Tea Q. 44 (1), 30-36. 1974. Printed in Sri Lanka.

AGRICULTURE AND WATER POLLUTION

*A. W. R. Joachim

(Water Resources Board, Sri Lanka)

The pollution of the environment—air, water and soil—has become an alarming feature of present-day existence in developed countries consequent on their intensive industrialisation and technological development since the 1940s, and especially in urban areas where industrial wastes have created serious problems of water pollution. Pollution caused by soil erosion, animal husbandry activities, and heavy fertilizer and pesticide usage in crop production operates mainly in rural areas. Agents of water pollution common to both rural and urban areas are sanitary wastes, sewage and modern detergents. The danger of pollution, especially of soil and water, has now spread to the developing countries where agriculture has been intensified and modern techniques of production have been adopted to keep pace with the need to feed rapidly-increasing populations. In this paper, which serves merely as an introduction to a subject of great complexity and far-reaching importance, only such aspects of water pollution as are likely to be contributed to by agriculture will be dealt with.

Because of the generally accepted view that any measures required for raising agricultural productivity and ensuring its economic viability are justified in the endeavour to feed an enhanced world population, water pollution in relation to Agriculture has not perhaps received adequate attention. In recent years, however, Agriculture has increasingly been listed as one of the major contributors to water pollution, at least in developed regions where the use of agrochemicals is quite extensive.

RECENT PUBLICATIONS ON WATER POLLUTION IN AGRICULTURE

Three useful publications on water pollution in Agriculture have been published recently. These furnish valuable information on various aspects of the subject in relation to the United States and the United Kingdom. The first entitled 'Agricultural Practices and Water Pollution' is a collection of papers read at a Conference in November 1969 on 'The Pollution of Water by Agriculture'. It represents the authoritative views of the leading agricultural, biological and social scientists, hydrologists, engineers, geologists and other specialists of the United States on the subject. The second is an analytical report of the American Chemical Society on 'Cleaning Our Environment—the Chemical Basis for Action' (2) published in 1969, and the third a publication in 1970 by the Agricultural Research Council, U.K. on the present position in regard to "Toxic Chemicals in Agriculture in the U.K. (3rd Report)" (3). This is a comprehensive survey of the research work carried out in that country and elsewhere on pesticides in general and of the organochlorine insecticides in particular.

* Formerly, Director, Tea Research Institute of Sri Lanka, and Director of Agriculture, Sri Lanka.

Three other interesting publications have appeared. The first is an issue of *The Tea Quarterly*, Volume 42, Part 4, December 1971, which is devoted to the theme 'The Environment and Agriculture', and contains a wealth of information both of local and general interest on the topic (4). The second is an issue of 'Chemistry in Britain', Volume 8, Number 2, February 1972, which contains a very illuminating study by Barry Commoner, Professor of Botany at the Centre for the Biology of Natural Systems, Washington University, Missouri, U.S.A. on 'The Environmental Cost of Economic Growth' (5). This gives a semiquantitative evaluation of the environmental costs of economic growth in Agriculture and Industry in the United States since World War II. The third is the Presidential Address of Dr D. L. Gunn, former Director of the Tea Research Institute, to the Association of Applied Biologists, U.K. in 1972. This address is reproduced in this issue of *The Tea Quarterly* (6) as being an up-to-date, comprehensive, searching and unbiased analysis of the problems relating to the use of the organochlorine insecticides, particularly of DDT, in Agriculture and Public Health *vis-a-vis* animals and man. Reference to all these publications will be made in this survey.

SOURCES OF WATER POLLUTION

The chief sources of water pollution in Agriculture are (a) sediments caused by soil erosion, (b) animal manures and wastes, (c) fertilizers, and (d) pesticides, which include insecticides, fungicides, herbicides and soil fumigants. These are briefly considered below:

(a) *Sediments from Land Erosion*

Sediments are a major pollution material of surface water. Soil eroded from cultivated land is the chief source of sediment in rivers, streams and reservoirs, but road construction, stream bank and gully erosion, housing developments and logging operations are also important contributory sources. These sediments contain and adsorb organic and inorganic compounds which supply plant nutrients such as nitrogen and phosphorus to the water, and thereby often promote excessive growth of bacteria, algae and other plant life in lakes, reservoirs and channels. In consequence, a depletion of dissolved oxygen occurs especially on the death and decay of these organisms and this may result in deleterious effects on fish and the onset of anaerobic conditions conducive to foul odours and undesirable tastes in the water. The process of enrichment of water with nutrients and its after effects is known as eutrophication. Sediments also asorb pesticides. The consequences of this will be discussed when pesticides as pollutants of water are considered.

(b) *Animal Manures and Waste*

Cattle and other domestic livestock manure constitutes a large proportion of farm waste, especially in countries where animal husbandry is intensively practised. In the United States it is reckoned that over 1.5 billion tons of animal waste per annum or about 20 times that of the human population, have to be returned back to earth. In the process, a part of the nutrients in the manure enters the surface water through runoff or leaching and contributes to the pollution effects referred to earlier. Even

ground waters may be thereby polluted. The problem of animal waste disposal varies with different situations, but is most widely and effectively tackled through field spreading and recycling of wastes. Oxidation tanks or 'lagoons' for the storage of farm manure are useful in reducing the pollution hazard.

(c) *Fertilizers*

Agricultural output is determined to a large degree by adequate fertilizer inputs. In the United States, where over 12 million tons of nitrogen, potassium and phosphorus are used annually in food production, it is reckoned that at least one third of the food produced is due to the use of fertilizers. It has thus enabled that country not only to feed its own enhanced population on a reduced extent of farmland, but also to export large quantities of food towards meeting the needs of an increasing world population.

The two main fertilizer nutrients affecting water pollution are nitrogen and phosphorus. A study of the sources of nitrogen in water supplies in the United States revealed that rural runoff from agricultural as well as non-agricultural land, industrial waste, and farm animal and domestic waste are the main sources of nitrogen in water. The nitrogen is mainly in the form of nitrates, ammonia being generally in small proportions. The contribution of nitrogenous fertilizers to the nitrogen contents of both surface and ground water in relation to that from other sources is not known with precision, but there is much evidence that nitrate nitrogen does leach through soil into the drainage and ground water in favourable circumstances.

Commoner's studies (5) on nitrogenous fertilizers in the United States revealed the very surprising finding that the amount of fertilizer nitrogen used per unit of crop production in 1968 was five times that used in 1949. Nitrogen in excess of the crop's needs is partly leached from the soil as nitrate to the surface waters where it becomes a serious pollutant and is partly dispersed elsewhere in the ecosystem. Excess nitrate in potable water may also directly affect human health and that of infants in particular. The necessity for restricting levels of nitrogen application to approximate crop needs is obvious. Further, ammonium fertilizers are preferably used to nitrates in heavy rainfall, hilly areas as they are readily adsorbed by the soil.

Phosphorus is the key element in water pollution. Soluble phosphates added to most soils undergo rapid fixation and only low concentrations of the element are, therefore, found as water-soluble phosphate in streams, reservoirs, *etc.* With the inflow of runoff from agricultural areas carrying phosphate-laden silt in suspension and from urban areas containing sewage effluent, detergents and other phosphate-containing industrial wastes, the water is considerably enriched in phosphorus. Aided by the nitrates present, algae and other water plants grow luxuriantly and cause the ill-effects of eutrophication referred to above.

(d) *Pesticides*

These are chemicals used for controlling plant pests, plant diseases and weeds, and are known respectively as insecticides, fungicides and herbicides. In the United States alone it is reported that about 700-800 million lb per annum have been used for these purposes in recent years. There is little doubt that they have been responsible for very appreciably increasing the production and conservation of man's food and other requirements. Further, some of them have also been used for the control of human diseases—for example DDT in the control of malaria—at low cost and with great efficacy.

Investigations

It should however be mentioned that Commoner's investigations (5) on the changes in the environmental impact index of pesticides between 1950 and 1967 in the United States have shown that while the quantity of pesticides used per production unit in 1967 was 2.68 times that in 1950, the total crop produced only increased by about one third. The need for using increasing amounts of insecticides to maintain productivity is obviously due to factors such as the destruction of beneficial predators and parasites and the emergence of resistant strains of the pest.

Modern pesticides are mainly synthetic organic chemicals of varied composition and character, numbering over 300 active ingredients made up into about 10,000 formulations. They may be grouped into four main categories: (1) organochlorine and (2) organophosphorus insecticides, (3) organic herbicides and (4) inorganic and organic fungicides.

Insecticides

When these tested chemicals are used with proper care and in the concentration and rates recommended for agricultural purposes as sprays, dusts or granules applied by aircraft or ground equipment to crops and soil, obvious ill-effects on man are only rarely noted. Side-effects of an adverse nature may, however, occur in other sectors of the biosphere and even in man. Some of the chemicals used in the early stages were found to be toxic to man and animals but they have been replaced by others comparatively harmless to vertebrates. Most of these pesticides are degraded or decomposed in the soil or metabolized within the plant or insect to a large degree, and leave little or no residues. The organo-chlorine group of insecticides such as DDT and dieldrin are the important exceptions. These organochlorine chemicals, and DDT and its related compounds in particular, are widely found in the environment in varying amounts and in the tissues of plants, animals and even man. Though only very slightly soluble and occurring in water in traces (as parts per trillion), they are readily dissolved by fats and are adsorbed by sediments and their organic components. The main source of contamination of water is the runoff and sediment from treated areas containing residues of the pesticides and comprising, in part at least, organochlorine chemicals like DDT. In developed countries, aerial spraying and waste discharge from pesticide factories are the other important causes of such pollution.

These pesticide residues are reported to be taken up selectively from the sediments in suspension or as deposits, by plankton or earthworms and hence by small fish which in turn may be taken up by larger fish or birds. The concentration of pesticidal residues is thus magnified at each stage of the food chain. This biological magnification* is known to have both lethal and sublethal effects on certain species of fish, birds and wild life, and several instances of such have been reported from different parts of the world.

* See observations by Gunn (6) in this issue, however.

It is a surprising fact that DDT and its related compounds have been found even in the fat of penguins and other animals in the Antartic. These chemicals also occur in body fat of human populations in amounts varying from 2 to 3 ppm in the U.K. and West Germany, through 12 ppm in the U.S.A. to 19 ppm in Israel and 26 ppm in India (3).

As a result of these findings and observations over a number of years, the organochlorine insecticides have become suspect and their use has been controlled or even banned in some countries, but 'no evidence has been produced of risk to man from organochlorine insecticides such as DDT or dieldrin when applied properly or occurring as residues in the normal diet.' This is the view positively expressed in the UK publication which has been endorsed by the World Health Organization (3 & 4). Until such time as further evidence on all the issues involved is forthcoming, we could continue their usage in Sri Lanka, but preferably use chemicals which do not have the persistence of organochlorine insecticides. In regard to the organophosphates, the comparatively harmless malathion should be used rather than the more toxic ones of this group of chemicals.

Herbicides

Herbicides are mainly organic chemicals used for controlling and destroying weeds. They are presently applied to about three-fourths of the arable land in the United Kingdom and to no less than 120 million acres of cultivated and grazing land in the United States. Some of the more common herbicides in use are 2, 4-D, MCPA and paraquat. In general, herbicides do not present toxic hazards to mammals when used properly, as they decompose relatively rapidly in the soil and do not leave significant residues in crops grown on treated soils. By their use, crops can be grown under reduced cultivation or with no cultivation (3).

Chemicals, both inorganic and organic have been and are being used for the control of aquatic weeds in lakes, water courses, fish ponds *etc.* by direct spraying of the affected areas. In Sri Lanka, spraying experiments for the control of *Salvinia auriculata* have been carried out from time to time. Great care will have to be exercised in the selection, the rate and mode of application of the chemicals used for this purpose if water from sprayed areas is for domestic usage or fish culture. Biological control, if effective, and manual and mechanical methods if not, offer the safest method of weed control in these circumstances.

Fungicides

Fungicides, including copper, sulphur, mercury and nickel compounds as well as organic chemicals have been and are being used for controlling plant diseases both in temperate and tropical regions. Fungicides were first applied on a large scale in Sri Lanka for the control of Blister Blight of tea, copper salts being the chemicals then used. The maximum copper content in made tea was fixed by regulation and fungicide dosages and applications have accordingly been related to this safe limit. Tests carried out recently by the Tea Research Institute also show that residual copper contents in the soil as a result of prolonged spraying with copper fungicides are not likely to reach danger levels (4). The use of copper for the control of Blister Blight on tea in Sri Lanka has now been drastically reduced. There is, in general, little likelihood of contamination of foodstuffs through the rational use of fungicides for disease control, if the recommended amounts and concentrations of the chemicals and instructions for their use are correctly adopted. Of the well-known fungicides the organo-mercurials, largely used earlier as seed disinfectants, were the most toxic, but they have now been replaced by comparatively safe organic fungicides.

The use and marketing of chemicals for agricultural purposes are controlled in a number of countries by laws and regulations which ensure that the product is useful for agricultural purposes and is not a hazard to public health or wild life. Tolerance values for residues in crops or chemically treated food have also been fixed. A large body of data exists for residues in foods in the United States and the United Kingdom. These are, fortunately, far below the legal standards prescribed (2 & 3). It is proposed to introduce shortly a law to provide for the registration and the regulation of the sale of pesticides in Sri Lanka.

HOW CAN WE SOLVE WATER POLLUTION PROBLEMS CAUSED BY AGRICULTURE?

Sri Lanka imported in 1971 over 30,000 tons of fertilizer at a c.i.f. cost of about Rs 120 million, and the equivalent of approximately 1,800 tons of agrochemicals inclusive of those used for public health spraying at a value of about Rs 10 million. The need for both chemical fertilizers and agrochemicals is bound to increase appreciably with the new agricultural developments envisaged in the current Five-Year Plan, and the problems of water pollution can be expected to become more apparent unless due precautions are taken. It is, therefore, necessary that systematic investigations on various aspects of the pollution problem in relation to Agriculture, as outlined in this article, should be undertaken without delay. It should however be mentioned that some useful research has been carried out on certain measures to alleviate the agricultural pollution problem locally (4) and that other investigations are in hand. Until such time as further practical recommendations are forthcoming, the following suggestions based on the experience of other countries are proposed for consideration and adoption where feasible:

1—Adopt sound conservation farming and use all animal manures on crops. Re-cycle farm wastes, especially liquid manure, to best advantage.

2—Adopt soil conservation practices to reduce soil erosion and water runoff from the land, particularly where pesticides are used to control pests and diseases.

3—Ensure that every watershed or catchment above reservoirs and tanks is protected.

4—Use rates of nitrogen and other fertilizers to approximate crop needs, especially on sloping land in high rainfall districts. Ammonium salts are preferred to nitrates in such areas as they are readily adsorbed by soils.

5—Develop water diversion structure around farm sheds, dairies, etc. so that no runoff flows directly into a water course. A storage tank or 'lagoon' where aerobic or anaerobic degradation of animal manures can take place is useful in reducing the pollution hazard.

6—Take every possible measure to minimize or eliminate possible adverse effects resulting from the use of pesticides by using the minimum amount needed.

7—Use chemicals carrying a minimum of danger and adverse side effects, and adopt all precautions recommended for the handling and use of these chemicals. In the interests of safety and efficiency it is desirable that spraying be carried out by trained personnel on a contract basis for farmers' co-operatives, cultivation committees, Productivity Committees, *etc.*

8—Methods such as mechanical or biological control and male sterilization of insects should be experimented with and adopted wherever possible. Resistant crop varieties should be used where available.

9—Conduct routine investigations into residual effects of all agrochemicals used so as to eliminate the more hazardous materials.

REFERENCES

1.—WILLRICH, T. L. & SMITH, G. E. (Ed.) (1970). "The pollution of water by Agriculture". Iowa University, USA.

2.—AMERICAN CHEMICAL SOCIETY. (1969). Cleaning our environment—A chemical basis for action.

3.—AGRICULTURAL RESEARCH COUNCIL, UK. (1970). Toxic chemicals in Agriculture in the UK.

4.—FERNANDO, L. H. & DE SILVA, R. L. (Ed.) (1971). The Environment & Agriculture. *Tea Quarterly* **42** (4).

5.—COMMONER, B. (1972). The environmental cost of economic growth. *Chemistry in Britain* **8** (2).

6.—GUNN, D. L. (1972). *Ann. appl. Biol.* **72**, 105-127. Reprinted *Tea Q.* **44**, 9-29. (1974).

Accepted for Publication—10th November 1973.