

Rock Salt and Salt Affected Soil in Northeast Thailand

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ABSTRACT

The northeast region of Thailand, called Khorat Plateau consisting of two large basins (Khorat Basin and Sakon Nakorn Basin), covers an area of some 17 million ha or about one third of the country. From geologic surveys rock salt layers have been found belonging to Maha Sarakham Formation lying underneath the two areas. These layers of rock salt vary in thickness from a few meters to more than 1,000 m and their depths below the ground surface also vary from location to location. This underground rock salt is the main cause of salinity to its upper-most ground water and surface soils. Department of Land Development soil surveys indicate that, at present, 2.76 million ha in the whole Northeast area are saline soils and another 3.10 million ha are potential salt-affected soils. Mismanagement of the environment by such human activities as deforestation, building reservoirs, or improper salt manufacture can widely expand the salt-affected areas.

The local people of the northeast have manufactured salt from rock salt by either making salt fields with solar evaporation or boiling saturated salt brine. The average salt production from these two methods is about 6.25 t/ha/day and 40 kg/m³ (boiling stove)/day, respectively. The total amount of salt production is approximately 400,000 tons/year. However, making salt in this way damages the land and its environment. The bittern which seeps or drains from salt fields ruins the nearby public water resources, agricultural land and ecosystem. Large trees are also cut down to use as firewood for salt production. The Thai Government is trying to reduce the deleterious effects of such traditional salt making by controlling the area and procedures of salt production.

Returning the salt-affected area to useful cultivated land has been tried with several methods such as: setting a bed of coarse materials at a depth of 30 cm from surface for cutting off transportation of brackish water by capillarity (the first such attempt in the world); reducing soil evaporation by mulching with crop residues; leaching away salt from the soil surface; improving soil structure properties with organic matter and growing halophyte plants on the land. Mangroves, the halophyte from coastal areas, are introduced to test on the salt-affected soil and brackish water in the Northeast. As a result of this research, the improved saline area can successfully yield many vegetable crops such as baby corn, tomato, onion, kale, egg plant or chili.

INTRODUCTION

Northeast Thailand occupies an area of 15,140,000 ha or 33.13% of the country. The area covers a broad concentric structure, Khorat Plateau, which contains two evaporite basins — Khorat and Sakon Nakorn basins. In 1923, rock salt was first discovered in Northeast Thailand as a by-product during the search for commercial deposits of fossil fuel. From systematic geologic studies of Khorat Plateau (Sethaput, 1985) layers of rock salt distributed over 50,000 km² and belonging to Maha Sarakham Formation were found. The rock salt layers vary in thickness from a few meters to more than 1,000 m and also vary according to the depth underground. The mass quantity of the rock salt underneath is hard to estimate accurately. However, it is believed that under those two basins, there are billions of tons of rock salt.

HISTORY OF ROCK SALT

According to Sattayarak (1985), Khorat Plateau, together with the parts of Vietnam, Laos and Kampuchea, are believed to have acted as a micro-continent prior to the Late Palaeozoic. During the Permian era, seawater flooded over a vast area of the landmass. The first phase of Indosinian Orogeny disturbed the depositional basin to some degree and the sea level generally began to retreat. At the end of the Permian, intrusive igneous rocks were formed. Subsequently, the third phase of Indosinian Orogeny occurred and slightly affected the older formation. With the dry and arid climate, red sediments were gradually laid down to fill the huge Khorat basin. Until the Middle Cretaceous, the rise of the global sea level and change in basin configuration created three strata of rock salt of the Maha Sarakham Formation. Sedimentary strata, unconformably

Thickness (m)

58-794	Clay Sandstone Silt stone Mud stone
0-5	Gypsum/anhydrite
20	Upper rock salt
19-83	Clay
0-3	Gypsum/anhydrite
1-171	Middle rock salt
8-66	Clay
0-2	Gypsum/anhydrite
0-7	Coloured rock salt
1-19	Sylvite, rock salt
0-224	Carnallite Rock salt Tachyhydrite
2-395	Lower rock salt
1	Anhydrite
1	Sandstone (greyish green)
144	Sandstone (reddish brown)

Fig. 1. Profile of rock salt and potash. Adapted from Japakasetr (1985). Not to actual scale.

overlying the salt formation, are believed to be wind deposit with minor fluvial deposits. The present topography results from salt domes and drying up of ancient and modern rivers.

In 1923, rock salt was discovered in Northeast Thailand as a by-product during the search for commercial deposits of fossil fuel (Japakasetr, 1985). From systematic geologic studies of Khorat Plateau, core drilling programs for potash and rock salt were implemented throughout the basins during the period 1973-1982. The drilling program established three main evaporite sequences at various depths. However, in some areas there may be one or two sequences depending on how much the evaporite layers were domed up and erosion had taken place. Several layers of clay and claystone were found separately, each layer overlying each evaporite sequences (as illustrated in Fig. 1).

The lowest evaporite sequence starts with a thin anhydrite layer about 1-2 m thick spread over the whole area of the two basins. This is followed by the mass of rock salt 134 m thick on average. Another anhydrite layer under the rock salt is also underlain

by reddish green sandstone about 0.4-2 m thick in the upper part and thick reddish brown sandstone in the lower part. The rock salt layer itself is quite pure except for some black organic materials, particularly encountered in the lower part. The lowest evaporite sequence, the thickest rock salt bed, contains potash minerals in its upper part in most places. The other two evaporite sequences are essentially rock salt, but the middle one has occasional traces of carnallite and sylvite. The thickness of the middle and upper evaporite sequence average 70 and 20 m, respectively. The thickness of lower and upper clay which divide the evaporite sequences average 35 and 43 m, respectively.

The whole component of rock salt is halite, the chemical formula of which is NaCl. The halite is a cubic crystal shape and is normally either white or colourless. If impurified, it may show a mixture of other colours such as yellow, red, blue or purple. This mineral has a saline taste, is readily dissolved in water, and has a hardness of 2.5 and a specific gravity 2.17. The halite's surface always looks and feels moist.

SALT MANUFACTURE FROM ROCK SALT

People in the northeast have known for many decades that there is salt in the soil. They bring the soil with white crystals to the surface to leach with water. They then boil or dry the rinsed water in the sun to obtain the salt for family consumption. Salt production has developed from this local practice to a commercial scale by three methods: solar evaporation, boiling and solution mining.

Solar evaporation

In this method the paddy field is divided into small blocks each about 25×30 m in size. The ground is packed by a heavy roller to prevent water from leaching downward. Then the underground brine is pumped out from a well which is dug out down to about 60-80 m depending on the location of rock salt. The brine is pumped into each field to a level of 10-20 cm above ground. The brine concentration is about 19-25°Bé depending on the location. The fields are then left to dry in the sun for 10-15 days depending on the temperature during solarization. The salt produced is normally proportional to the level of brine water at the start of drying. The brine water level of 10 cm will normally yield salt 1 cm thick; 20 cm of brine will yield salt 2 cm thick (brine level: thickness of salt produced = 10:1). According to many salt farmers, salt yield by the solar evaporation method is estimated to be around 1 t/1,600 m²/day or 6.25 t/ha/day. Salt produced by this method has 90% purity of NaCl and is mainly used in industrial factories.

Boiling

The concept of producing salt by this method is the same as that by the solar evaporation method except fire heat is used instead of solar heat and an iron pan instead of a paddy field. The size of iron pan is normally 6 m long, 2 m wide and 0.25 m high. In boiling, the brine water is poured into the pan to a level of 0.15 m from the bottom. Firewood and rice husk are the fuels which used to boil the pan gently for about 10–11 h. Each pan will yield about 400–500 kg salt at one time. Salt produced from the boiling method is normally purer than that from the field. However, the cost of production of boiling salt is higher mainly due to the cost of burning materials. Salt produced by this boiling method is mostly for general use.

Solution mining

This method is used by salt factories on a larger commercial scale. The production system is mechanical vapour recompression. The salt brine is made by pumping fresh water down into the ground to dissolve rock salt. The salt concentration is 300 g/l. The brine water is pumped out to a tank where it is purified by chemical reaction. The brine water is then evaporated through a heating tower and turbo compressor until the salt is crystallized to small grains. The salt grains are centrifuged to remove excess water. The almost dry salt is then mixed with potassium iodide and passed through a final dryer to remove all water remaining in the grain. The final product will be a homogenized mixture of salt crystal and potassium iodide which is very pure and dry. Using this method the factory can control drainage of bittern or other waste by-product from the production process which can damage the environment. The product and by-product from the rock salt mined can be used widely in many areas of industrial production.

DAMAGE FROM LOCAL SALT MANUFACTURE

The local manufacture of salt by solar evaporation and boiling methods causes much damage to the natural environment: 1. Fresh water in natural resources becomes brackish and unfit for consumption.

2. The fresh water fish and shellfish such as shrimps, crabs and molluscs which are the natural food of the local people cannot survive in the brackish water.

3. The forests are gradually destroyed.

4. The area of salt-affected land increases.

5. Sinkholes occur in the salt manufacturing area.

SOIL SALINIZATION AND FACTOR ENCOURAGEMENT

The Department of Land Development's soil surveys (Wichaidij, 1983) indicate that, at present, 2.76 million ha in the whole northeast area are saline soils and another 3.10 million ha are potential salt-affected soils.

The mechanism of soil salinization can be either (1) direct salinization in cases where salt-bearing rocks are situated near the soil surface, or (2) secondary salinization by "saline seep" at lowland areas (Sinu-wong and Takaya, 1974). Saline seep is the way in which saline or brackish water moves from one place to another under flooding or leaching. The areas through which this water passes or in which it is accumulated can suffer salinity problems. The dynamics of soil salinization are significantly affected by the climate of the region, as shown in Fig. 2.

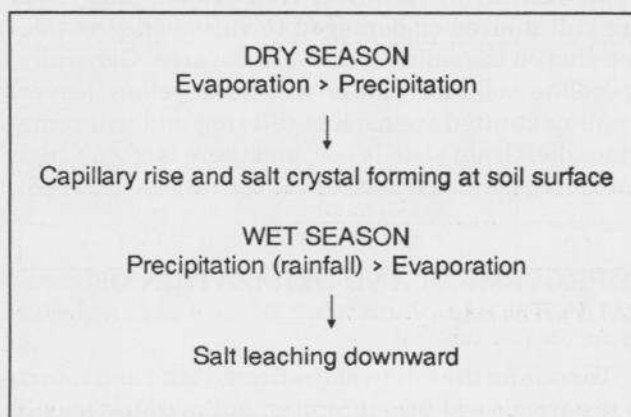


Fig. 2. Annual phenomena of soil salination in northeast Thailand.

The main factor leading to an increase in salt distribution in several areas is the destruction of natural environments. A prominent case is deforestation by shifting cultivation or by illegal lumbering. This reduces the area of forest that can absorb water and more rainfall percolates into the soil. When this water reaches the salt bed area salt is dissolved and transported to the lowlands, turning the normal lowland into a salt-affected area as shown in Fig. 3.

The effect of a saline soil on vegetation is easily recognized. In strongly affected areas there will be almost no vegetation. Only a few strong halophyte species can grow in such conditions. Farmers have to leave their farmland idle. In moderate or slightly salt affected lowlands, rice can still be grown during the rainy season because the rainwater suppresses the brackish water downward. The brackish water,

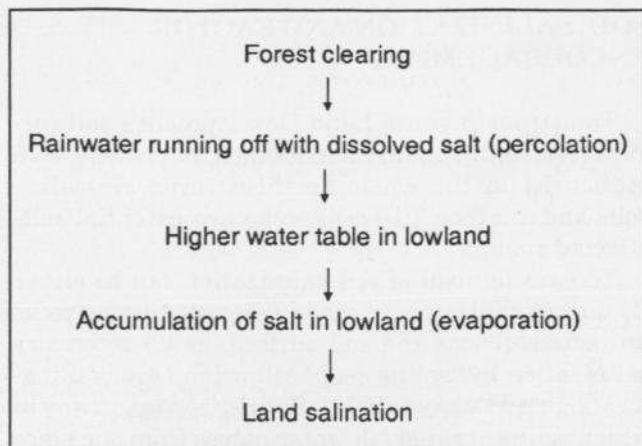


Fig. 3. Forest clearing and land salination.

which has a higher specific weight, lies underneath the rice root zone, while the fresh water stays in the upper soil layer. However, crop growth and yields are still injured or damaged to various degrees depending on the saline content in the area. Generally, on saline soil rice plants will have yellow leaves, small or stunted stems, less tillering and will sometimes die. Grain yield is low, and there is often a high percentage of shrivelled seed (Topark-Ngarm, 1988).

IMPROVEMENT AND UTILIZATION OF SALINE SOIL

To reclaim the fallow salt-affected land and return it to agricultural use, improvement methods should be based on the prevention of the rise of dissolved salt by capillarity to reach the soil surface. Various techniques have been tried, as follows:

Prevention of the rise of dissolved salt by cut-off zone construction

This technique — the first such attempt in the world — is the idea of the junior author to create a new soil surface to overcome the problem of rising dissolved salt (Topark-Ngarm and Sugi, 1989). The new soil surface is approximately 50 cm higher than the original soil surface. It is formed by digging trenches in the salt-affected area and piling the dug soil on top of the original soil surface. The technique is also refined by laying down material such as gravel, rice husk, and twigs to a depth of 30 cm below new soil surface. With this technique a cut-off zone is created to disconnect the soil capillary. In the rainy season when percolation takes place, the salt is leached downward from the upper zone through the cut barrier and accumulates underneath. In the dry season with no rainfall and high evaporation, the

dissolved salt rises upward through a capillary pore but is unable to pass the cut barrier which consists of a macropore. In such cases the salt accumulates under the cut barrier. With this technique the salinity in the upper soil zone can be reduced year by year. After a three-year trial of this technique at the Khon Kaen University, it was found that the salinity of soil decreased with the reduction of EC value from 7.04 mS/cm to 1.5–2.0 mS/cm.

Covering soil surface

Covering soil surface with vegetation or mulching the soil with cut grass, rice straw or other crop residue is another means to prevent or reduce soil evaporation. Reduction of soil evaporation results in reduction of capillary rise and the rising of salt from brackish water to the surface of the soil. Results from experiments in the JSPS-NRCT program (Topark-Ngarm, 1988) showed that growing some grasses on the bare soil or mulching the soil with rice straw in the salt-affected area during the dry season could reduce soil EC and stabilize soil reaction (pH).

Adding organic material to the soil

Organic matter such as compost or manure will improve soil structure, increase soil permeability and reduce the effect of the salt. Organic matter will also improve soil fertility.

Reforestation

Because felling trees in the forested area of the uplands is an initial cause of soil salinization in the lowland areas, reforestation should overcome the problem of salt-affected soil to some extent. Trees can absorb large amounts of rain, and reduce the water run-off and seepage down the slope. With such action, soil salinization should be less in lowland areas where there is a forest upstream. Reforestation not only reduces salt distribution but also rehabilitates the natural environment. The climate and vegetation can be more regular and productive in areas with a nearby forest. The Thai government has expended great efforts in reforestation in all regions of the country especially in the northeast. Several fast-growing tree species have been tried in many locations to reclaim the forest areas. In the northeast, there are many tree species that can grow well in areas of higher rainfall and in the normal soil, but most do not grow well on salt-affected soil. In reforestation and utilization of the fallow salt-affected soil, several mangrove species have been tried in Khon Kaen area. As the first attempt in the world, a species of mangrove *Rhizophora stylosa* was intro-

TABLE 1

Heights of 4 mangrove species (cm) grown under different soil improvements at 1 year after transplanting

Mangrove Species	Soil amendments							
	Gravel + rice husk		Rice husk		Cow dung		Control	
	Aug. 1989	Aug. 1990	Aug. 1989	Aug. 1990	Aug. 1989	Aug. 1990	Aug. 1989	Aug. 1990
<i>Melaleuca leucadendron</i>	34.3	193.5	42.0	226.3	38.3	151.6	40.0	100.0
<i>Heritiera littoralis</i>	73.5	119.5	79.0	105.0	50.4	91.7	59.0	81.0
<i>Xylocarpus granatum</i>	54.7	121.0	79.0	146.2	47.5	73.8	75.0	151.6
<i>Excoecaria agallocha</i>	35.0	183.2	26.5	174.0	30.8	179.7	33.4	107.9
Significant at 5%	*		N.S.		N.S.		-	

By *t*-test of relative differences.

Soil properties: texture S. (sand 93.56%, silt 1.20%, clay 5.21%). (0–10 cm. depth) organic C 0.33%, pH (1:2.5 H₂O) 8.03, EC (1:5) 7.15 mS/cm, CEC 0.91 meq/100 g soil. Exchangeable cations: Ca 12.7 meq/100 g soil, Mg 2.04 meq/100 g soil, K 0.17 meq/100 g soil, Na 46.1 meq/100 g soil.

duced from Okinawa, Japan in 1982 by the junior author to test at Changwat Maha Sarakham. This mangrove species could not, however, adapt to the area and it finally died. Subsequently (1986–1991), there have been many experiments to find suitable mangrove species for inland salt-affected area. The results, in general, are satisfactory. Table 1 presents the result of one mangrove trial with some soil improvement (Topark-Ngarm et al., 1991). After one year, *Excoecaria agallocha* and *Melaleuca leucadendron* grew to a height of 2 m which was about five times higher than that of the seedling while *Xylocarpus granatum* and *Heritiera littoralis* were about twice as tall as their seedling heights.

From 1982 to 1991 the JSPS–NRCT program at the Khon Kaen University has tried to improve the saline soil in the area using many of the above-mentioned techniques simultaneously. In salt-affected areas which previously were left idle, many vegetables such as baby corn, tomato, onion, kale, egg plant or chili can now grow.

CONCLUSION

It can be concluded that although Northeast Thailand has vast quantities of rock salt, conventional salt production by the local people creates serious damage to the environments. Land salinization and failure in agricultural production results from the mismanagement of such local salt-productive land. Several studies on the improvement of salt-affected soil have been carried out with results, which are so far satisfactory.

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