The Chemistry Of Natural Waters

A PROBLEM IN THE ADAPTATION OF FOREIGN TEACHING PRACTICES TO ETHIOPIAN CONDITIONS

R. M. Baxter

IN certain branches of science, notably biology, it is obvious that textbooks and practices designed for temperate regions are completely unsuitable for use in Ethiopia. This problem is being dealt with. In chemistry, on the other hand, the principles are universal and it might be assumed that foreign textbooks could be used in Ethiopian schools without any particular difficulty. I should like to call the attention of teachers to one situation where this is not so, and where in my opinion a too close adherence to a teaching practice which is traditional in temperate regions has led to a certain degree of misunderstanding on the part of Ethiopian students.

This problem came to my attention during the grading of the 1970 Ethiopian School Leaving Certificate Examination in chemistry, which included the following question:

In many parts of the world, for example the Red Sea coast of Ethiopia, there is abundant sea-water but a shortage of fresh water.

a) Describe some of the ways in which sea-water may be made suitable for drinking, irrigation, etc.

b) Discuss some other useful materials that can be obtained from sea-water.

The answers to this question were painfully instructive to the examiner. They revealed, incidentally, that an appallingly large number of students complete the twelfth grade without gaining any understanding of the nature of solutions, since many suggested that sea-water could be made useable by filtration, or by allowing it to stand in large tanks so that the salt could settle out. In particular, however, many students proceeded to describe, more or less correctly, procedures that may be used for the softening of hard water.

The softening of hard water and the desalting of sea-water are both included in the chemistry syllabus for secondary schools. Most students must surely know that the predominant ions in sea-water are sodium and chloride; indeed most students mentioned sodium chloride as a useful material obtainable from sea-water in their answers to part B. It must be concluded that they have had the chemistry of hard water and its softening so impressed upon them that the regard the softening of hard water as virtually synonymous with water treatment in general.

Practically all textbooks on chemistry for use in secondary schools in the temperate region deal at some length with the problem of hard water, and the chemistry of the processes involved in softening it. I suppose the reason for this is that it provides an excellent example of the explanation of a phenomenon of everyday experience in chemical terms. Most children in those parts of the world have probably had difficulty in obtaining a lather with certain waters, or have seen an accumulation of scale in a tea-kettle. The chemical reactions involved probably seem rather complicated to beginning students, and no doubt they derive genuine intellectual satisfaction from mastering them. In an industrial society a certain number of children will grow up to be engineers or mechanics of one kind or another, and no doubt it is desirable that they should understand the dangers of scaling in boilers and how it may be avoided by appropriate treatment of feed water. In short, there are excellent reasons why students in the temperate zones should learn about hard water at an early stage of their study of chemistry.

There are, of course, wide variations in the compositions of surface waters even over relatively small regions. However there are, in general, important differences between the composition of a typical Eastern African surface water and that of a typical surface water from North America or Europe. These differences can be readily seen in the following table. (The data for Lake Zwai are taken from Talling and Talling, 1965, and the others from Livingstone, 1963).

	Lake Zwai Ethiopia	Avon River England	Lake Erie North America
Bicarbonate	250	318	121
Sulphate	30	60	28
Chloride	18	20	17
Sodium	64	38	8
Potassium	14	–	1
Calcium	10	106	39
Magnesium	10	3	9
Total Hardness	65	277	135
Silica	47	5	2

All figures represent milligrams per liter, except total hardness, which is given in p.p.m. [The hardness of water is conventionally calculated as parts per million (p.p.m.) of calcium carbonate. 40 mg of calcium per liter or 24 mg of magnesium per liter is equivalent to 100 p.p.m. of calcium carbonate.]

Water with less than 61 p.p.m. of total hardness is considered to be soft. If it has 61-120 p.p.m. it is considered medium hard, 121-180 p.p.m is almost soft, Lake Erie water is hard, and water from the Avon River is very hard.

There are no doubt harder waters in Ethiopia than the water of Lake Zwai, but it may be regarded as a fairly typical example. Probably few Ethiopian children have ever particularly noticed the formation of insoluble calcium or magnesium soaps with water, or the formation of scale on domestic kettles. In any case, except for personal washing, soap is probably little used in Ethiopia. In many country areas *endod* is used, and elsewhere soap has probably been largely displaced by synthetic detergents. A discussion of the properties of hard water, which has considerable educational value for students in temperate regions, is for most Ethiopian children probably as remote from their experience as the chemistry of moon rocks, or perhaps even more remote, since they have at least seen the moon. It becomes merely something else to be learned, and serves to broaden the gap between what they learn in school and their everyday experience. This gap takes a long time to bridge; I have known a fourth-year student, in a research paper dealing with analyses of Ethiopian river waters, to state quite casually that the predominate cations in fresh waters are calcium and magnesium, although his own data showed that this is not true, in general, in Ethiopia.

From the technological point of view the problems of Ethiopian waters are quite different from those of waters of the temperate zone. It is easy to calculate from the data given in the table, that in both the specimens of temperate zone water described the concentrations of bicarbonate ion and calcium ion are very nearly equivalent. If the water were boiled both of these ions would be almost completely removed by precipitation of calcium carbonate, leaving a dilute neutral solution of salts. In the Ethiopian water on the other hand there is a large excess of bicarbonate over calcium. If all the calcium (and magnesium as well) were to be precipitated by boiling, the result would be essentially a solution of sodium carbonate. The small amount of carbonates precipitated would perhaps not be a serious problem, but the high alkalinity of the water might well cause a variety of corrosion known as caustic embrittlement. If an Ethiopian engineer, indoctrinated with principles of water treatment appropriate for other places, were to attempt to soften boiler feed water by adding lime he might easily convert sodium carbonate to sodium hydroxide and raise the alkalinity still further. The high silica content of Lake Zwai water is also worth noting. This a rather general characteristic of Ethiopian waters. It is possible that the formation of silica scale might prove to be a serious problem in the operation of high pressure boilers.

If teachers in Ethiopian schools feel they must discuss hard water and its treatment, it would seem reasonable that they might take note of the following. Conventional hard water is predominately a solution of calcium and magnesium ions with equivalent amounts of bicarbonate ions, in temporarily hard water, or sulphate ions, in permanently hard water, and not much else. Temporarily hard water may be softened by boiling or by adding an appropriate quantity of lime, and the resulting water is a neutral, very dilute, solution. Permanently hard water may be softened for example by ion exchange, and the resulting water will be a solution of sodium sulphate, also neutral.

Water of this kind is almost unknown in Ethiopia.

Surface water in Ethiopia is almost always predominately a more or less concentrated solution of sodium bicarbonate. It may contain a certain amount of calcium and magnesium ions and so be somewhat hard, but it is not usually more than slightly hard. The problems associated with the use of such water are in many ways quite different from those associated with the use of conventional hard waters, and the means that are appropriate for dealing with the latter may be quite inappropriate in Ethiopia.

The desalting of sea-water is not, in general, of much practical interest in temporate regions, since abundant fresh water is usually available. In the tropics it is of much more interest, and certainly in many parts of Ethiopia a cheap desalting process would be of tremendous value. It would seem reasonable for Ethiopian school-children to learn something about the technically feasible ways in which sea-water may be desalted, as well as some of the economic problems that prevent them being of general practical value. Perhaps some clever Ethiopian schoolboy might grow up to solve these problems some day.

REFERENCES

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