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Effect of Trace Metals on Growth Rate of Algae

Gabriel H. Srouji
Ouachita Baptist University

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Gabriel H. Srouji

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INTRODUCTION

Heavy metals, although only in traces, are essential for all forms of life. They are taken up by the living cell in the form of cations, and their uptake is strictly regulated because most or all of them are toxic in excess. A remarkable specificity has been found: seldom can an excess of one essential metal prevent the damage caused by deficiency of another. In fact, such an excess often increase the injurious effect of deficiency.

Metal-binding substances, many of which function by chelation, form a class of substances which have furnished many useful drugs and other substances of value in selective toxicity. They are manufactured in huge quantities for this purpose, particularly those that are used in agriculture as fungicides. They function by upsetting the delicate balance of trace heavy metals. Some of them withdraw metals from living tissues, but many others reinforce, strongly, the natural toxicity of heavy metal.

Apart from their use as agricultural fungicides, metal - binding substances have found three types of use in veterinary and human medicine. Some are used to defferentiate between vertebrates and their parasites. Such substances make a valuable contribution to the fight against fungi, bacteria, and viruses. Others, which may be describe as antidotes, are used to distinguish between essential and poisonous metals. The third type is required to defferentiate between normal and pathological processes, e.g. in rheumatic diseases, cardiovascular disease, and cancer.

Metals in the living cell :

(a) The heavy metals : copper, iron, Manganese Molybdemum, cobalt, and zinc.

(b) The lighter, and usually more abundant, metals: calcuim, magnesuim, sodium, and potassium.

Copper is probably an essential trace element for plants but the amount is small and the average soil content of around 10p.p.m. is adequate to supply it.

It was well known that fairly quantities of the element are inimical to organism but more especially to fungi and algae hence the use of copper compounds in agriculture. The continued use of such preparations as Bordeaux mixture on vines in parts of Southern Europe has led apparently to the ground beneath them being quite green with copper salts but without any deleterious effect. It must be observed, however, that soluble copper salts are verry readily adsorbed by organic matter and immobilized. Copper-defficient soils have been recognized in some coastal regions such as the 'polders' of Holland, the everglades' of Florida, and certain parts of west and south Australia. In these places plant diseases develop, including poor cropping of cereals and chlorosis in fruit trees.

Herbivorous animals seem to react perceptibly to copper deficiency and several diseases of sheep and cattle have been reported. Only in exceptional cases, as for example near the outcrop of oxidized copper ores, deos the soil contain toxic quantities of copper.

In vertebrate blood copper exists as a series of copper proteins. It is also a constituent of a number of enzymes. It is important in the synthesis of haemoglobin. The adult human body may contain 100-150mg of copper. Copper is an essential element in the respiratory pigment haemocyamin in the blood of marine invertebrates such as molluscs and crustaceans. Other specific copper compounds which have been described include turacin, a copper porpphyrine, in feathers of some birds, and haemoglobin. Copper probably tends to form complex co-ordination compounds with various organic substances and may be precipitated in such forms in marine muds or sapropels. Subsequent bacterial action may lead to copper sulphides and even metallic copper and some of the copper of sedimentary deposits may have originated in this way.

Iron is a vital constituent of the porphyrin enzymes which are essential for all living cells. Other important iron compounds in mammals are the oxygen-transfer substances haemoglobin and myoglobin, ferritin, which transfers iron from the bowel to other tissues, and transferrin, which reduces the concentration of the (highly toxic) ferrous ions in the blood.

Iron-defiency in fruit trees causes poor crops. A soil may be rich in iron, and yet so basic that the iron is not available to the rootlets. EDTA, sprayed on such soil, extracts iron by forming the EDTA-ferric complex, which is absorbed by the rootlets. Experiments with tomato plants, grown in aniron-EDTA medium labelled with ^{59}Fe and with ^{14}C in the 2-position of the acetate group, showed that the plant absorbs the intact complex, which is translocated. Later, the organic part is broken down by metabolism which leaves the inorganic iron. When soil is poor in iron ferric EDTA is sprayed on the ground with the same good result.

Calcium: In many plants calcium oxalate is found and it has been suggested that the element acts by removing in an insoluble form excess of the oxalic acid which would otherwise be toxic to the plant. Some calcium is needed in the protein of the cytoplasm and the calcium pectinate which keeps cells together as tissues. The clases of plants called by ecologist calcicoles and calcifuges are so termed on account of their supposed need for rejection of calcareous soil.The differences are probably in the main due to different pH requirements which are controlled by calcium carbonate and also the physical conditions created in such a soil. Calcium ions could of course be quite readily absorbed from even an acid soil and plants of the calcicode type are not necessarily rich in calcium.

Potassium: This ion appears to be present in the plant in a soluble form and may be present in the cell sap in high concentration. There is much conflicting evidence, but it may be that one of the main functions of the element is to further catalytic activity in the formation of the starch by the plant.

Magnesium: The particular function of this element must lie in the formation of chlorophyll, the complex molecule of which contains a magnesium atom. There is also some evidence of the possible use of magnesium in phosphorus metabolism, particularly in connexion with lipoid substances.

Green algae are autotrophilic and they are of vast importance in the economy of Nature as providing a primary food source for higher organisms. In spite of their relative morphological simplicity they are able to elaborate all the characteristic organic molecules of larger plants. Many of them produce oils which are stored as globules in their cells. Marine microalgae are recognized as probably the major instrument for the fixation of carbon in a form which ultimately becomes liqiud petroleum. One of these groups of algae possesses the ability to absorb silica from water to produce complex skeletal structure These are diatoms. Diatoms are very numerous in lakes as well as the ocean and they thrive at relatively low temperatures and so are abundant in sub-arctic regions. The remains of diatoms form an important siliceous deposit- diatomaceous earth- which under different names has a great range of uses. There are also calcareous algae which can build up structures simulating coral.

These have also contributed with their remains to the formation of limestones. Their seasonal absorption of calcium carbonate in the case of small lakes can have the effect of causing pH variation in the water . In a similar manner there are seasonal variations in the silicate content of lake waters due to the act-ivitiesof diatoms.

Aguatic algae of some species such as Spirogyra have the capacity to remove surprisingly large quantities of elements from the water in which they grow. It has been found that this algae, growing in a mine water containing a total of 16 p.p.m. heavy metals, contained 2900p.p.m. zinc, 6600p.p.m. lead, and 920 p.p.m. copper. It is also stated that a large proportion of the copper content of certain lake waters is contained in the body structures of the plankton population.

Laboratory experiments have shown that small quantities of many elements are toxic to algae, but iron is the only one of these that is of importance in nature. Most algae grow best when the Fe_2O_3 content of the water is 0.2-2.0mg. per liter, and there is a distinct toxic effect when the amount of available iron is over 5mg. Many natural waters have total iron content of more than 5mg. per liter but these waters are not toxic, because of the buffer action of organic compounds or of calcium salts.

EXPERIMENT

Object: To observe the effect of trace metals on growth rate of Algae.

Procedure:

1- A basic nutrients were added to a trace metals pure water. The nutrients were:

Na^+	3 ppm.
K^+	2 ppm.
Ca^{++}	10ppm.
Mg^{++}	4 ppm.
NO_3^-	3ppm.
$PO_4^{\equiv}$	0.5 ppm.
NH_3	0.1 ppm.

2- A variant concentration of copper and iron were added to the vials containing the growth media:

Cu^{++}	0, 1, 2, 5, 10, 20, 50, 100, ppb.
Fe^{++}	0, 1, 2, 5, 10, 20, 50, 100, ppb.

3- A small amount of green Algae was added to each vial.

Results:

Cu^{++} \ Fe^{++}	0	1	2	5	10	20	50	100
100	X	X	B	B	L	B	D	Y
50	X	L	X	L	L	L	Y	Y
20	X	L	X	X	B	L	D	Y
10	X	X	L	X	X	X	D	Y
5	X	L	L	X	X	L	L	B
2	L	L	L	X	X	L	X	L
1	L	L	L	L	X	L	B	D
0	L	L	X	X	X	L	L	D

X : Green Algae , B: Black deposite , D : Dead Algea

L : Light Green, Y : Dead Algae+ Black deposite

References:

1- Albert, Adrien . Selective Toxicity . London: Methuen & Co. LTD. 1968. (PP. 297-300 .)

2- Smith, Gilbert . Fresh water Algae . New York: Macraw Hill, Book Company Inc, 1950. (P. 15.)

3- Day F. H. The Chemical Elements In Nature . New York: Reinhold Publishing Corporation , 1963. (pp. 76-77, 147-150.)

Conclusion:

This experiment has shown that algae grows best in 10ppb. iron and 10ppb. copper. Increasing or decreasing the concentrations of copper or iron kills the algae.

An excess of iron is very toxic to algae. In high concentrations of iron some of the algae is completly killed.

It was noticed that an excess of copper is not as toxic as an excess of iron.

In some of the high concentrations of copper, copper sulfide started precepitating.

In the second experiment , 20 vials that algae was still green in them, were taken and added to them different concentrations of copper:

0.1 , 0.2, 0.3 , 0.4 ,.............. 10, ppm.

no apreciable effect was noticed.