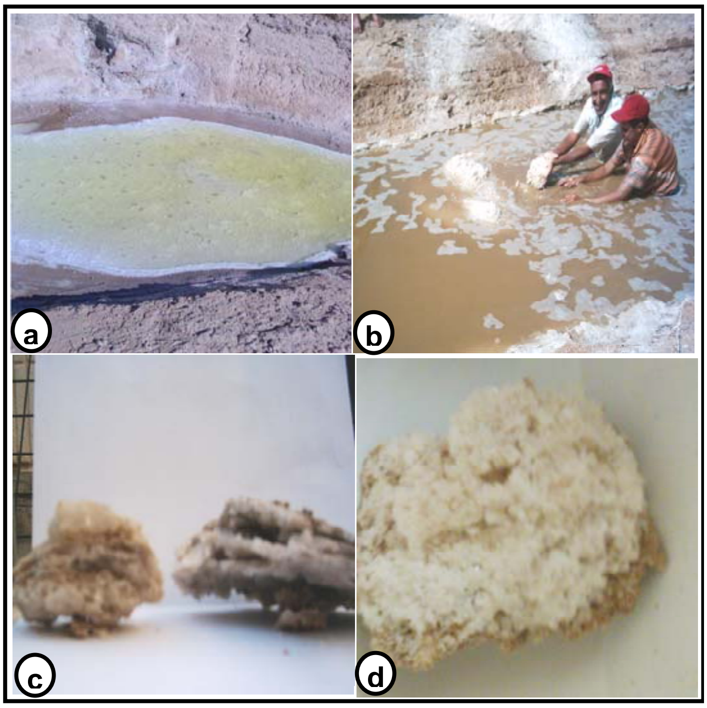

**Figure 2**: a-b, the primitive way of isolating water and accumulating of salts in Meha salt pond, summer, 2005. c-d, samples from salt harvested by peoples in the area. Brown to pink color masses and laminated salt.

(salt-resistant cement) pan is constructed in the area understudy with dimensions of 20x8x1 meter to save water with continuous checking and monitoring and to reduce any expected type of contamination (Figure 3).

**Figure 3:** Water accumulated in the constructed pond for evaporation, and part of the harvested salt.

The present work aims to study the mineralogy and chemistry of one of the solar salt pond in Iraq and to discuss the ability to use the harvested salt for various uses.

## 2. Geology, Geomorphology, and Climatology

Geologically, the area of study constitutes of many hilly and low mountainous area in which the main outcrops are composed of Miocene and Holocene sediments characterized mostly by red coloration. This area situated at the transition area between the southwest part of the foothill and unfolded zones of the physiographical classifications of Iraq (see Figure 1). Most of springs flow from the outcrops of gypsum layer of the Fatha Formation. This formation consists of cyclic alternations of gypsum, anhydrite, marl, limestone as well as the clastic rocks which are dominated at the upper parts of the formation; it also consists of salt layers with the depth [7].

Several salt ponds are found in Sharqat area, south of Mosul City. These ponds are distributed in area of about 2 Kilometers long and 1 kilometers width. Salt are produced in good quantities from these saline ponds but with primitive ways that reduce the quantity and quality of the produced salts. The main source of these salts are the water accumulated in low-relief areas in the region mainly in spring seasons which were drained from different seasonal wades.

The geomorphologic model reveals that the gradient of the valleys on the southwestern side has a gentle slop than the northeastern side; this phenomenon may reflect the effect of the geological structures of the area [8].

The main aquifer in the area of study is represented by the confined aquifer of fractured layers of the Fatha Formation, which is overlaid by impermeable clayey layers of the Injana Formation. The salt deposits solutes by the ground water, which flow throw the fractures and leaked upward throw the fault plane under the hydrostatic pressure of confined aquifer, the leaked water rising to be close the bottom of the valley. The depth of ground water ranged between 0.5-1m, and is leaked to the surface of the depressions in the bottom of the valley. The leaked water has very high concentrations of salt.

Evaporation depends on climatologic conditions of the area as temperature, winds, relative humidity in addition to the topographic nature. Maximum evaporation took place in summer season (June-August), with mean annual evaporation of 2584.3 mm. Relative humidity is low in the region since it located far from the sea or river effect. Maximum relative humidity in December is about 80% whereas; it is about 26.8% as a minimum value in July [9].

## 3. RESULTS

### 3.1. Mineralogy of the base of the salt pond.

The base of the constructed basin comprises mostly of silty mudstone. Mud is sampled from several shallow digging holes in different parts of the base. Ten samples of mud are analyzed using X-Ray diffraction techniques to identify the main mineralogical constituents of these sediments. Representative XRD scans of the analyzed mud are illustrated in Figure (4).

Scanning electron microscopic (SEM) study is achieved for these mud samples to identify precisely the mineralogical phases and their morphology and relationships (Figure 5). All these analyses were done at laboratories of Wollongong University, Australia. The main mineralogical components include; halite (mainly in the deeper samples), gypsum, carbonates (mainly of calcite with subordinate amount of dolomite, ankerite and siderite), Silicates dominated by feldspars (albite, orthoclase and microcline), quartz and muscovite as well as the clay minerals that are composed of kaolinite, illite, chlorite, illite-smectite mixed layers, and palygorskite. These minerals indicate mainly the weathering product of older clastics, carbonates and evaporite from the older Injana and Fatha formations as well the probable authigenic formation of carbonates minerals and gypsum.

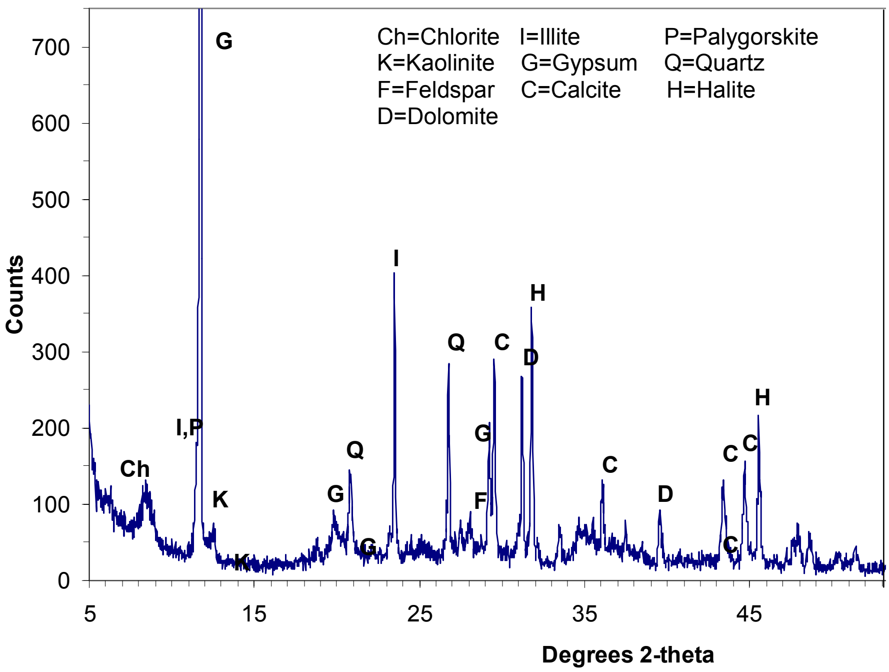


**Figure 4:** Representative XRD scan for the silty mudstone base of the Meha salt pont

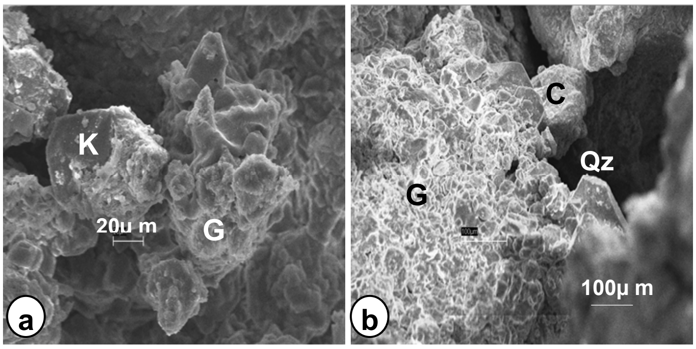


**Figure 5:** Scanning electron micrographs for the silty mud mudstone sample of the base of the salt pond. G-Gypsun, C-Calcite, Qz-Quarrtz, K-Kaoline

### 3.2. Mineralogy of the harvested salt

Salt crusts first precipitated on the floor as upward-growing cubic or chevrons crystals. This nature of precipitation is common for halite precipitation [1].

Salt is harvested after evaporation of the water accumulated in the constructed evaporation basin (pond) started at mid of July after a month of water accumulation and evaporation. The harvested salt generally is white, clean and is different in quality than those accumulated in the area by the old method of accumulation (i.e. by many citizens in the region). The harvested salt is analyzed both mineralogically and geochemically using updated techniques (X-Ray diffraction, and Scanning Electron Microscopy) in addition to wet chemical analyses and biological investigations. Representative XRD scans of polluted or impure salt (S1, old harvested), and pure salt (SP3, from the constructed pond) are illustrated in Figure (6). The mineralogical phases include; halite, sylvite and aragonite in varying quantities. Generally, much of halite is recorded in purely hard salt samples.

Scanning electron microscopic study for impure and pure hard salt samples is achieved using StereoScan 440 of Leica Cambridge Ltd. at the institute of semiconductor materials of Wollongong University, Australia. The representative images of this study are illustrated in Figure (7).

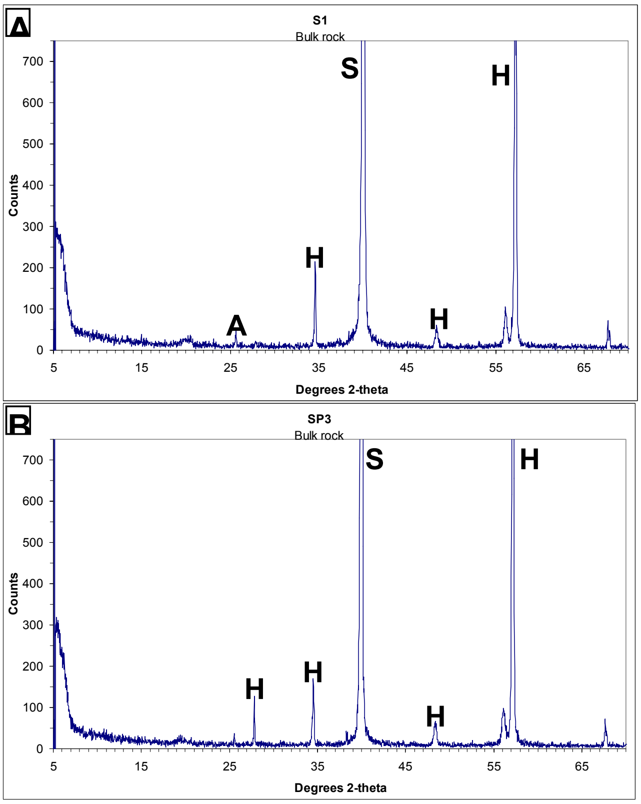


**Figure 6:** X-Ray diffractograms of the hard salt samles. A-Pollluted salt samles, grayish white color (old way of harvesting); B-pure salt sam ple from the contrycted pond harvesting. H=halite, S=sylvite, A=Aragonite.

The impure salt samples are composed of halite cubes embedded in clayey materials with cloudy nature due to contamination by these clay minerals in addition to some bacteria (Figure 7a-b), whereas, the salt harvested in the constructed pan is white, creamy with very little shows of grey color, and composed mostly of halite cubes of different sizes (Figure 7c-d).

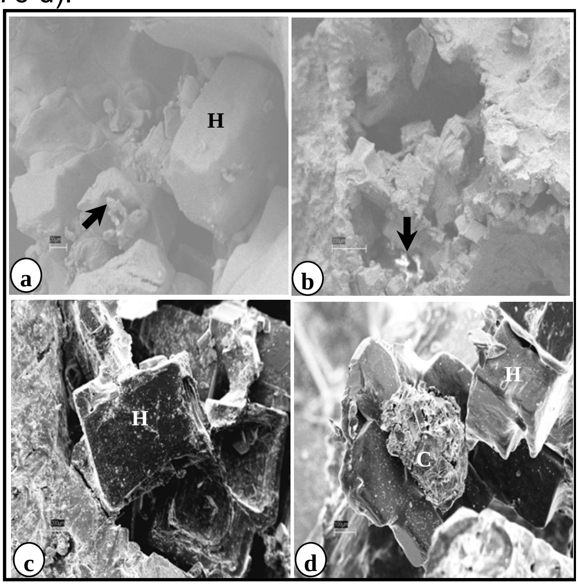


**Figure 7:** Scanning electron micrographs for selected salt samples. (a-b) from the salt harvested by primitive way containing halite cubes (H) embedded in clayey material and of cloudy color. Note the possible presence of bacteria (arrow). (c-d) clear halite cubes (H) with uncommon carbonate and clay material (C).

**3.3. Water quality analysis**

Water samples are collected from the accumulated water in the basin of the pond. These samples were analyzed to determine their chemical and some physical characteristic. The result of these analyses is tabulated in Table (1). These analyses are undertaken at Northern Fertilizers Company, Baiji, Iraq.

**Table 1:** Result of chemical analysis and some physical characteristic of water samples in the evaporation pond after 3 weeks of accumulation in the pond for the period 23 June-13 July 2007.

| $K^+$ ppm | $Na^+$ ppm | $Mg^{++}$ ppm | $Ca^{++}$ ppm | $Cl^-$ ppm | $SO_4^=$ ppm | $HCO_3^-$ ppm | $CO_3^=$ ppm | Analysis Time |
|---|---|---|---|---|---|---|---|---|
| 180 | 22344 | 33 | 760 | 32542 | 2505 | 3000 | 48 | 1st week |
| 397 | 41325 | 23 | 340 | 63625 | 611 | 1300 | 39 | 2nd week |
| 1120 | 60964 | 12 | 64 | 98314 | 22 | 200 | 36 | 3rd week |

| EC | TDS ppm | pH | Analysis Time |
|---|---|---|---|
| 152900 | 98600 | 7.18 | 1st week |
| 203000 | 191100 | 7.6 | 2nd week |
| 208000 | 234200 | 7.97 | 3rd week |

| Total counted salinity CTDS | Anion | Cation | Ni ppm | Fe ppm | Cu ppm | Analysis Time |
|---|---|---|---|---|---|---|
| 61412 | 1018.84 | 1016.83 | 0.07 | 0.2 | 0.036 | 1st week |
| 107660 | 1826.94 | 1825.81 | 0.07 | 1.2 | 0 | 2nd week |
| 160732 | 2773.75 | 2683.45 | 0.09 | 1.1 | 0 | 3rd week |

Hypothetical salt to be precipitated after 3rd week of evaporation is estimated to be mainly of halite with few amounts of sylvite in addition to rare magnesium and calcium salts (Table 2).

**Table 2:** Hypothetical salt precipitation

| | |
|---|---|
| $CaCO_3$ | 0.12% |
| $MgCO_3$ | 0.02% |
| $MgSO_4$ | 0.02% |
| NaCl | 98.78% |
| KCl | 1.06% |

**3.4. Geochemistry of harvested salt**

Chemical analysis of hard salt samples is done for 13 samples at Australian Laboratory Service (ALS Environmental), Sydney, Australia. The analyzed samples represent 3 from old polluted salt, 4 from old laminated salt and 6 from the recent harvested hard salt.
The mean concentration of Na and Cl in the analyzed sample samples is shown in Table (1). It is clear that the present salt samples contain god quantities of sodium and chloride for halite formation.

**Table 3**: Mean concentration of sodium and chloride in hard salt samples

| Salt sample | Sodium Major Cation ppm | Chloride Discrete Analyzer ppm |
|---|---|---|
| Mean polluted salt | 753000 | 353000 |
| Mean laminated salt | 742000 | 347000 |
| Mean pure salt | 792000 | 365000 |

### 3.5. Biological investigation

Biological investigations were done at AMS Laboratories in Sydney, Australia. These investigations showed that total aerobic plate count TM101 or Colony Forming Units (CFU) is much less for the pure salt samples (60 count as average) compared with 220 count for the laminated salt rock and 380 count for the polluted or impure salt samples taken from old salt harvested last year by traditional methods.

The biological study shows also that the main bacterial phases are bacilli and cocci. These organisms generally are associated with halite rocks and were concentrated in microenvironments that retain more moisture than ambient conditions and provide protection from temperature fluctuations and solar ultraviolet radiation [10].

## 4. CONCLUSIONS

Solar saltworks have produced salt by solar evaporation from wetland areas. These areas are continually decreased due to drainage, cultivation, and urbanization. Protection of these wetlands as an economically important salt resource and an ecologically high significant shelter for wildlife promote the increasing significance for safeguarding and developing global wetlands.

In Iraq, the main sources of salt in Iraq at the present are solar saltworks playas and brines, and sea water. Unfortunately, most of these sources are not well developed and primitive methods for water accumulation and salt harvesting are used.

In the current work, detailed mineralogical, chemical, some biological and physical characteristics analyses are achieved for one of the solar saltworks ponds in the desert region of Iraq. These analyses are undertaken for the pond silty mud base and for the harvested salt after water accumulation and evaporation by both primitive and new ways of harvesting in the pond understudy.

Comparison with the salt accumulated by primitive ways during last year indicated that the old harvested salt is contaminated with mud and other unwanted materials and of pink colors. Whereas, the salt harvested from the constructed pond is white and creamy.

Salt harvesting showed that good quantities with higher purity of salt could be obtained from the water evaporated in the constructed pond.

The chemical and biological investigations revealed that the harvested salt is a pure one and contain much of halite and less of sylvite and bacteria. In general, the salt is good for domestic uses and of course for various industrial uses.

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