2. PESTICIDE MANAGEMENT IN RELATION TO USER SAFETY

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INTRODUCTION

Since the introduction of DDT to control insect pests in the 1940s, man's use of chemicals to control the pests attacking his crops, livestock and health has increased. Many millions of tonnes of formulated pesticides are used each year to control a wide range of pests in agriculture and public health, and pesticide use is increasing (2). At least 30 per cent of the world's potential crop production is lost each year to pests, diseases and the effects of weather. Losses would very probably double if existing pesticide uses were discontinued. World sales of pesticides amounted to some $16,500 million in 1986, with developed country markets accounting for about 75% of total sales. Markets in industrialised countries are now generally regarded as static, with little potential for expansion. The developing countries, conversely, are regarded as having a dynamic and expanding market, and pesticide use is increasing rapidly. Despite increasing emphasis on integrated pest management and non-chemical methods of pest control, pesticides will remain the principal and, in many instances, the preferred means by which pests and diseases are controlled for some time to come.

Increasing use of pesticides leads to increasing risks to the user and the environment. Bull (7) highlights some of the documented problems throughout the developing world. Much emphasis is placed on controlling the pest organism, whilst safety to the user and the environment often becomes of secondary importance. In particular, misuse of pesticides through lack of training, lack of awareness and inadequate facilities and equipment may represent a serious potential hazard. The WHO recently estimated that throughout the world up to one million people may suffer symptoms of unintentional pesticide poisoning each year and, of these, as many as 2% may die as a result (35). To put these figures into context, WHO estimates that pesticides are responsible for less than 4% of all poisoning accidents throughout the world. The majority of these cases occur in developing countries. In these countries, poor controls on pesticide use and mishandling and misuse of pesticides due to lack of awareness of hazards may lead to contamination of the user and unacceptable or hazardous residue levels in produce and water supplies. The likelihood of pesticide poisoning occuring depends not only on the inherent toxicity of the product but also on how that product is used (7). Pesticide hazard is therefore a function of the toxicity of the pesticide and the potential for exposure to that pesticide(25, 28), and can be expressed, in simple terms, as:

HAZARD = TOXICITY x EXPOSURE

Toxicity is a fixed attribute for each individual pesticide. Exposure will vary according to the handling and use patterns, and depends on the degree and duration of contamination. Pesticides have a wide range of mammalian toxicities, from extremely toxic, such as parathion or methyl parathion, to only slightly toxic, or even those which are unlikely to present an acute hazard in normal use, in accordance with label instructions, such as cypermethrin, methoxychlor or tetrachlorvinphos. Some of the more commonly used pesticides and their hazard classifications are given in Table 1.

Table 1: Comparative mammalian toxicities and maximum acceptable daily intake of some commonly used pesticides

Pesticide	Toxicity[a, b] (mg/kg body weight) oral LD_{50}	dermal LD_{50}	Maximum ADI[c] (mg/kg body weight)
Insecticides			
aldrin	67	98	0.0001
carbaryl	300	>4,000	0.01
carbofuran	8	2,550	0.01
chlorfenvinphos	10	31	0.002
cypermethrin	>4,000	>2,400	0.05
DDT	113	2,510	0.02
deltamethrin	>2,200	>2,000	0.01
diazinon	300	>2,150	0.002
dimethoate	150	600	0.002
endosulfan	80	359	0.008*
fenitrothion	503	890	0.003*
malathion	1,200	4,100	0.02
methomyl	17	>1,500	
monocrotophos	14	336	0.0006
pirimiphos-methyl	2,018	>2,000	0.01
tetradifon	5,000	>10,000	
Fungicides			
benomyl	>9,590	10,000	0.02
binapacryl	150	750	0.0025
chlorothalonil	>10,000	>10,000	0.005*
triadimefon	363	1,000	0.01*
Herbicides			
2, 4-D	375		0.3
dalapon	9,330		
glyphosate	4,320	>5,000	
paraquat	150	236	0.001*

a Various sources
b LD_{50} values are for rats (or rabbits where rat data unavailable)
c Joint FAO/WHO recommended ADIs
* = are temporary values

It is important that the fact of differing toxicities is recognised by all pesticide users so that they act accordingly and take proper safety precautions, particularly when handling the more toxic products.

Problems of human safety in relation to pesticide use have been addressed in a number of review articles and books. There are many references to safety in Hayes' (7) review of pesticide toxicology. The same author has reviewed in detail much of the work on pesticide studies in man (18). Ecobichon and Joy (12) have reviewed in detail the neurotoxic effects of pesticides in mammals, and methods of studying the clinical toxicology of agrochemicals is covered in some detail by Wagner (34), with reference to some individual pesticides and their effects on man. Other authors have reviewed work on human exposure to insecticides (26), occupational exposure to pesticides (14,19,33) and pesticides and human health (13,15). Many researchers have addressed the problem of occupational exposure to pesticides in specific studies of pesticide usage (6,21,22,29,30).

PESTICIDE USAGE

There are many documented instances of accidental poisoning due to misuse, abuse or ignorance in handling and application of pesticides (4,5,8,23,27). The main influences on human safety in pesticide usage in the field are:

- choice of pesticide (inherent toxicity and volatility)
- choice of formulation (type/concentration may affect hazard category)
- method of application.

Workers' own attitudes and experiences can affect human safety; a 200-fold variation in dermal exposure among workers using parathion on tree crops has been documented(36).

Dermal contamination is generally the most likely route of pesticide entry into the body under field conditions (26). Routes of entry and factors affecting pesticide penetration into the body are discussed by Dedek (11) and dermal absorption of pesticides has been reviewed in detail by Bainova (3). Many instances of pesticide poisoning amongst field workers applying pesticides have been documented (20,26,31), and the effects of pesticide residues on those workers entering treated crops within the recommended safety period (20,26,31).

Farmers' perceptions of pests and pesticide usage have been reviewed by a number of workers (1,9,10,32). Abrahamse (1), in a survey of pest control practices in some parts of Zambia, highlights the variability of practices and perceptions, dependent on whether or not farmers were "progressive" in outlook. Cox (10) has surveyed pesticide use patterns and economics of pesticide use in Tanzania, as well as assessing farmers' abilities to forecast return (increased yield) on investment (pesticide application). Variation in pesticide use practices is often an adaptive response to the differences in the expected yield increase of the crop and hence return on investment. User recommendations, although known, are often modified in the light of farmer experience.

Problems relating to safety may be encountered at any stage of the 'life history' of a pesticide, from manufacture and formulation, through storage, distribution and marketing to end use and disposal of the wastes and empty containers. Staff of the Overseas Development Natural Resources Institute (ODNRI) have been carrying out some research into pesticide use and human safety with the aim of trying to quantify the hazard to pesticide users. This research attempts to identify the main operational hazards to users of pesticides (the term 'users' includes all those who come into contact with pesticides in their normal work; for example manufacturing workers, storekeepers, distributors, farmers and field workers) and to investigate the ways in which various types of hazard may be minimised, given the practical constraints under which users, particularly in developing countries, often have to operate. Research techniques are based on the use of structured evaluation, by checklist or questionnaire, of pesticide safety practices in different countries, together with physico-chemical field contamination trials to determine the distribution and magnitude of the contamination of pesticide applicators under normal spraying conditions.

PESTICIDE STORAGE

It is estimated that less than 0.2% of all the pesticides manufactured for agricultural purposes in industrialised countries is wasted before use. In developing countries, perhaps as much as 10% may be wasted before application due to poor transport and storage facilities. Observations in many countries, including Somalia, Pakistan, Mauritius, Burma and Indonesia (16) have indicated the likely problems that may occur in pesticide stores. Such problems include the siting of stores too near to other premises such as private dwellings or shops. Several instances were found of stores being sited near to fuel pumps, and in one or two instances pesticide stores have also been found to be selling fuel supplies such as kerosene or gas cylinders. Stores are rarely purpose-built and quite frequently are too small for the quantity of pesticide stock carried. Ideally, there should be some means by which spilt pesticide can be retained or prevented from contaminating the surroundings, but this is rarely found in any but the largest stores.

Mixed storage of pesticides with seeds and fertilizers is a fairly frequent occurrence, and occasionally food or drink may also be stored - a potentially very hazardous situation. It is common to find the storekeeper's office or desk inside the store, and many stores could improve general housekeeping standards. These can be hazardous situations because pesticides could contaminate fertilizer and seed stocks and have phytotoxic effects in some circumstances. Additionally, farmers and field workers using seed stocks contaminated with pesticide are unlikely to be aware of the fact, and may themselves become contaminated. Bad housekeeping leads to accumulation of out-of-date stocks and therefore wastage of costly products. Also, inefficient storage systems may lead to damaged containers, contamination of packages and pesticide spills. Fumes from vaporising pesticide spills may cause low-level chronic poisoning of store keepers, particularly if the office or desk is within the store.

FARMERS AND FIELD WORKERS

Surveys of farmers and field workers have shown that when handling the concentrate, mixing spray solutions, and when spraying, some safety instructions are obeyed. However, in some instances, incorrect concentrations of spray solutions are used. Farmers sometimes have a tendency to increase doses on the assumption that the greater the concentration the better will be the control achieved. This, of course, is wasteful of pesticide and could also encourage the development of resistance in the target pest, as well as adversely affecting the environment.

Standards of maintenance of application equipment can be variable, and cost and availability of spare parts for repairs will influence maintenance procedures. In recent visits to Asia, a total of 66 farmers and farm workers were surveyed by questionnaire. Results indicated that many farmers were unaware of some of the dangers of pesticide contamination; many tended to overdose when spraying, particularly on vegetable crops, with consequent risk of unacceptable residues on market produce; equipment was poorly maintained, with consequent effect on the amount of pesticide contamination received during spraying operations; some farmers failed to follow even the most basic rules of safety when handling and using pesticides; on a number of occasions, pesticides were improperly stored, sometimes in the general living quarters within easy reach of small children. In general, farmers and farm workers are aware that pesticides can be harmful to man, and most recognise the oral and inhalation routes of pesticide entry into the body. However, only about 30-40% of farmers appear to be aware of the dermal route of entry. This has serious implications for the safety of pesticide applicators. Research by Maibach <u>et al</u>.(25) with parathion has shown that pesticides can penetrate the skin of different parts of the body at different rates, penetration through the skin of the forearm being the slowest, and penetration through the genital area being some twelve times faster than this. In general, skin that is thin, or with blood vessels close to the surface, or which is cut or abraded will allow rapid pesticide penetration.

Adequate and suitable protective clothing is rarely available and first aid facilities to treat any pesticide poisoning may often be some distance away. In surveys carried out in the Philippines and Thailand, over 50% of the Filipino farmers had suffered symptoms of pesticide poisoning; in Thailand the figure was lower, at 36% of the sample. However, the Thailand National Environment Board has initiated its own, much larger, survey of farmers and preliminary results indicate that the percentage could be considerably higher, as much as 70%. In a recent visit to the Philippines, a very brief survey of rice and mango farmers in a small area indicated that levels of pesticide poisoning incidence could be as high as 80% for rice farmers and between 30 and 40% for mango farmers. ODNRI is now undertaking a much larger scale survey of the incidence of pesticide poisoning amongst rice, vegetable and mango farmers in the Philippines.

Farmers and field workers tended not to observe a recommended safety interval after spraying and before re-entering the crop. However, in the Sudan, an arbitrary safety interval of 24 hours was sometimes quoted. A very small survey in Tanzania indicated that this is a more widespread practice, 24 hours being the usual safety period quoted. In some countries in South East Asia, farmers have been known to spray the crops in the early morning and then, on hearing of good market prices, to harvest and market produce later in the day.

OCCUPATIONAL EXPOSURE TRIALS

In field trials in the Philippines and Thailand, non-toxic model pesticides with tracer dyes were used to determine the extent of contamination of farmers during spraying operations. Suits of light-weight protective material were used as targets to collect spray deposits for quantitative analysis. Trials were done in rice, mango and vegetable crops. Results indicated difference in patterns of contamination on the different crops. This is, in part, due to differences in crop height and to the technique of application (mango farmers, for example, often climb inside trees to spray the upper canopy). Whole body contamination levels also varied between crops and crop heights.

This research into pesticide contamination amongst pesticide applicators in rice, vegetable and tree crops has shown that gross contamination levels can be very high and concentrated on particular areas of the body, such as the lower trunk in rice sprayers, and on the upper body and head of tree crop sprayers.

The safety implications for workers applying pesticides in tropical conditions, where minimal protective clothing, if any, is worn, should be given careful consideration, and particularly where the more hazardous pesticides and formulations are used.

LITERATURE CITED

1. Abrahamse, T. (1980) Pest control decision making in developing agriculture: Tonga farmers of the Mazabuka District of Zambia, a case study. COPR Unpublished Report, 47 pp.

2. Anon. (1985) Farm Chemicals 148 26-30.

3. Bainova, A. (1982) Dermal absorption of pesticides. In: Kaloyanova, F. and Tarkowski, S. (Eds.) Toxicology of Pesticides. European Co-operation on Environmental Health Aspects of the Control of Chemicals, Interim Document 9, WHO, Copenhagen, 288 pp.

4. Baker, E.L., Zack, M., Miles, J. W., Alderman, L., Warren, McW., Dobin, R. D., Miller, S. and Teeters, W.R. (1978) Epidemic malathion poisoning in Pakistan malaria workers. The Lancet 1. 31.

5. Bakir, F., Damluji, S.F., Amin-Saki, L., Murtadha, M., Khaklidi, A., Al-Rawi, N.Y., Tikriti, S., Dhahir, H.I., Clarkson, T.W., Amith, J.C. and Doherty, R.A. (1973) Methyl-mercury poisoning in Iraq. Science 181 230.

6. British Agrochemicals Association (1983) Spray Operator Safety Study. British Agrochemicals Association, London, 24 pp.

7. Bull, D. (1982) A Growing Problem: Pesticides and the Third World Poor. OXFAM, Oxford, 192 pp.

8. Chogo, J. B. and Ngowi, A.V.F. (1984) Health problems associated with pesticide use in agriculture and public health. Tanzania. TPRI Arusha Miscellaneous Report 1016, 13 pp.

9. Clark, A.R.L. (1988) A study of organophosphorus compounds used on fruit farms in Kent. International Pest Control 30 14-19.

10. Cox, P. (1985) Pesticide Use in Tanzania. Overseas Development Institute, London, 64 pp.

11. Dedek, W. (1980) Solubility factors affecting pesticide penetration through skin and protective clothing. In. Tordoir W.F. and van Heemstra-Lequin, E.A.H. Studies in Environmental Science No. 7. 47-53.

12. Ecobichon, D.J. and Joy, R.M. (1982) Pesticides and Neurological Diseases. CRC Press, Boca Raton, 281 pp.

13. Gunn, D.L. and Stevens, J.G.R. (Eds.) (1976) Pesticides and Human Welfare. Oxford University Press, Oxford, 278 pp.

14. Gunther, F.A. and Gunther, J.D. (1980) Residue Reviews 75 1-189.

15. Hallenbeck, W.H. and Cunningham-Burns, K.M. (1985) Pesticides and Human Health. Springer-Verlag, New York, 166 pp.

16. Haines, I.H. (1985) Chemistry and Industry 18 621-623.

17. Hayes, W.J. (1975) Toxicology of Pesticides. Williams & Wilkins, Baltimore, 580 pp.

18. Hayes, W.J. (1982) Pesticides Studied in Man. Williams & Wilkins, Baltimore & London, 672 pp.

19. Honeycutt, R.C., Zweig, G. and Ragsdale, N.N. (1985) Dermal Exposure Related to Pesticide Use. ACS Symposium Series 273, Washington, DC, 529 pp.

20. Jindrichova, J. and Rukl, V. (1967) Pracov. Lik. 19 449-453.

21. Kazen, C., Bloomer, A., Welch, R., Oudbier, A and Price, H. (1974) Arch. Env. Health 29 315-318.

22. Lavy, T.L. and Mattice, J.D. (1986) Progress in pesticide exposure studies and future concerns. Tox. Letters 33 61-71.

23. Loevinsohn, M.E. (1987) Insecticide use and increased mortality in rural central Luzon, Philippines. The Lancet June 13, 1359-1362.

24. Long, T. (1984) Pest Management 3 24-34.

25. Maibach, H.I., Feldman, R.J., Milby, T.H. and Serat, W.F. (1971) Archs. Env. Health 29 315-318.

26. Matsumura, F. and Madhukar, B.V. (1984) Exposure to Insecticides. In. Matsumura, F. (Ed.) International Encyclopaedia of Pharmacology and Therapeutics, section 113; Differential Toxicities of Insecticides and Halogenated Aromatics, 1-26.

27. Milby, T.H., Ottoboni, F. and Mitchell, H.W. (1964) Parathion residue poisoning among orchard workers. J.A.M.A. 189 351.

28. Nesheim, O.N. and Criswell, J. (1982) Oklahoma State University Extension Facts 7457 1-4.

29. Plimmer, J.R. (Ed.) (1982) Pesticide Residues and Exposure. ACS Symposium Series 182, Washington, DC, 213 pp.

30. Siewierski, M. (1984) Determination and Assessment of Pesticide Exposure. Studies in Environmental Science No. 24, Elsevier, New York, 222 pp.

31. Simkin, A.Z. and Mironov, E.P. (1971) Klin. Med. 49 133-134.

32. Tait, J. and Napompeth, B. (Eds.) (1987) Management of pests and pesticides: farmers' perceptions and practices. Westview Studies in Insect Biology, Westview Press, Boulder & London, 244 pp.

33. Tordoir, W.F. and van Heemstra-Lequin, E.A.H. (Eds.) (1980) Field Worker Exposure During Pesticide Application. Studies in Environmental Science No. 7, Elsevier, Amsterdam and London, 208 pp.

34. Wagner, S.L. (1983) Clinical Toxicology of Agricultural Chemicals. Noyes Data Corporation, New Jersey, 306 pp.

35. WHO (1986) Informal Consultation on Planning Strategy for the Prevention of Pesticide Poisoning. Document WHO V8C/86.926 WHO, Geneva, 28 pp.

36. Wolfe, H.R., Durham, W.F. and Armstrong, J.F. (1967) Archs. Env. Hlth. 14 622-633.