THE SOCIAL RESPONSIBILITY OF THE CHEMISTRY TEACHER

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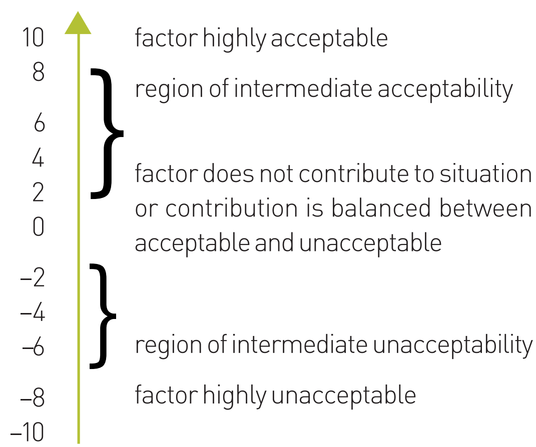
The last two decades have seen the development worldwide of many new chemistry curricula for the secondary level, nearly all of which have been characterised by an increased academic—and even esoteric—content. The same period has witnessed a relative decrease in students, especially the more able ones, taking chemistry degrees in many countries. It is my contention that this is an example of cause and effect and that to motivate more able students to consider courses and careers in chemistry, it is necessary at the secondary level that chemistry should be seen to have relevance to the students.

What then does the modern student see as relevant? The burning issues seem to be pollution, environmental conservation and social awareness, and successful chemistry teaching must therefore enable students to see connections between the subject-matter and social concerns. In addition to what students see as relevant it is in any case an important part of our task to develop a sense of social responsibility in our pupils and to produce citizens and consumers who are aware of the pros and the cons relating to scientific developments so that they can make rational decisions in the face of the conflicting barrage of opinions presented by the media. Several attempts have now been made in various countries to take examples of the significance of chemistry and to show how by a consideration of health, well-being, sociological, economic, geographic and related factors chemistry itself takes on more meaning to the able and concerned pupil.

Overall Acceptability

In the June 1979 issue of *School Science Review,* there is a very relevant article by W.G. Burtons[1] in which he suggests that pupils should be asked to identify all factors relevant to a particular case study and to categorise them into social and political, industrial and economic, environmental and personal. Each factor is then evaluated on a scale as shown:



After the evaluation, a summation is made. A positive result suggests overall acceptability whilst a negative one indicates an unacceptable situation.

Case Studies

He then outlines three useful case studies: the "poisoning of Michigan" in which 1000 Kg of polybrominated biphenyls accidentally got into animal feed; "Minamata 'Disease'" as a result of mercury poisoning and "The Seveso story" in which 1500 Kg of tricholorophenol and 2.5 kg of 2, 3, 7, 8 - tetrachlorodibenzo-p-dioxin (TCDD) were accidentally discharged to the atmosphere. For each case study some of the relevant factors are listed; for example, some factors relevant to the Seveso incident are:

Social and political

Seveso has become an undesirable place to live.

Community life has been disrupted by evacuation of residents and the presence of guards.

The incident may have affected the passage of a sensitive abortion bill through the Italian Parliament.

The incident may have affected the balance of power in local government.

The herbicide has found a use in warfare.

Industrial and economic

The factory provided employment.

2, 4, 5-T has helped farmers combat weeds.

Medical treatment for the victims has been expensive.

Compensation to victims will be expensive.

The cost of decontamination will be high.

Environmental and personal

A large area of land has been destroyed.

Local people have lost pets and livestock.

People may go through life feeling less well than they should because of TCDD.

What is it like to grow up with a face disfigured by chloracne? A family may produce and have to bring up a deformed child. A woman may have to face the prospect of having an abortion or producing a deformed baby.

The major failing of these examples seems to be that, even if pupils evaluate the factors and give a final positive rating, the negative aspects of chemical industry are given undue prominence by selecting accidents for detailed study. After all, accidents are the exceptions rather than the rule and we should perhaps concentrate more on the norms of industry, although affording due mention of problems encountered.

Coincidentally the same issue of the *School Science Review* give an account more on these lines in an article by S.D. Rust[2] entitled "Soaps and Detergents—a 'social' treatment". In this he outlines how one could tackle this theme historically and in terms of scientific developments and associated improvements in pollution control; pupil experiments are included in his approach, which concluded with a discussion of concerned for the environment caused by the inclusion of phosphorus and boron compounds in modern detergent formulations—a good example of where social responsibility and an ability to evaluate the advantages versus the disadvantages is important.

Industrial Case Study

An interesting industrial case study is provided by the production of ethanol by fermentation of molasses. The latter contains about 50 per cent sugar and can be fermented in the well-known way using the yeast *Sacharomyces cerevisiae* to yield a solution containing 11 per cent ethanol at a conversion efficiency of about 80 per cent. This solution if subsequently concentrated by distillation a 'slop' containing 13 per cent solids by mass is left behind. One can build a discussion around this process in which the economic value to the sugar industry is highlighted, together with the socio-economic implications of transporting the molasses and other raw materials to the site of the factory and the industrial uses and social problems associated with the end-product. An obviously important by-product is the carbon dioxide produced in large quantities and used *inter alia* in the soft drink industry and as a refrigerant: in this latter context it is used for keeping miners cool whilst working underground. In South Africa, for example, this provides a link with a very important economic base of the country.

Ecological Effects

However, what is perhaps more interesting is what happens to the 'slop'. In South Africa, disposal as liquid effluent into a local river was entirely ruled out by local regulation—and rightly so as the biological oxygen demand of such material is naturally extremely high. Attempts were made to burn the material but the resultant smoke and smell were unacceptable and the company was thus compelled to find a use for it. The solution was found in spray drying the material and later adding to the product maize meal gluten, wheat bran, mono-calcium phosphate urea and salt. Under the trade name of 'Rumevite' this material has shown promise of revolutionising the beef industry by preventing the loss in mass and condition of animals during winter feeding and formulation plants are now also operating in the UK, Australia, Venezuela and Zimbabwe. In contrast the Brazilians have recently begun to operate a similar plant and are disposing off their 'slop' direct into the local river with catastrophic ecological effects.

There are some more interesting case histories in 'Chemical Industry: Social and Economic Aspects' by F.R. Bradbury and B.G. Dutton[3] including one of topical interest namely the development of tetraethyl lead as an 'anti-knock' reagent. Curiously this is also taken up by C.B. Hunt[4] in the June 1979 issue of *School Science Review* in an article entitled 'Chemistry and the Internal Combustion Engine'. Here the author sets out ultimately to describe some chemical aspects of the internal combustion engine, to view some developments in their historical and social contexts and to illustrate the compromises resulting from the interplay of technological and socio-economic factors.

Food Availability: a problem

An aspect of chemistry which could well be given more attention in schools is the potential for good which it holds; many pupils might be awakened to the fascination of the subject if they could see more clearly the fields in which they might be able to make socially significant discoveries: currently, world population is doubling every thirty years, thus producing a problem of food availability—a problem not unknown in India. Chemistry might contribute to the solution of this problem by improving birth control methods, by supplementing food resources either by producing new feeds, or by developing new fertilisers and by finding chemical ways of slowing down or stopping bio-deterioration. According to Bradbury and Dutton, annual losses due to fungi equal to two per cent of the whole industrial output of North America and Western Europe, whilst the rodent population of the USA consumes or damages food equivalent to $9 per worker (1972 prices); a second field pregnant with potential is that of biologically acceptable methods of disposal of cartons of various types but especially those made of plastics, whilst environmental control by techniques such as chemical seeding of clouds still needs much development work.

Perhaps the principles incorporated into high school syllabi could be illustrated with examples from the field of pharmaceuticals and issues such as drug use and abuse could be stressed. Over-riding all other areas of concern must surely be that of energy and it must be part of the chemistry teacher's job to make pupils aware both of the magnitude of the problem and of the social consequences of not solving it. An awareness of the importance of petroleum as a chemical feedstock compared with the extravagance of using much of it purely for travel needs is to be emphasised—especially in the USA judging from published information—whilst the public should be made more aware of alternatives such as the Lurgi process for producing oil from coal as performed so well in South Africa, and the potential of solar, tidal and wind energy. This must be as important a part of a scientific education for the average citizen as, say, a knowledge of atomic orbital shapes as required by so many syllabi in various countries!

Removing Pollutants

Basic chemical ideas and techniques can be linked well with social concern in a consideration of water resources. The shortage of fresh water is acute in many areas of the world and desalination by such methods as electro-dialysis, reverse osmosis and flash distillation is likely to become much more significant in the next decade or two. The chemist is also called on to devise ways of removing pollutants from effluent water such that it will have no significant detrimental effect on plant and animal life and to ensure the satisfactory condition of recycled water. Typical consent conditions for discharge into streams are:

Constituent	Maximum allowed (mg 1-1)
Biological oxygen demand	20
Suspended solids	30
Sulphide (as S)	1
Cyanide (as CN)	0.1
As, Cd, Cr, Cu, Pb, Ni, Zn, individually or in total	1
Free chlorine	0.5
Oils and greases	10
pH	5-7
Temperature	30^0C

These provide a challenge both to the chemist controlling discharge and to the analyst monitoring such discharges.

More Awareness

In essence therefore, my message is simple; the chemistry teacher must himself or herself be aware of areas in which colleagues have to make decisions with social consequences and must instill in pupils the need for thoughtful appraisal of the soil effects—both positive and negative—of chemical advances. Pupils who can accept this more challenging approach to chemistry will, in my view, ultimately get more satisfaction from their studies and wish to take up the practice of chemistry as a career.

We also need to think again whether it is ultimately in our pupils' best interests to study the various sciences, and indeed other related subjects, in isolation from each other. The examples I have given only make sense when discussed in a broad interdisciplinary context and perhaps we should really be covering many traditional disciplines under the one subject of environmental science.

Making Chemistry more Relevant

There are now many materials available to help teachers make their chemistry more relevant. These sometimes take the form of practical projects as described by Daniels and Tomlinson[5] or as simulations and case studies of which several now exist, or as games which combine chemistry and industrial issues. Surely suitable subjects for such material would be both Sindri and Tata, although before materials of this type will be freely used in school, teachers will need an assurance that examination questions will reflect the philosophy outlined above. This has now happened in the UK and I conclude this article by quoting a question posed by an English examining Board.

The following map is of a fictitious island, Jumb, which lies some 350 km south-east of a friendly industrial state, Terania.

Jumb is scenically attractive with a craggy coast indented by many small bays with sandy beaches. The area of limestone hills has a small region of spectacular caverns. In the north, the swamp region harbours several species of plants which grow nowhere else in the world together with a population of small reptiles which are uniquely adapted to the specific environment. During July and August many Teranians visit Jumb for their holidays and visitors are beginning to come from other parts of the world. The eastern coast and the adjacent hills are becoming particularly popular with tourists.

The population of Jumb is 140,000, with the towns marked on the map housing almost all the people. Coastal fishing was a major industry but in recent years the catches have decreased to a point at which only a small amount of subsistence fishing is carried out. There are small manufacturing industries in each of the towns providing for the consumer needs of the population, but, apart from coal-mining, main employment is seasonal agriculture and tourism. The deposit of sulphur-containing iron ore in the south-east of the island has only recently been discovered and the government of Jumb is anxious to develop a steel industry because

Scale 1 : 500 000

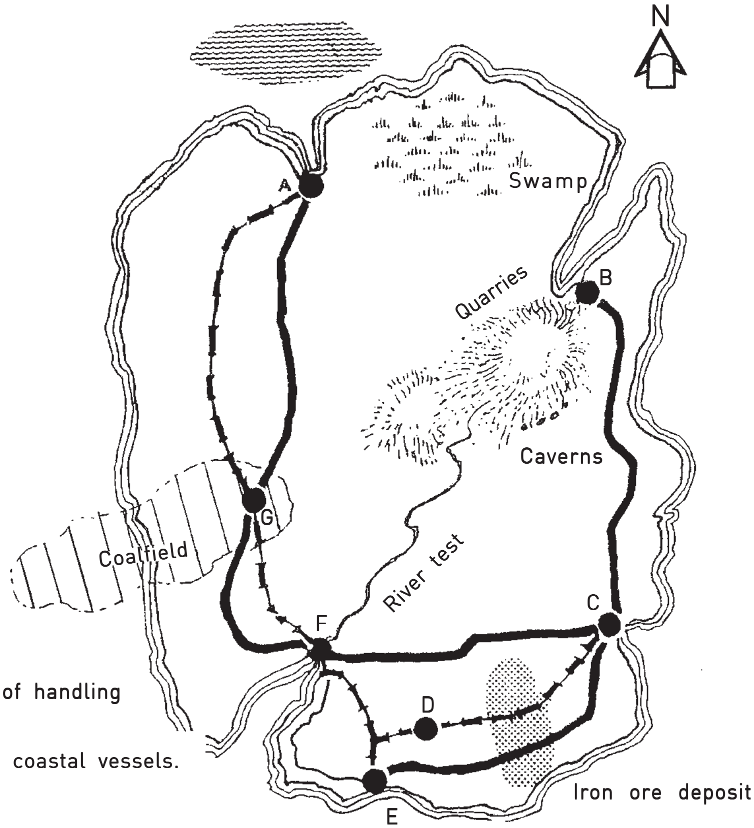
Key

Existing main roads

Existing railways

• Towns

A	15 000 population
B	22 000 population
C	15 000 population
D	10 000 population
E	10 000 population
F	10 000 population
G	22 000 population



Town A is the only port capable of handling large ocean-going ships.
Towns B and F can handle small coastal vessels.

Terania is willing to buy all the steel which Jumb can export. Such a development could provide additional employment in steel production and result in the development of light industries.

(a) Explain where you would recommend the construction of a steel works employing 4,000 men. Give reasons for your recommendation and state why you would prefer your site to others which might be alternatives.

(b) Suggest what pollution problems might arise from the development of a steel industry and discuss ways in which the dangers could be reduced. (1) Give special attention to measures which could be taken to preserve the island's amenities for the development of tourism.

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