SODIUM CHLORIDE UPTAKE by ALGAE

Resources Research, Inc.

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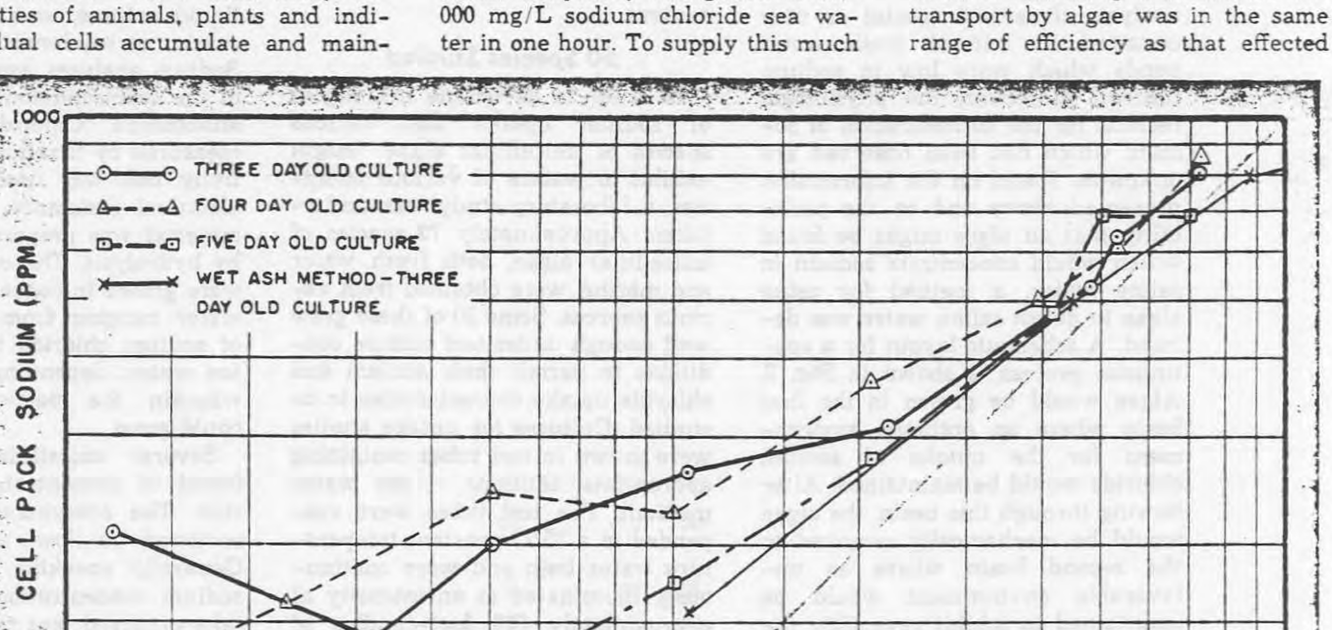
ALTHOUGH it is fundamental to life that all organisms constantly accumulate or exclude certain ions present in the environment, until recently little attention had been paid to the physiological mechanisms of ion transport from the standpoint of possible importance in the field of saline water conversion. In 1957, Resources Research, Inc. undertook a literature study to review the status of active ion transport by physiological mechanisms and to seek possible engineering implications.

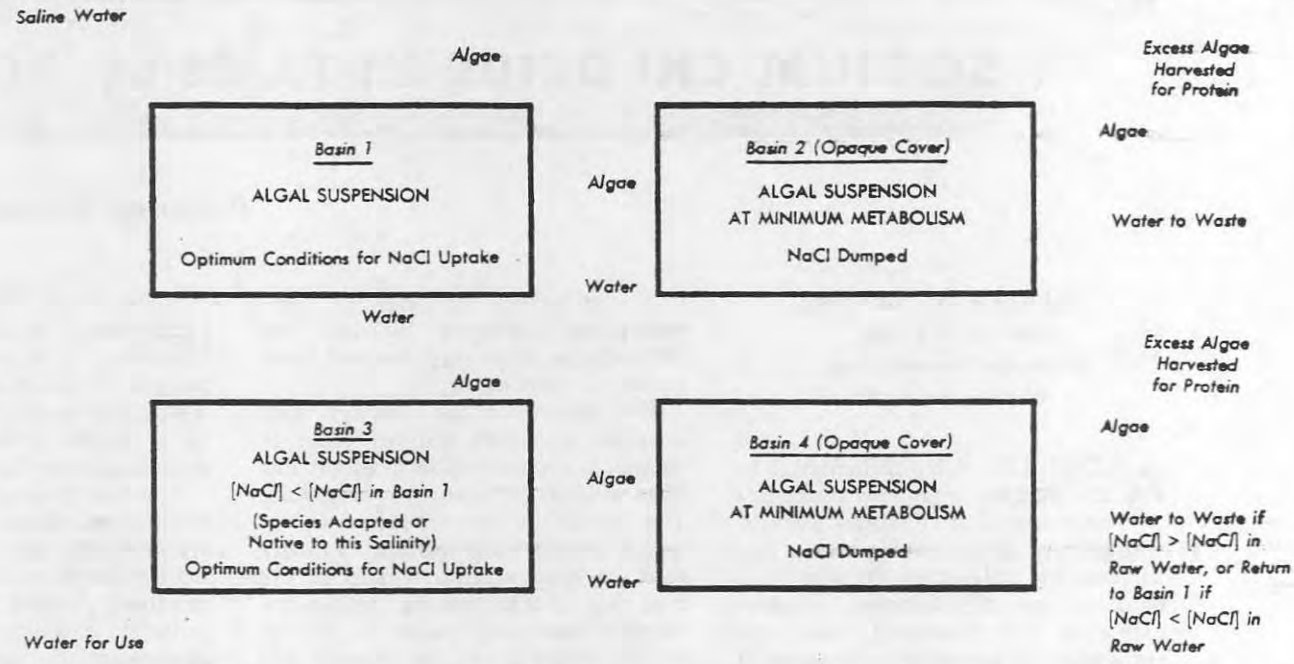
On the basis of available information, there seems to be a striking similarity in physiological mechanisms achieving and maintaining dynamic imbalance of various ions distributed between intracellular and extracellular fluid. Thus, many varieties of animals, plants and individual cells accumulate and maintain ions against considerable concentration gradients through the expenditure of energy derived from metabolic processes.

The ability of the isolated frog skin to transport sodium chloride against a concentration gradient has been studied by many investigators. The available data were used to make calculations which indicate that the energy requirements of the frog skin in transporting sodium are three to six watt-hours per gallon of 30,000 mg/L sodium chloride sea water desalted. This closely approaches the theoretical minimum of 2.8 watt-hours per gallon for the desalting of sea water by any possible means. For the conversion of sea water, this efficiency exceeds the efficiencies which might be achieved by conventional processes under development by a factor of twenty or greater. However, based on the rate of sodium transport by the frog skin, 227 square meters of membrane surface would be required to desalt completely one gallon of 30,000 mg/L sodium chloride sea water in one hour. To supply this much surface in a two-dimensional arrangement would be unwieldy. However, a three-dimensional arrangement, such as that afforded by a suspension of a finely divided material, might produce a more nearly practicable configuration.

The literature study had revealed that certain algae occurring in fresh water ponds were known to concentrate sodium against a concentration gradient. *Nitella*, for example, was found to produce a 46-fold internal concentration of sodium when grown in pond water containing 5 mg/L of sodium. If unicellular algae might concentrate sodium from brackish or sea water, a biological process of desalting might be feasible. An algae the size of *Chlorella*, with an average diameter of five microns, would provide the 227 square meters of membrane surface in 25 gallons of a 2 percent packed cell volume suspension of the organism. This concentration of cells could be maintained in a mass culture. Assuming that sodium ion transport by algae was in the same range of efficiency as that effected



● FIG. 1. *Growth experiments performed on Chlamydomonas show organisms take up sodium from dilute solutions of sea water.*



● **FIG. 2. Flow diagram for hypothesized use of algae in saline water conversion, showing arrangement for two-stage process.**

by the isolated frog skin, and that it might be possible for some species of algae to maintain approximately this efficiency in saline waters, one gallon of fresh water per hour might theoretically be produced by a 25-gallon sea water suspension of the organisms.

The meager information in the literature concerning the uptake of sodium by algae was confined to the analysis of several species as they occurred in natural fresh water ponds which were low in sodium content. Moreover, the physiologic reasons for the concentration of sodium which had been observed are unknown. Based on the information presented above and on the possibility that an algae might be found which would concentrate sodium in saline water, a method for using algae to desalt saline water was devised. A schematic layout for a continuous process is shown in Fig. 2. Algae would be grown in the first basin where an optimum environment for the uptake of sodium chloride would be maintained. After flowing through this basin, the algae would be mechanically removed to the second basin where an unfavorable environment would be maintained to inhibit reversibly the metabolism of the cells. Thus denied energy necessary to maintain their internal concentration of sodium chloride, the algae would secrete salt in approaching equilibrium with the environment. The algae would then be mechanically removed from the second basin and returned to the first to take up additional sodium chloride, gradually depleting the salinity of the water in the first basin as the cycling continued. The sodium chloride enriched water in the second basin would be wasted. Sodium depleted water would be drawn from the first basin for use or for introduction into a second stage of the process. Excess algae would be harvested for their protein content.

50 Species Studied

In order to determine the degree of sodium uptake that various species of unicellular algae might exhibit in waters of various salinities, a laboratory study was undertaken. Approximately 70 species of unicellular algae, both fresh water and marine, were obtained from various sources. Some 50 of these grew well enough under test culture conditions to permit their sodium and chloride uptake characteristics to be studied. Cultures for uptake studies were grown in test tubes containing appropriate dilutions of sea water medium. The test tubes were suspended in a 25°C constant temperature water bath and were continuously illuminated at an intensity of approximately 600 foot-candles of fluorescent light. Cultures were continuously aerated with 5 percent CO_2 in air. Zero time analyses for sodium, chloride and conductivity were made on each culture after its inoculation with the test species. At intervals, aliquots were withdrawn from the culture tubes. The portions were centrifuged and analyses for sodium, chloride and conductivity were made of the supernatant liquid or the packed cells or both. In this manner, the change in sodium chloride concentration between the cells and the suspending liquid was studied. Some of the cultures were grown for as long as two weeks and the appropriate corrections for change in liquid volume, as a result of evaporation or condensation, were made. Sodium analyses were made by use of the spectrophotometer with flame attachment. Chloride content was measured by titration and a conductivity cell was used to determine electrical resistance. The cell pack material was prepared for analyses by hydrolysis. The organisms tested were grown in concentrations of sea water ranging from several mg/L of sodium chloride to full strength sea water, depending on the range wherein the particular organism could grow.

Several unicellular algae were found to concentrate sodium chloride. The concentrations, however, occurred in low salinity waters. Generally speaking, the maximum sodium concentration in which uptake occurred was that corresponding to several percent sea water. From determinations performed on *Chlamydomonas* it was evident that, when grown in dilutions of sea water containing less than approximately 700 mg/L of sodium, the organisms did take up sodium. The 700 mg/L sodium level was contained in a 7 percent dilution of Atlantic Ocean water. It is thus shown that, for the organisms studied, effective sodium concentrations do not occur in waters of sufficient salinity to be of practical significance. The data obtained, however, represented the first study of this nature and concerned only a small portion of the many unicellular species of algae which might be examined. The fact that significant sodium uptake has been established, and that this varies with different species, indicates that additional research on unstudied species and on physiological factors which might increase uptake, could result in enhancement of sodium uptake by biological means.

The study revealed several other interesting facts. Both fresh water and marine algae were found to grow in surprisingly wide salinity ranges. Some fresh water species grew well when placed directly in 50 percent sea water and some marine species were readily cultured in 25 percent sea water. Marine species which were easily cultured were found to exclude sodium to a marked degree. The possibility thus arises that marine algae might be mass cultured in sea water and harvested for protein which would not contain excessive quantities of salt. This, in effect, might provide a means for growing a "fresh water crop" in arid regions without actually desalting sea water and then applying it to the land.

Acknowledgments

The work described was performed under contract with the Office of Saline Water of the U. S. Department of the Interior. Those participating in the laboratory phase of this work were Aharon Gibor, John Clendenning, Harry Williams, Donald Wetherell and Harry Sadler.

PESTICIDES and LAKE REHABILITATION

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DURING the past few years there has been a rapid growth in development and use of synthetic and naturally occurring organic chemicals in agriculture. There appears to be a trend toward use of synthetic organics or "synicides" to control plant disease, parasites and undesirable vegetation. Considerable quantities of these substances ultimately reach surface water supplies through runoff and irrigation return flows.

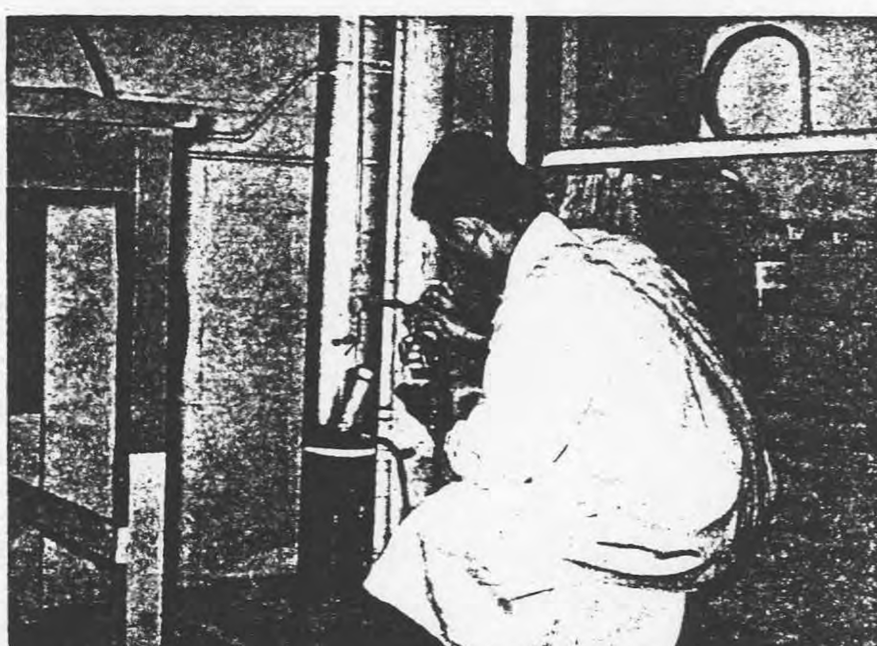
The highly toxic properties of many "synicides" to fish and other aquatic life have been subjects of considerable study. Little appears to be known about the physiological significance of such substances in drinking water supplies. It has been suggested that in some instances biochemical degradation byproducts may be of equal or greater importance than the original organic. Analysis and interpretation of the organic constituents found in natural waters, particularly in agricultural areas, are seriously restricted by a general lack of information regarding the biochemical behavior of these substances in natural waters.

In order to provide a basis for finding answers to some of these questions, research sponsored by the Public Health Service was initiated in the Sanitary Engineering Laboratories concerning the biochemical destruction of the major classes and types of "synicides."

Materials Investigated

According to available information more than 300 organic compounds have been developed commercially for use as pesticides. Available time and facilities do not permit a direct detailed study of each of these substances. A method of classifying these compounds was developed to serve as a basis for planning preliminary study. Examination of available information regarding chemical structure disclosed that most of the commercially significant pesticides are closely related chemically. Thus it appeared that preliminary information pertaining to a considerable number of substances could be obtained through study of a relatively few materials.

Pesticides representative of each major classification group were obtained from industry. Wherever



● SAMPLING from a water column overlying Green Lake bottom sediment to determine uptake of nutrients under various biological and physical conditions.