LET MICROORGANISMS HELP, NOT HARM SALT MANUFACTURE

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Abstract: A biological system able to help or harm salt manufacture inevitably develops in the ponds of every solar saltworks. A physical system (the circuit of connected ponds with associated gates, pumps, and dikes) properly constructed or modified and appropriately managed allows development and maintenance of a biological system helpful to salt manufacture. A helpful biological system, consisting of microorganisms suspended in the water and on floors of ponds manufactures and utilizes desired quantities of organic substances, and enables continuous and economic production of high quality salt at design capacity. Harmful biological systems create and release into the water and on the floors excessive quantities of organic substances that decrease surface areas and volumes of the ponds, decrease the quantity and quality of salt, and they require constant struggle and expenditures for continued operation. Causes of harmful systems include ecological, demographic, and climate conditions that enable increasing concentrations of nutrients to enter the ponds at the intake, from land runoff, birds, and disasters. Contributing causes of harmful systems include inappropriate design and regulation of the physical system, and inability to manage the biological system. Design and construction requirements to prevent or correct these problems and to establish helpful biological systems include ponds of sufficient numbers with adequate surface areas, maintenance of unchanging salinity at each point in each pond, baffles to control back mixing, shallow and uniform water depths, gates and pumps of sufficient capacity to maintain desired depths, flows, and salinity. Also required are constant surveillance of the physical and biological systems, and regular inspection of the integrity of the salt crop and/or salt floor. Information required for the harvested salt includes losses in the wash process, contaminant and water content, and crystal characteristics. Biological information required includes water color, composition and concentration of the dominant organisms suspended in the water and on floors, extent of deposits in corners and on floors of ponds, and usual and unusual events. Computer programs locally developed or purchased can assist display of the data, utilization of information, and management of biological and physical systems.

Key Words: biological management, saltfields, salinas, solar saltworks

This paper reviews practical biological and physical information to aid construction and management of new and existing solar saltworks (salinas, saltfields) and to facilitate continuous and economic manufacture of high quality salt at design capacity. Although primarily intended for officials and managers of saltworks with seawater intake, information presented also finds applications for saltworks with intakes from lagoons, lakes, subterranean locations, and combinations of these sources. This report is based mainly on the author's experiences at many saltworks as well as study and utilization of information from scientific journals, trade and commercial publications.

My report includes 1) an overview of the physical and biological system of a solar saltworks with seawater intake, 2) an overview of the structure and function of a salina possessing a biological system helpful to salt manufacture, 3) an overview of the structure and function of a saltfield with a biological system harmful to salt manufacture, 4) causes of harmful biological systems, and 5) requirements to establish and maintain helpful biological systems. For convenience, ponds will be considered in three groups: low salinity—from Be 3.5 to Be 9 (S.G. 1.025—S.G. 1.067), intermediate salinity—from Be 10 to Be 18 (S.G. 1.075 to 1.143), and high salinity–from Be 19 to Be 30 (S.G. 1.152 to 1.263).

1. Overview of the Physical and Biological Systems of a Solar Saltworks

Every solar saltworks consists of a physical system—a series of connected ponds through which seawater flows, evaporates by wind and sun, and deposits common salt, sodium chloride. The physical system houses in each pond a biological system--communities of microorganisms suspended in the water, and communities of microorganisms on the floors. The communities inevitably develop a biological system in every solar saltworks. The biological system can provide essential services (a helpful biological system), or it may result in a constant struggle for continued operation of a salina (a harmful biological system).

2. Overview of Structure and Function of a Solar Saltworks Whose Biological System Helps Salt Manufacture

In the ponds of the low salinity range, many kinds (species) of microorganisms, seaweeds, seagrasses, mollusks, and crustaceans are well represented. The photosynthetic microorganisms of the group use light, minerals, carbon dioxide and water to manufacture quantities of new organic substances greater than the consumer organisms are able to utilize. This activity enables development of appropriate quantities of suspended and floor communities in the low salinity ponds, and allows export of the unused organic substances to the downstream ponds where they become inorganic and organic nutrients to power new groups of microorganisms. The floor community (mats) of the low salinity range consists of microorganisms organized in layers anchored to the floors with seaweeds and seagrasses which remove nutrients from the water, maintain desired thickness, control seepage, and aid evaporation.

In ponds of intermediate salinity the microorganisms consume more organic substances than they manufacture by photosynthesis. Nutrients from the low salinity ponds establish suspended and floor communities, but sufficient imported and locally produced organic substances remain for export to power the biological system of downstream high salinity ponds. The suspended community of intermediate salinity, mainly of consumer microorganisms, includes Artemia (brine shrimp) which perform valuable services. These small animals ingest microorganisms, particulates, and gypsum crystals, and consume and utilize the organic substances for their bodily functions. The excreted waste products released in microscopic bags (fecal pellets) are not returned to the water, but drop to the floor, become overgrown by the floor community, and are permanently locked away. This activity enables delivery to the downstream high salinity ponds nutrient-depleted water and suitable food (dead Artemia) for the red halophilic bacteria (the Archaea), and brine largely free of microscopic gypsum crystals. In the intermediate salinity ponds the floor community organized in leathery layers, removes nutrients from the water, aids evaporation, controls leakage, and maintains thickness.

In high salinity ponds consumption of organic substances by the suspended community is greater than manufacture of new organic substances by photosynthesis. Many Artemia imported from upstream become moribund and die, and their bodies, along with certain other suspended and dissolved organic substances, are consumed by the resident red halophilic bacteria. With adequate oxygen and appropriate food, these red microorganisms multiply to develop large populations which decrease organic substances, increase solar energy absorption, and aid evaporation. In the first half of the high salinity range, the floors are covered by hard sheets of gypsum. Below the sheets, bacteria erode the lower parts of the deposit and provide some control on gypsum accumulation. In the rest of the high salinity range (the crystallizers) red halophilic bacteria reach their highest concentrations, continue to consume organic substances, and improve evaporation; these processes aid deposition of high percentages of solid sodium chloride crystals which cohere sufficiently to develop firm crops and salt pavements on the floors able to support harvest machinery.

3. Overview of a Saltfield with a Harmful Biological System

In ponds of the low salinity range the suspended community--large numbers of few kinds of microorganisms--manufacture by photosynthesis excessively large quantities of organic substances which prevent or decrease development and function of nutrient-removing layered mats of the floor community. These conditions result in delivery of massive quantities of nutrients—microorganisms, organic, and inorganic substances downstream to the ponds of intermediate salinity. Ponds of low salinity also have fast accumulating black deposits on their floors, peripheries and corners, resulting in decreased pond volumes and surface areas, and diminished water delivery to the downstream system. Suspended and floor communities may be dominated by one or more of the highly undesirable photosynthetic microorganisms Aphanothece halophytica, and Ochromonas, and the macro-organisms Cladophora, and Lamprothamnium, which after reaching large concentrations contribute excessive quantities of organic exports to the downstream ponds.

In ponds of the intermediate salinity range, excessive concentrations of nutrients imported from upstream, together with the salinity of this range, provide conditions highly favorable to the growth, reproduction, and organic release, of Aphanothece halophytica, a unicellular organism of the cyanobacteria. Accumulating organic substances from Aphanothece halophytica exclude most competing organisms, and result in delivery of nutrients and viscous brine to the downstream ponds. Nutrient removal activities by Artemia and the floor communities are ineffective, suppressed or absent. Excessive nutrients and favorable salinity are also highly advantageous to the reproduction of Dunaliella salina, an undesirable microorganism of the green algae group that releases organic substances to the water, and establishes and exports large populations to the downstream ponds.

In ponds of the high salinity range, large concentrations of microorganisms and organic nutrients (from Aphanothece halophytica and other sources) imported from upstream accumulate and decrease the effectiveness of the red halophilic bacteria population to consume these substances. In these conditions Dunaliella salina remains alive, reproduces slowly, and continues to release organic substances. The two sources of organic substances may result in highly viscous water. Deleterious effects of high viscosity include increased solubility of gypsum, gypsum formation as individual microscopic crystals or white powder suspended in the brine, and salt deposition as small cubes, and conglomerates of layered, hopper-shaped crystals. The shape and size of these crystals, and the organic-laden brine enable gypsum and liquid to become incorporated in the salt. In addition to soft crops and pavements, brine that tightly adheres to the crystal surfaces increases the cost of harvest, road and dike maintenance, and hauling. High losses in the wash process required to bring the assay of these crystals to acceptable concentrations often requires expensive modifications of the wash equipment, treatment of the salt with caustic compounds, crushing the crystals, dual wash, and prolonged stockpile residence to decrease contaminant and water retention.

4. Causes of Harmful Biological Systems in Saltfields

Outdated design concepts, traditional construction techniques, and use of management methods based largely on physical considerations, are among the chief causers of harmful biological systems. However, changing ecological, demographic and climate conditions not underway at the time of construction have also resulted in harmful biological systems.

Errors in saltfield design, construction, and management include 1) inadequate numbers and surface area of ponds at each salinity range, particularly in the low range 2) incorporation of deep lagoons within the circuit of ponds (these have no floor communities, their photosynthetic microorganisms use most of the light energy received to manufacture suspended microorganisms, and they undergo important changes in microorganism composition and nutrient content), 3) inadequate control features and management that maintain salinities, depths, and flow rates at desired levels, and 4) mixing of seawater intake with brines of other sources. Saltworks with these characteristics may have an initial period of successful operation while the floors and attached organisms of the ponds are active nutrient removers. After floors and organisms become saturated with nutrients or covered with organic substances, their ability to remove nutrients decreases, and the ponds export damaging quantities of organic substances to the downstream system.

Other causes of harmful biological systems include disasters of nature—cyclones, hurricanes, excessive rainfall, disasters caused by human neglect, and disasters caused by changing ecological, demographic and climate conditions. All these causes impact solar saltworks by their negative effects of increasing nutrients that reach the ponds, and all result in massive accumulations of organic substances on floors and in the water.

5.Requirements to Establish and Maintain Helpful Biological Systems

Included are sufficient numbers of ponds, which allow only small increases of salinity within each pond, adequate surface area at each salinity range, shallow water with minimal wave action, small salinity differences between ponds, and an unchanging salinity gradient throughout the circuit of ponds. These stable conditions allow the largest numbers of species (kinds of microorganisms) to develop and efficiently compete for nutrients, prevent dominance of producers and releasers of organic substances, and develop effective nutrient-removing mats that remain on the floor.

Devices and equipment that aid stable conditions include baffles that dampen wave action and prevent backmixing, extra pumps at each pump station, fully adjustable gates of adequate dimensions, dikes impervious to water, and use of a computer-assisted program to aid management efforts. Other management aids include continuous gathering, display and utilization of physical and biological data, and fast access to all parts of the saltfield. In addition to salinity, depths, and flows, measurements and anecdotal records on the concentrations of important organisms of each salinity range, the condition and extent of mats, and the presence or absence of deposits on floors and corners are required. In high salinity ponds, information includes firmness of the gypsum deposit, presence or absence of organic substances above the gypsum and presence or absence of individual microscopic gypsum crystals in the water and on the floor. In crystallizers, firmness of the crop and salt floors, width of mushy salt perimeters, and crystal characteristics and size range of the harvested salt. Data at the wash process includes salt losses, wash efficiency for removal of each contaminant, and water content.