SOME PROBLEMS ARISING FROM THE PRACTICAL USE OF AQUATIC HERBICIDES

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Summary The paper outlines the responsibilities of the Water Authorities for water quality control and indicates aspects of the use of aquatic herbicides upon which information appears to be lacking. Attention is drawn to the importance of adequate supervision and training in their use and some examples are given of pollution incidents which have occurred. In conclusion areas for further investigation, discussion and control are suggested.

INTRODUCTION

The use of herbicides for aquatic weed control has become, in recent years, an increasingly important feature of river management. This development has been watched closely by those concerned with water quality control and some disquiet is felt at the possible widespread and routine use of herbicides.

The attitudes of the former river authorities to herbicide use varied. Some did themselves employ herbicides for aquatic weed control whilst others were firmly opposed to them and continued to employ manual and mechanical methods. With rising labour costs and recruitment problems, however, chemical weed control became more attractive. Mechanical methods frequently involved high capital outlay and often presented problems of access. However, in general, chemical weed control was not employed on rivers which were subsequently used for public water supply. Particular resistance to the use of aquatic herbicides often arose from water companies and boards concerned at such use on rivers and tributaries upstream of their abstraction points.

On 1st April 1974, the functions of the river authorities became the responsibility of the new water authorities who also assumed responsibility for water supply and sewage disposal, thus giving recognition to the interdependence of these different stages of the water cycle. With their responsibilities now including the recreational use of waters, the new authorities have an added interest in keeping rivers clear for their optimum use for sports such as angling and boating.

LEGAL ASPECTS

There are two principal Acts of Parliament under which river pollution is controlled in England and Wales. It is an offence under the Salmon and Freshwater

Fisheries Act 1975 to cause waters containing fish to become poisonous or injurious to fish or the spawning grounds, spawn or food of fish, as a result of allowing liquid or solid matter to enter such waters and the Rivers (Prevention of Pollution) Acts 1951-61 make it an offence to allow any poisonous, noxious or polluting matter to enter a stream. The latter requirement is embodied in the Control of Pollution Act 1974 (which has yet to be implemented) and is substantially extended to include coastal waters and specified underground waters. The term 'stream' is defined as a natural or artificial river, watercourse or inland water but does not include any lake or pond which does not discharge into a stream. However the 1974 Act provides that this definition may be extended to any prescribed lake, loch or pond under regulations to be issued by the Secretary of State.

The Control of Pollution Act provides a defence against prosecution if a pollution incident occurs as a result of an act or omission which is in accordance with good agricultural practice. For this purpose the Ministry's agricultural Codes of Practice will provide the yardstick of 'good agricultural practice' but it is not yet clear whether the Code of Practice relating to the use of aquatic herbicides will serve the same function.

In the present context the effect of the operative legislation is that where pollution has occurred as a result of the use of herbicides the person or persons responsible may be prosecuted by the relevant water authority. But the legislation does not provide machinery for the water authorities to act in advance to prevent pollution occurring from the use of herbicides. This aspect is dealt with by the Ministry of Agriculture, Fisheries and Food Code of Practice for the use of aquatic herbicides and the Code stresses that before a herbicide is used the appropriate river authority (now water authority) should be consulted about the possibility of pollution. Many users do comply with this provision but it is by no means universal practice and although water authorities are now urging users to notify them in advance there is no legal requirement that they should do so.

The Code of Practice draws attention to the use of herbicides in watercourses from which water will eventually be used for public water supplies and states that they should not be used in such watercourses unless the pollution prevention officer of the river authority (now water authority) is satisfied that there will be no toxic hazard and that no undesirable taste, odour or colour will develop in the water when taken and used for public supply.

PUBLIC WATER SUPPLY

Where river water is stored in a reservoir prior to treatment, an opportunity is provided for a reduction, by dilution and biodegradation, in the concentration of herbicide residues which may be present. However the conventional treatment processes of coagulation, sedimentation, softening and filtration which follow have very little effect upon dissolved herbicide residues. Chlorination, in fact, may enhance the odour of some organic compounds in water (Croll, in press).

The Pesticides Safety Precaution Scheme requires that a manufacturer provides information upon both the acute and chronic mammalian toxicity of his product. Clearance under the Scheme of a product for use in aquatic weed control is only given if this evidence indicates that when the herbicide is used in accordance with the Government's and the manufacturer's recommendations and the MAFF Code of Practice, it will not in any way endanger the health of a person who might subsequently drink that water.

Several water authorities, however, have expressed reservations about the use of herbicides on waters which are subsequently used for public water supply. This attitude reflects the seriousness with which the water authorities view their responsibilities to the water consumer. Widespread and regular use of aquatic herbicides will tend to increase the risk of residues reaching water supplies and will extend the period during which they may be present. Further re-assurances are needed that aquatic herbicide residues, their principal breakdown products and other materials present in formulations do not present a threat to the health of the consumer.

The possibility of chemical weed control resulting in taste and odour in water supplies is a real one, both from the herbicide itself and from substances released during the subsequent decay of vegetation. The threshold odour of 2,4-D is low, lying between 0.01 and 0.1 mg/l, and a possible degradation product, 2,4-dichlorophenol, has a threshold odour of 0.002 mg/l (Faust & Aly 1964). Information on threshold odours is not available for all herbicides which have been cleared for aquatic use. Such data for aquatic herbicides in both unchlorinated and chlorinated waters would permit problems of this kind to be anticipated and avoided. If breakdown products are found to occur in the water in appreciable concentrations there is also a need to determine threshold odour values for these substances.

However satisfied one might feel that a herbicide will be perfectly safe if used in accordance with recommendations, strenuous efforts are needed to ensure that recommended procedures and rates of application are closely adhered to and that accidental spillages do not occur. The question might be asked whether the financial savings resulting from the use of herbicides in water supply rivers justify the increased risk to the consumer (if only from its misuse) which this entails. Alternatively one could consider the cost of providing additional water treatment plant to remove herbicide residues in the light of the savings resulting from chemical control. Croll (in press) has indicated that efficient removal of 2,4-D is achieved using activated carbon treatment but information on the removal of other herbicides appears to be lacking.

Considerations of this kind indicate the importance of suitable methods of analysis for low levels of herbicides in water to enable monitoring to be carried out where necessary. However, provided such techniques are available, it is difficult to see the justification for withholding agreement to the proper use of herbicides on those parts of public water supply river systems which are remote from abstraction points if their use is not precluded by other factors.

DIRECT EFFECTS UPON AQUATIC FAUNA

Information is available on the acute toxicity to both fish and fish food organisms of all herbicides cleared for aquatic use. In addition an assessment of the effects upon the invertebrate fauna is now usually made during the course of field trials. The former Essex River Authority conducted aquatic invertebrate surveys following application of various cleared herbicides at recommended rates and no direct effects of the herbicide were detected.

Laboratory toxicity tests using aquatic organisms are usually conducted over periods of 48 to 96 hours. However for slow release products, which may in some instances remain in the water at phytotoxic concentrations for periods in excess of thirty days, extrapolation of LC_{50} values obtained in short-term tests is highly questionable.

Until recently the chronic toxicity of aquatic herbicides to fish has received little attention, but Tooby et al (1974) have shown that dichlobenil residues accumulate in fish tissues and that long-term exposure to 1 mg/l concentrations can be lethal for fish. With the more widespread and regular use of herbicides and the appearance of slow-release preparations the period during which a fish may be exposed to herbicides will be extended. In these circumstances the question of chronic effects becomes more important than it has been in the past.

EFFECTS UPON THE GENERAL CHARACTER OF WATERCOURSES

As a result of the diverse uses to which the watercourses in this country are put, it is only the upland streams and rivers which can be considered today to be substantially in their natural state. Rivers are receiving increasing quantities of effluents, being developed and regulated as water resources, improved for land drainage purposes and used for recreational pursuits. The water authorities have the task of developing rivers such that they may meet in the best possible way, all demands placed upon them. Hence they must be aware of the likely effects of any new development upon the flow regime, quality and ecology of the river. Indeed in considering proposals which related to their statutory functions they are obliged under S.22 of the Water Act 1973 to 'have regard to the desirability ... of conserving flora and fauna' and to 'take into account any effect which the proposals would have ... on any such flora or fauna.'

Manual and mechanical methods of weed clearance have played a part in shaping the present character of our watercourses. Chemical weed control will clearly impose rather different pressures upon the river system and if used widely as a routine management technique is likely to lead to some long-term changes in the ecology and character of watercourses. Such changes may not detract seriously from the value of a watercourse to the various users and may therefore be acceptable but in order to make a judgement further information is needed.

A comparative study was carried out by Roberts (1974) at sites in Essex where manual or chemical methods had been used for a period of five years. The subjects of this study were small watercourses in which emergent vegetation gave rise to land drainage problems. Those which were treated chemically received annual spring applications of dalapon and 2,4-D and some sites also received an autumn application of dalapon. Significant differences in the flora were found between the sites receiving chemical treatment and those where manual control was practised. However, no significant overall difference was found between the aquatic invertebrate communities at the two types of site although it was suggested that the large scale removal of emergent vegetation could have an adverse effect upon waterside species of birds. Brooker (1975) has also suggested a possible effect upon bird life and upon invertebrates living in the aerial parts of emergent vegetation as a result of the extensive use of herbicides but in a short-term study involving the use of dalapon and 2,4-D he found no adverse effect upon aquatic invertebrates.

Further work is needed to learn of the longer term effects of other herbicides and for comparative purposes the effects of mechanical as well as manual methods. It is proposed that the Anglian Water Authority will carry out more field investigations of this kind including a consideration of the possible long-term effects of different weed control methods upon fish populations.

DE-OXYGENATION OF WATERS FOLLOWING HERBICIDE APPLICATIONS

Dead and dying weeds in water impose an oxygen demand upon the water as a result of respiration by the dying plants and the bacterial activity associated with their decay. In circumstances where the biomass of decaying weeds is large and water temperatures are high this demand can be very severe. Normally oxygen removed from the water is replaced from the atmosphere through the water surface and by oxygen produced in the photosynthetic activity of submerged plants. Following the cutting or herbicide treatment of submerged weeds photosynthetic oxygen production falls rapidly. In stagnant and slow flowing waters re-aeration through the water surface is slow, especially where the ratio of surface to volume is low, and severe deoxygenation of the water can occur. This in turn may result in the death of fish and other aquatic life and give rise to aesthetically objectionable conditions.

When weeds are cut manually or mechanically they can and should be removed from the water if significant deoxygenation is likely to occur. However, weeds are not normally removed when chemical methods are employed and the problem is controlled by applying the herbicide at a time of year when the plant biomass is relatively low, e.g. April. Or, if it becomes necessary to treat when weed growth is well established, planned spaced applications may be made, i.e. the water body is treated in sections with a sufficient time interval between each application to ensure that at any one time the biomass of decaying weed is not excessive.

The practice of controlling weeds after heavy growth have become established and the difficulty of determining the maximum area which can be treated safely is illustrated in the examples given below. Adequate training, experience and planning are essential if problems are to be avoided. Brooker (1974) has recently suggested a promising technique for predicting both the severity of deoxygenation following a herbicide application and the likelihood of a fish mortality occurring. Such an approach necessitates more detailed preliminary work than is usually undertaken but would be well justified where there are fisheries interests.

CASE HISTORIES

It is perhaps appropriate to describe some incidents which have arisen recently as a result of the use of herbicides and which serve to illustrate some of the points which have been made.

1. A fenland drain which contained filamentous algae and submerged vascular plants was treated with copper sulphate in early September. Within three days of the application a severe fish mortality had occurred in the 5.8 km section which had been treated. It was estimated subsequently that some 15,000 fish died in this section and immediately downstream. Copper and dissolved oxygen concentrations in the water course at this time are shown in Table 1.

Table 1

Dissolved oxygen (% saturation) and copper concentrations (mg/l) following treatment of a water course with copper sulphate

Sampling Station	Distance from u/s end of treated section (km)	6th September		10th September		12th September	
		D.O.	Cu	D.O.	Cu	D.O.	Cu
A (u/s of treatment)	-	-	-	89	0.02	61	0.02
B (treated section)	1.0	53	2.23	26	0.23	89	0.02
C (treated section)	4.5	33	1.08	nil	0.54	nil	0.45
D (treated section)	5.8	36	1.15	75	0.36	59	0.25
E (d/s of treatment)	5.9	90	0.08	-	-	-	-
F (d/s of treatment)	7.0	-	-	111	0.17	98	0.20

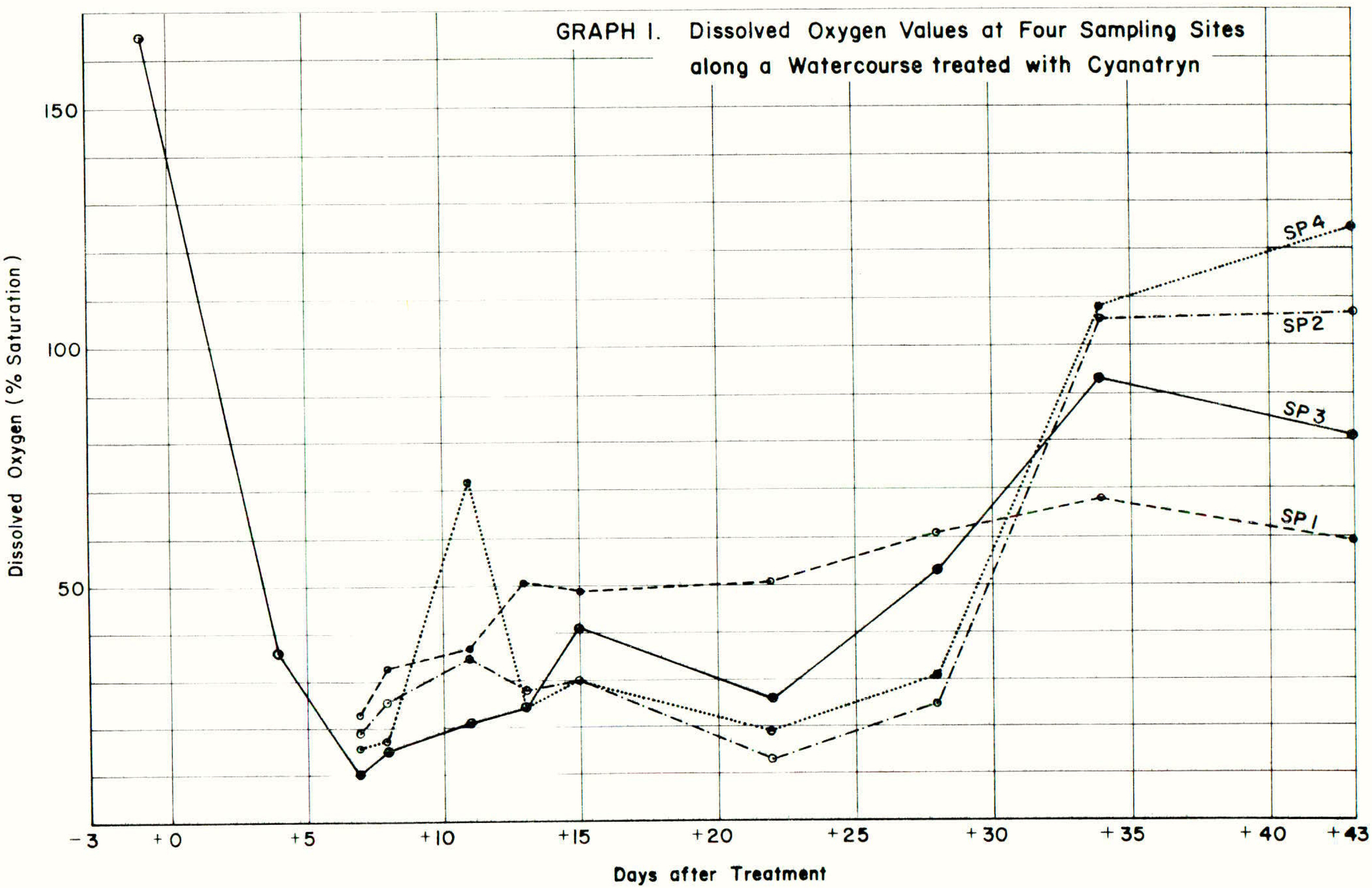
De-oxygenation of the water was the major factor leading to the fish mortality but the copper concentration was also at a level which was toxic to fish (Brown 1968). The herbicide used had not been cleared under the P.S.P. Scheme and it was present in the water at more than twice the normally used maximum concentration of 1 mg/l as Cu (Robson 1973). Furthermore, an excessive quantity of weed was destroyed with a single application with very severe effects upon dissolved oxygen levels. At sampling station C, the dissolved oxygen level was still at 15% saturation eight days after treatment and had not returned to normal levels until some four days later. The former river authority concerned did not receive prior notification that the herbicide was to be used.

2. A 0.8 km section of a West Country drainage channel was treated during the month of July to remove excessive weed growth which was making fishing difficult. Terbutryne was applied at the recommended rate. Shortly before treatment was carried out the water temperature was 18°C and the dissolved oxygen was at 80% saturation. Two days after treatment the dissolved oxygen was at 24% saturation and had fallen to 16% on the third day. Further de-oxygenation continued and zero dissolved oxygen was recorded in some parts of the watercourse. Emergency aeration using high pressure pumps was employed for a period of ten days and submerged weed over a distance of 2.5 Kms. was removed using mechanical buckets. Despite these efforts a substantial number of specimen fish died as a result of oxygen depletion.

3. Cyanatryn used to treat 1.65 kms of a small drainage channel in late June. The watercourse contained dense growths of submerged vascular plants and small quantities of filamentous algae. There was very little flow in the channel and the chemical was applied under scientific supervision to achieve a nominal concentration in the water of 0.25 mg/l a.i. Following treatment oxygen levels were severely depleted for some thirty days (Graph 1). Only small fish, principally sticklebacks and minnows, were present in the drain and they were seen to be swimming in increasing numbers near the surface seven days after treatment but no dead fish were observed. The temporary rise in dissolved oxygen level after the seventh day was attributable to some apparent regrowth and photosynthetic oxygen production which was not sustained. Despite the indications that severe inhibition of photosynthesis had occurred the treatment was regarded as largely unsuccessful with regrowth of some submerged weeds after the twenty-eighth day and heavy growths of emergent vegetation developing. The failure to effectively destroy the submerged vegetation resulted from an unexpected inflow of freshwater which diluted the cyanatryn. This problem could only have been overcome by applying at a high rate initially or making a repeat application.

Marked de-oxygenation following applications of triazine compounds has been reported elsewhere (Haddow et al 1974) (Eastman 1975) and appears to be a critical factor in their use. This may be attributable to their mode of action upon treated plants (Payne 1974) whereby photosynthetic oxygen production is rapidly halted but respiratory oxygen demand continues for some time.

4. Instances have occurred where the treatment of weed growths with herbicides has been successful in controlling the primary cause of the problem but has been followed by other growths which were equally undesirable. The margins of a lake which was some four hectares in extent were treated with dichlobenil in May to control


GRAPH I. Dissolved Oxygen Values at Four Sampling Sites along a Watercourse treated with Cyanatryn
Dissolved Oxygen (% Saturation)
150
100
50
−3
+0
+5
+10
+15
+20
+25
+30
+35
+40
+43
Days after Treatment
SP 4
SP 2
SP 3
SP 1

canadian pondweed (Elodea canadensis) and hornwort (Ceratophyllum sp.) which were interfering with angling. Dissolved oxygen levels fell following treatment and some 100 fish died but most of the two troublesome weeds were destroyed. During July, however, a prolific growth of a filamentous alga developed and the angling club concerned were again anxiously seeking a means of controlling this troublesome situation. They were advised that if the fish populations were not again to be put in jeopardy the weed should be physically removed.

5. A survey carried out by the former Great Ouse River Authority in 1973 showed that most aquatic herbicides used in their area were ones which were approved for such use. However appreciable quantities of copper sulphate and some MCPA were being used, neither of which have been cleared or approved for aquatic use. In other areas a paraquat formulation which has not been approved for aquatic use has been used. Although paraquat has been cleared this particular formulation contains a wetting agent which has a high toxicity to fish and therefore renders it unsuitable for such use.

Adequate supervision and training in the use of herbicides is essential if the Recommendations for Safe Use and the Code of Practice are to be observed and every effort should be made to ensure that instructions on labels are clear and intelligible. This is important not only for safe use but to prevent wastage of money and effort as a recent incident demonstrated. A series of marshland ditches were sprayed regularly each April to control emergent reeds. Dalapon was normally used but when the foreman went to collect the chemical from the stores he was told that the usual formulation was not available and was given another product with which he duly treated the watercourses for which he was responsible. Later in the summer the ditches were heavily choked with reeds and no real benefit could be seen from the spraying. Upon investigation it was found that the chemical which had been used was maleic hydrazide, a growth retarder for use on perennial grasses on banks.

CONCLUSIONS

1. The user of herbicides should recognise that, whilst such techniques might offer operational advantages, there are other aspects of their use of which he should be aware when deciding upon the best means of weed control.

2. Further dialogue is necessary between the water industry, the Department of Health and Social Security and the Regional Health Authorities on the public health implications of the long-term ingestion of residues of herbicides and their degradation products in drinking water.

3. Threshold odour concentrations in both chlorinated and unchlorinated waters should be established for herbicide formulations which are cleared for aquatic use and for any major degradation products which may persist in the water.

4. The long-term toxicity of aquatic herbicides to representative fish species should be assessed in laboratory and field tests and the tissues of fish which have been subjected to long-term exposure analysed for herbicide residues.

5. When new herbicides are being examined for clearance consideration should be given to the possible effects of their extensive and regular use as well as occasional use. A readily accessible list of formulations cleared for aquatic use should be made available.

6. Selected watercourses which have received regular and substantial applications of herbicides should be monitored to assess any long-term ecological changes resulting from this method of control. Similar investigations are needed for comparative purposes where manual and mechanical methods have been used.

7. More reliable and precise methods of predicting the deoxygenation effects of herbicide applications should be developed and planned spaced applications adopted as standard practice where it is anticipated that problems such as those outlined in this paper may arise.

8. There is evidence that the Code of Practice is not always followed closely and the need should be fully recognised to notify the Water Authorities and to obtain their agreement and comments on proposed herbicide use. This raises the question of whether there is a need for a statutory requirement that the consent of the water authority be obtained before any aquatic herbicide is used, particularly on water supply rivers. Certainly closer liaison between the user and the scientific staff of the water authorities would ensure the safer and more effective use of herbicides.

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