

# THE INFLUENCE OF ALGAE ON THE NATURAL ENVIRONMENT

by

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In the development of the various scientific disciplines certain contacts have been established between neighbouring sciences, while other endeavour still proceeds almost on its own. The study of the influence of the environment on chemical reactions has given us a large part of physical chemistry, while the inverse, the study of the influence of chemical reactions on the (natural) environment has been, in the last decades, developed as geochemistry. Much of our physiology and ecology deals with the influence of the environment upon the organism, while the inverse, the influence of the organism upon the natural environment (geobiology) has hardly been studied systematically. This influence is great, as already realized by Pasteur a century ago. Moreover, this study completes the picture of the relations of "give and take" between the organism and its milieu and the author believes that a true ecology should concern itself with the mutual relations between organism and environment rather than view the landscape (or seascape) entirely from the biological point of view. Blumea twice before has been so kind as to accept ecological notes from the author of this paper. Because of the interest Professor Lam has always taken in this ecological approach, the author hopes that this short note will not be a complete dissonant in the, chiefly taxonomic, matter contained in this volume.

By a study of the influence of various groups of organisms on the estuarine environment Baas Becking and Wood (1) arrived at the conclusion that, primarily, the following groups are of geochemical importance; sulphate-reducing bacteria, thiobacteria, purple bacteria, iron bacteria and algae. The limits of the potential algal environment surpass the regions of most other groups, the thiobacteria excepted. The range of conditions in which algae may occur, be it temperature, salinity, pH or electrode potential is very wide indeed. Algae occur in all aqueous environments; evaporate, geothermal, soft and hard freshwater, estuarine and marine water and also in buffered and non-buffered products of pyrite oxidation (Baas Becking, Wood and Kaplan, 4). The author recently isolated, from mirabilite at Mawson Base, Antarctica, a green polyblepharid while Kaplan (12) describes the occurrence of bluegreens at 86°C in the hot springs of the Rotarua district, N—Z. From this same region Kaplan described a *Navicula* at pH 1.2, while several algae occur in a solution of trona (sodium carbonate-bicarbonate) at pH 10.55. The above anecdotal remarks only serve to illustrate the extent of the algal potential milieu.

We have, as yet, only a very imperfect idea as to the influence of the algae upon the aqueous environment. From the, necessarily limited, experience of the author it appears that *accumulation, excretion and secretion enter in these processes coupled to photosynthesis and respiration* by mechanisms only partly understood. Apart from the above processes there are obviously many others not studied, or not even realized by science. In this paper we will confine ourselves to the first-mentioned processes. From the few examples studied we arrive at an incomplete picture of the influence of algae on their environment, but this picture is enough to make us realize that this influence is great, and often even dictatorial. The subject matter will be dealt with under the following headings:

I Accumulation

- II Secretion and excretion
- a. pectinoids
  - b. reducing substance
  - c. oxidising substances.

**I. Accumulation.** The role of the iodine will serve as an example.

Red algae and kelps concentrate the iodide of the surrounding seawater (ca 50  $\gamma$ /L, Reith 1930) more than a hundred thousand fold in their cells. Respiratory energy ("salt-respiration") is needed to perform this feat, but about the selectivity of this process we remain uninformed. This accumulation of iodide, inshore and estuarine, is world wide and takes place on a vast scale. It is known that, in decomposing kelp, molecular iodine is formed (Blinks, 6). Even a higher oxidation-stage, the iodate, is present, not only in decomposing kelp, but in the ocean far from land. Long ago Müntz (1887) has shown in its microbiological formation from iodide. The presence of appreciable amounts of iodate in seawater has thusfar escaped attention because of its particulate nature. It will not pass through a filter. It may be present in the water as an organo-complex (Baas Beeking, Haldane and Izard, to be published this year). Evidence exists that this iodate will slowly react with the chloride in the seawater, ultimately forming perchlorate (Baas Beeking, Haldane and Izard, Nature, in press) probably via  $ICl$  and  $Cl_2$ . A flow of perchlorate formed by this (and may be by other) process(es) therefore emanates from estuaries and from coastal regions, slowly attacked by bacteria and reverting to chloride. It has been known for a long time (Sjollema, 1896) that perchlorate in small concentrations (Ca 30 ppm) is toxic to higher plants. More than this concentration was found by us occasionally in seawater.

It seems tempting to ascribe the toxicity of seawater to higher plants to the influence of this perchlorate and it is even more tempting to ascribe the "marine" nature of the algae to their tolerance to perchlorate. Without indulging in further speculation the fact remains that, under the direct or indirect influence of organisms a highly oxidised inorganic compound is formed, hitherto known only to occur, as an end-product of oxidative weathering, in the Chilean niter beds (Clarks, 8; Goldschmidt, 9).

**II. Secretion and Excretion**

a. Pectinoids. Many algae seem to secrete continuously, pectinoid substances which form their outer wall and which are sloughed off continuously

(Wurdaek, 17). It could be shown that this outer pellicle may serve as an accumulator for metals as well as for phosphates (Baas Becking and Mackay, 2).

It seems probable that these compounds enter into combination with uronic acids, formed by the decomposition of the pectinoid, as Johnston (11) has shown the chelating action of uronic acids upon phosphates. The phosphate content of *Enteromorpha* studied by us, varied from .20 to .56 % of the dryweight; the iron content varied from .14 to .99 %. This demonstrates the action of the pellicle, and the ash analysis of *Enteromorpha* seems to give a picture of its environment rather than of its internal composition. The phosphate may be completely solubilized by hydrogen sulphide (Baas Becking and Mackay, 2) and so become available again in its biological cycle. The author is convinced that the chelating function of the pellicle will exert itself on other substances as well.

b. Reducing substance. It was found by Haas (10) that *Polysiphonia* liberates methyl sulphide in seawater. Bywood and Challenger (7) found that *Enteromorpha intestinalis* secretes dimethyl sulphide formed from a sulphonium salt. When *Enteromorpha* is placed in seawater in the dark, both pH and electrode potential will drop, the latter to negative values, so entering the region in which sulphate reduction is active (Baas Becking and Mackay, 2). Not only *Enteromorpha* and other Ulvaceae, but also bluegreens (*Lyngbya*, *Calothrix*) and marine phanerogams (*Zostera*, *Posidonia*) show similar depression of the electrode potential in the dark (E. T. F. Wood, 16). While the secretion of the highly reduced substances (possibly products of sulphonium salts) promote bacterial sulphate reduction by the creation of a suitable environment, the possibility is by no means excluded that the excreted organic sulphides themselves will yield, after initial breakdown, iron sulphides. Sulphate reduction requiring, in the absence of algae, or of *Zostera*, several days of incubation will be observable within 24 hours in their presence. In the aqueous environment, algae, therefore, may be the direct or indirect cause of the formation of the highest oxidation state of terrestrial compounds as well as of the formation of highly reduced compounds.

c. Oxidizing substances. Photosynthesis, by removal of both carbonic acid and bicarbonate ion from seawater, will cause a decrease in the acidity until a pH of ca 9.4 is reached, when calcium carbonate starts to precipitate. We may simulate this removal by blowing nitrogen through seawater, when the carbon dioxide equilibrium is shifted in a similar way (see Baas Becking, 3). However, photosynthesis of submerged aquatics will do more than increase the alkalinity. The electrode potential of the milieu will increase concomitantly with the pH instil, at high pH values (in the absence of calcium and magnesium they may reach 10.55) the highest electrode potentials observed at that alkalinity ( $E_h = +.440$  volts) are encountered. With Miss Mackay the author was able to show that the relations between potential and pH is linear over a large range and that this relation is a continuous extension of the "dark-effect" described above. Cell free filtrates made from various algal cultures (*Dunaliella parva*, *Enteromorpha intestinalis*) retained their characteristics for several hours. It seems likely, therefore that algae, in the light, excrete oxidizing sub-

stances. Other marine and freshwater algae (Lyngbya, Chlorella) have the region of highest oxidation potential extended to +.760 volts at pH 5. Attempts to identify this water soluble (probably organic) (group of) substance(s) have failed thus far. Crocetin, quercetin and flavones showed no significant potentials. The fact remains, however, that, apart from the extremely acid range, the highest oxidation potentials formed in natural waters occurred in algal cultures or in natural waters (brines) rich in algae.

Together with certain bacterial groups, algae, therefore, dominate in their influence on the aqueous environment, actually creating, in many places, the boundaries of this environment.

It would require a book rather than a brief note to do justice to the title of this paper. The few anecdotal remarks made will be sufficient, however, to impress us with the fact that ecology should be considered as the study of the *mutual* relations between the organism and its environment. Modern sedimentary geology is taken cognizance of this fact and experimental biology is penetrating into geology just as geological considerations have become part and parcel of ecology.

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