Approaches for regulating water in South Africa for the presence of pesticides

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Abstract

The public health significance of pesticide pollution of water sources in South Africa has received little attention from policy-makers and regulators, unlike microbiological quality of potable water. This anomaly is reflected in the current legislation in South Africa which is marked by inadequate regulatory standards for pesticides in water. Due to high costs, technical constraints and shortage of laboratory skills for pesticide analyses in South Africa, the poor regulatory framework has no monitoring data on which to base policy. In contrast, international experience in setting standards for maximum permissible levels of pesticides in water is extensive. The different approaches used by the World Health Organisation, the United States Environmental Protection Agency and the European Union are outlined, as well as the assumptions underlying these different approaches. Drawing on these models, recommendations are made as to how to integrate concerns for pesticide safety in environmental regulation and risk assessment in South Africa. Such measures would ensure consistency with recent developments in environmental management in South Africa that give primacy to a number of key environmental policy principles. A public health perspective should ensure that growing international concerns for long-term adverse health and environmental impacts arising from the presence of pesticides in water are adequately addressed in regulatory controls in South Africa.

Keywords: Water regulation, standards, pesticides, health

Introduction

Long-term low-dose exposures to pesticides are increasingly thought to cause chronic health problems, including reproductive, immunological, respiratory, neurological and carcinogenic impacts (Maroni and Fait, 1993; Schettler et al., 1996; Gray and Ostby, 1998; Dalvie et al., 1999; Porter et al., 1999; Kirkhorn and Schenker, 2002; Colosio et al., 2003). Although much of the scientific evidence for these associations stems from epidemiological studies in the workplace, environmental routes of exposure, including ingestion of pesticides in water, are thought to be of greater public health significance because of the very large numbers of people potentially exposed, the difficulties in controlling chemically contaminated environments and the fact that small changes in contaminant levels may have significant adverse population outcomes (Barnes and Kalita, 2001; McKay and Moeller, 2001).

The public health significance of pesticide pollution of water sources in South Africa has received relatively little attention from policy-makers and regulators, unlike microbiological quality of potable water, which remains a high priority of legislative measures. This anomaly is reflected in the current drinking water guidelines in South Africa (Department of Water Affairs and Forestry, 1996a), which have detailed standards for inorganics and coliform content (Table 1) but few standards for organic contaminants, and only one standard for a pesticide, atrazine. Given that South Africa is the main market for pesticides in sub-Saharan Africa (Dinham, 1993), this is an important gap.

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Monitoring for pesticides in water is made difficult in South Africa by a range of factors. These include the high costs of analyses, and of analytical equipment required such as a gas chromatograph, high-pressure liquid chromatograph and mass spectrometer. There is also a shortage of laboratory skills and institutional capacity available in South Africa for pesticide analyses (Rother and London, 1998) and an absence of practical, feasible and cost-effective field monitoring protocols (Dalvie et al., 2002).

The absence of a regulatory framework and water standards for, and monitoring data on pesticides, means that South Africa lacks the capacity to address a potentially serious public health matter. It is usually the poorest and most marginalised groups in society who bear the brunt of environmental pollution from pesticides (London and Rother, 1998).

International water standards

In contrast, international experience in setting standards for maximum permissible levels of pesticides in water is extensive due to concerns for adverse health and environmental impacts, even at low levels and particularly for organic pesticides of high persistence. Standards for human health (Table 2) are generally much less stringent than standards for aquatic ecosystems (Table 3).

There are two approaches in setting drinking water standards internationally. Agencies such as the World Health Organisation (WHO) and the US Environmental Protection Agency (EPA) adopt a health-risk based approach whereby safe levels for humans are inferred using various extrapolations, assumptions and safety factors from toxicological data obtained on laboratory animals. More recently, the EPA has even moved to consider using data from human experiments to set pesticide tolerances (Anonymous, 2003), an action somewhat controversial in the scientific community

TABLE 1 Current South African drinking water guidelines	
Substance	**Target water quality range: Domestic use**
Algae	1-1 µg/ℓ chla 0-50 bg algal cells/mℓ 0-0.8 *Microcystin* cells/mℓ
Aluminium	0-0.15 mg/ℓ
Ammonia	0-1.0 mg NH_3/ℓ
Arsenic	0-0.01 mg/ℓ
Asbestos	0-1x10 fibres/ℓ
Atrazine	0-0.002 mg/ℓ
Cadmium	0-5 µg/ℓ
Calcium	0-32 mg Ca/ℓ
Chloride	0-100 mg/ℓ
Chromium (VI)	0-0.05 mg/ℓ
Coliforms	0-5 © counts/100 mℓ
Coliphages	0-1 counts/100 mℓ
Copper	0-1 mg/ℓ
Dissolved organic carbon	0-5 mg C/ℓ
Enteric viruses	<1 TCID50/10ℓ
Fluoride	0-1 mg/ℓ
Iron	0-0.1 mg/ℓ
Lead	0-0.01 mg/ℓ
Magnesium	0-30 mg/ℓ
Manganese	0-0.05 mg/ℓ
Mercury	0-0.001 µg/ℓ
Nitrate/Nitrite	0-6 (a & b) mg/ℓ
Odour	1 t
Organic carbon	0-5 mg/ℓ
PH	6-9 pH units
Phenol	0-1 µg/ℓ
Potassium	0-50 mg/ℓ
Protozoan parasites	<1 cysts or oocysts/10ℓ
Radionuclides	0-0.5 Gross ∞ activity Bg/ℓ 0-1.38 Gross β activity 0-0.89 Uranium 238 Bg/ℓ 0.0228 Thorium 232 Bg/ℓ 0-0.42 Radium 226 0-11 Radon 222 0-0.42 Radium 228
Selenium	0-0.02 mg/ℓ
Sodium	0-100 mg/ℓ
Sulphate	0-200 mg/ℓ
Total dissolved solids	0-450 mg/ℓ
Trihalomethanes	0-100 µg/ℓ
Turbidity	0-1 NTU
Vanadium	0-0.1 mg/ℓ
Zinc	0-3 mg/ℓ

(Kamenetsky, 2003). In contrast, the European Economic Community has taken a more stringent approach by setting permissible levels of pesticides at the lowest limit of analytical capability as a means to drive down exposures to pesticides (EEC, 1980; Premazzi and Ziglio, 1995).

The EPA approach to non-carcinogens is to establish minimum contaminant levels (MCLs) and minimum contaminant level goals (MCLGs) which are based on an acceptable daily intake (ADI), the ingested amount of pesticides allowed for humans extrapolated from toxicological data. MCLGs differ from MCLs by taking account of the practical feasibility of implementing a standard but are set as close as possible to MCLs. For carcinogens, the EPA models the amount of pesticide intake associated with an "acceptable" risk (a lifetime increased risk of 1 in 10^6) assuming linear extrapolation to low-dose exposures typical of environmental pollution scenarios. Additionally, health advisories (HAs) are non-enforceable guidelines for emergency spills and treatment techniques (TTs) are applied where no adequate data exist to inform standards (Anonymous, 1988; Environmental Protection Agency, 1992; Environmental Protection Agency, 1999). The EPA does not have separate standards for total and individual pesticides, but under the US Food Quality Protection Act (EPA, 1997) the EPA must, when setting tolerance levels for pesticides, take into account available information concerning the cumulative effects of pesticides that have common mechanisms of toxicity.

Similarly, the WHO (WHO, 1993) bases its guideline values (GVs) for non-carcinogens on a percentage of a tolerable daily intake (TDI). Adjustments are made to take into account vulnerability of children (greater fluid intake per body mass) and for environmentally persistent chemicals. For carcinogens, the WHO's GVs are based on an "acceptable" increased risk of 1 in 10^5 risk, also extrapolated linearly to low doses. Many countries adopt the WHO standards because it is too costly and complex to conduct their own risk assessment.

The EEC directives set maximum admissible concentrations (MACs) for pesticides in drinking water at the analytical detection limit for chlorinated pesticides, as a surrogate for a zero standard (Premazzi and Ziglio, 1995). The MAC is set at 0.1 µg/ℓ for any pesticide and 0.5 µg/ℓ for total pesticides.

By placing such low limits, the EEC has signalled that threshold limits are to be led by analytical capabilities and thereby as policy tools to reduce overall pesticide usage. There are a number of policy objectives underlying European standard-setting for pesticides including:

- The primacy of prevention, the "polluter pays" principle
- The optimal use of scientific information to inform standard-setting
- Application of the precautionary principle where data are insufficient
- The recognition of the transboundary nature of many pollution problems (Commission of the European Communities, 1996)

Some EU member states (Sijm et al., 2001; Babut et al., 2003) have begun developing different approaches to achieve the ambitious targets proposed under the European Union's water quality framework (EC Directives 1980 and 1998).

Along with standard-setting, the EEC uses other regulatory mechanisms to protect groundwater. For example, pesticides are registered only if they can be shown to be environmentally safe and will not be registered if they have "unacceptable" impacts on drinking water, or if no methods for analysis exist which can meet the levels of detection demanded by EEC standards (Premazzi and Zigio, 1995). EEC directs member countries to consider both health and environmental consequences under anticipated conditions of use and by taking into account scientific uncertainty and all routes of exposure.

Some criticisms of regulatory approaches

There are significant difficulties in establishing causation for chronic health outcomes from low-dose exposure, and of characterising a dose-response relationship, particularly for extremely low exposure levels typical of environmental exposures. While this uncer-

TABLE 2
Summary of international standards for pesticides in drinking water (mg/ℓ)

Type of Standard:	USEPA								Australian	WHO
	MCL standard	Child advisories			Adult advisories			Advisory at 10-4 cancer risk		
		1 day	10 day	Longer term	Longer term	DWEL	Lifetime			
Pesticide										
Acifluorfen		2	2	0.1	0.4	0.4		0.1		
Alachlor	0.002	0.1	0.1			0.4		0.04	0.002	0.02
Aldicarb	0.003	0.01	0.01			0.035	0.007		0.001	0.01
Aldicarb sulfone	0.003	0.01	0.01			0.035	0.007			
Aldicarb sulfoxide	0	0.01	0.01			0.035	0.007			
Aldrin			0.0003	0.0003	0.0003	0.001		0.0002	0.0003	0.00003
Ametryn		9	9	0.9	3	0.3	0.06		0.05	
Ammonium sulfamate		20	20	20	80	8	2			
Atrazine	0.003	0.1	0.1	0.05	0.2	0.2	0.003		0.02	0.002
Bentazon		0.3	0.3	0.3	1	1	0.2		0.03	0.03
Bromacil		5	5	3	9	5	0.09		0.3	
Butylate		2	2	1	4	2	0.35			
Carbaryl		1	1	1	1	4	0.7		0.03	
Carbofuran	0.04	0.05	0.05	0.05	0.2	0.2	0.04		0.01	0.007
Carbon tetrachloride	0.005	4	0.2	0.07	0.3	0.03		0.03	0.003	
Chloramben		3	3	0.2	0.5	0.5	0.1			
Chlordane	0002	0.06	0.06			0.002		0.003	0.001	0.0002
Chlorotoluron										0.03
Chlorpyrifos		0.03	0.03	0.03	0.1	0.1	0.02		-	
Cyanazine										0.0006
2,4-D	0.07	1	0.3			0.4	0.07		0.03	0.03
2.4DB										0.09
DCPA		80	80	5	20	0.4	0.07		-	
Diazinon		0.02	0.02	0.005	0.02	0.003	0.0006		0.003	
1.2-Dibromo-3-chloropropane										0.001
1.2-Dibromoethane										0.0004 -0.0015
1.2-Dichloropropane										0.004
1.3-Dichloropropene										0.002
Dichlorprop										0.1
Dimethoate										0.006
Dieldrin		0.0005	0.0005	0.0005	0.002	0.002		0.0002	0.0003	0.00003
Diphenamid		0.3	0.3	0.3	1	1	0.2		0.3	
Diphenylamine		1	1	0.3	1	1	0.2		-	
Diquat	0.02					0.07	0.02		0.005	
Disulfoton		0.1	0.1	0.003	0.009	0.001	0.0003		0.003	
Endosulfan									0.03	
Endothall	0.1	0.8	0.8	0.2	0.2	0.7	0.1		0.1	
Ethylene dibromide	0.00005	0	0	0				0.00004	0.001	
Endrin										0.0006
Fenamiphos		0.009	0.009	0.005	0.002	0.009	0.002		0.0003	
Fonofos		0.02	0.02	0.02	0.07	0.07	0.01		-	
Fenoprop										0.009
Glyphosate		20	20	1	1	4	0.7	-	1.0	
Heptachlor	0.0004	0.01	0.01	0.005	0.005	0.02		0.0008	0.0003	0.00003
Heptachlor epoxide	0.0002	0.01	0.01	0.0001	0.0001	0.0004		0.0004	0.0003	0.00003
Hexachlorobenzene	0.001	0.05	0.05	0.05	0.2	0.03		0.002		0.001
Hexachlorocyclopentadiene	0.05					0.2				
Isoproturon										0.009
Lindane	0.0002	1	1	0.03	0.1	0.01	0.0002		0.00005	0.0003
Malathion		0.2	0.2	0.2	0.8	0.8	0.1			
MCPA			0.1	0.1	0.4	0.02	0.004			0.002
Mecoprop										0.001

TABLE 2 (continued)
Summary of international standards for pesticides in drinking water (mg/ℓ)

Type of Standard:	USEPA								Australian	WHO
	MCL standard	Child advisories			Adult advisories			Advisory at 10-4 cancer risk		
		1 day	10 day	Longer term	Longer term	DWEL	Lifetime			
Pesticide										
Methomyl		0.3	0.3	0.3	0.3	0.9	0.2		0.03	
Methoxychlor	0.04	0.05	0.05	0.05	0.2	0.2	0.04		0.3	0.02
Methyl parathion		0.3	0.3	0.03	0.1	0	0			
Metolachlor		2	2	2	5	3.5	0.07		0.3	0.01
Metribuzin		5	5	0.3	0.5	0.5	0.1		0.05	
Molinate										0.006
Naphthalene		0.5	0.5	0.5	1	0.1	0.02			
Oxamyl	0.2	0.2	0.2	0.2	0.9	0.9	0.2		0.1	
Paraquat		0.1	0.1	0.05	0.2	0.2	0.03		0.03	
Pendimethalin										0.02
Pentachlorphenol	0.001	1	0.3	0.3	1	1		0.03	0.01	0.009
Picloram	0.5	20	20	0.7	2	2	0.5		0.3	
PCBs	0.0005							0.0005	0.0005	
Prometon		0.2	0.2	0.2	0.5	0.5	0.1			
Pronamid		0.8	0.8	0.8		3	0.1			
Propachlor		0.5	0.5	0.1	0.5	0.5	0.09			
Propazine		1	1	0.5	2	0.7	0.01		0.05	
Simazine	0.004	0.004	0.07	0.07	0.07	0.2	0.004		0.02	0.002
2.4.5-T										0.009
Tebuthiuron		3	3	0.7	2	2	0.5			
Terbacil		0.3	0.3	0.3	0.9	0.4	0.09		0.03	
Terbufos		0.005	0.005	0.001	0.005	0.005	0.0009		0.0005	
Terbuthuthylazine										0.007
Toxaphene	0.003	0.004	0.004			0.01		0.003	0.003	
Trifluralin		0.08	0.08	0.08	0.3	0.3	0.005	0.5	0.05	0.02

Sources: USEPA, 1986; WHO, 1993; National Health and Medical Research Council, and Agriculture and Resource Management Council of Australia and New Zealand, 1996; USEPA, 2002
MCL: Maximum contaminant level
DWEL: Drinking water equivalent level

tainty in epidemiological research is recognised in the scientific community, it is not easily considered by policy-makers (Macrory, 1998) who rely on a burden-of-proof approach that facilitates administrative decision-making.

Health-based limits for pesticides in water (such as those developed by the EPA and WHO) have been severely criticised (Premazzi and Ziglio, 1995; Anonymous, 1996) because of the reliance on empirical evidence, which is lacking for the majority of pesticides, meaning that most pesticides remain without standards. For example, the WHO has drinking water standards for only a small proportion of the thousands of pesticide active ingredients manufactured and many that do have standards are pesticides that are no longer in general use (Whyatt, 1990).

Moreover, current toxicological models do not adequately address the problem of mixtures which is the most common scenario for exposure, particularly in developing countries. The WHO method of providing for mixtures is by incorporating safety factors into standards, by considering individual pesticide as additive and by stating that special considerations should be made where mixtures could be a problem. Although the WHO, in theory, accommodates differential risks for particularly vulnerable groups, only one (DDT) of the 36 pesticides for which GVs have been established in two sets of guidelines since 1993 (WHO, 1993; 2004), provides standards for infant intake. The linear extrapolation to low-dose effects used to estimate acceptable risk from pesticides known as carcinogens may be an incorrect assumption (Perera and Boffetta, 1988). Lastly, epidemiological studies investigating the health effects due to low exposure levels generally require large study samples, with attendant high costs, and imply the exposure of large numbers of people to the pesticides under study. It is thus little surprise that so little data exist to inform standards for pesticides.

On the other hand, the policy-based approach of the EEC imposes standards set by analytical capabilities that may be difficult or impossible to enforce in developing countries where technological capacity and human resources are limited and public awareness of pesticide exposure hazards are low. Moreover, standards that are not health-based may themselves over- or under-estimate health risks.

National and international environmental policy developments

South Africa's legislation on pesticides is extremely complex and fragmented, being spread across 14 Acts and 7 different government departments (Rother and London, 1998). However, a number of key changes have taken place in the legislative framework dealing with the environment.

Firstly, the overall framework for national environmental management is set by the National Environmental Management Act (Department of Environmental Affairs and Tourism, 1999), in terms of which the Department of Environmental Affairs and Tourism (DEAT) is endorsed as the lead agency in co-ordinating environmental policy. Amongst the policy principles contained in the Act are an emphasis on prevention, the need to minimise negative environmental impacts if pollution cannot be avoided, environmental justice and a risk-averse and cautious approach which takes into account the limits of current knowledge about environmental decision making.

In addition, the Department of Water Affairs and Forestry (DWAF) has introduced a range of legislation changing the nature of water management and related environmental practices in South Africa (DWAF, 1996 a & b; DWAF, 1997; DWAF, 1998 a & b). Chief in this process is the introduction of water management by catchment, a pricing system to support equity and sustainability of water resources, and regulation according to water quality objectives rather than a sole reliance on uniform effluent emission standards (Lazarus et al.,1997). The Act also emphasises public participation and provides for greater community involvement in water management structures. In addition, DEAT is currently finalising a National Chemicals Profile as a basis for re-evaluating South Africa's capacity for safe management of chemicals (DEAT, 2004). Within this process of improving chemicals management, it may be possible to address the problem of water pollution by pesticides.

A number of international policy developments focus on pesticides. For example, the United Nations Environment Programme (UNEP) protocol to eradicate persistent organic pollutants (POPS) will see the phasing out of a number of pesticides deemed to pose a risk of irreversible harm on a global scale (UNEP, 1999). National governments are encouraged to undertake monitoring for these pesticides in water to assist in their eradication.

TABLE 3
Water standards to protect aquatic ecosystems (mg/ℓ)

Substance	South Africa	United Kingdom	US EPA	Australia	Canada
Aldrin	0.01	0.01		0.01	0.004
Arsenic					0.005
Atrazine	0.01				0.0018
Azinphos-methyl				0.01	
Bromacil					0.005
Bromoxynil					0.005
Captan					0.0013
Carbaryl					0.0002
Carbofuran					0.0018
Chlordane	0.025			0.004	6.0
Chlorothalonil					0.00018
Chlorpyrifos				0.001	0.000002
Cyanazine					0.002
DDT	0.0015	0.025		0.0005	0.001
Deltamethrin					0.0000004
Dicamba					0.01
Dichlorophenols					0.0002
Diclofop-methyl					0.0061
Dieldrin	0.005	0.01		0.002	
Dimethoate					0.0062
Dinoseb					0.00005
Endosulfan	0.00001			0.001	0.00002
Endrin	0.002		0.05	0.003	0.0023
Heptochlor	0.005			0.0003	
Lindane	0.015			0.003	0.00001
Linuron					0.007
Malathion	0.1			0.07	
MCPA					0.0026
Methoxychlor	0.02			0.04	
Metolachlor					0.0078
Metribuzin					0.001
Mirex	0.001			0.001	
Monochlorophenols					0.007
Parathion	0.008			0.004	
Pentachlorophenol					0.0005
Simazine					0.01
Tebuthiuron					0.0016
Tertrachlorophenols					0.001
Toxaphene				0.002	
Trichlorophenols					0.018
Trifluralin					0.000020
2,4 Dichlorophenol	4.0				4.0

Sources: Dallas and Day, 1993; DWAF, 1996 b; USEPA, 2002; Canadian Council of Ministers of the Environment, 2004; Drinking Water Inspectorate (UK), 2003; WHO, 2004.

South African options

Recent studies (London et al., 2000; Meintjies et al., 2000; Schultz, 2001; Dalvie et al., 2003, Sereda and Meinhardt, 2003) have confirmed widespread contamination by pesticides of surface- and groundwater at low concentrations in South Africa, confirming the existence of a problem requiring an appropriate policy response. How can concerns for pesticide safety be integrated with environmental regulation and risk assessment in South Africa drawing on the different international models for regulating pesticides in drinking water? As a minimum, consideration should be given to developing and adopting health-based standards for pesticides in drinking water on which to base protective measures. The WHO and EPA standards could easily be used as a starting point as has been done for occupational health and safety standards for chemical exposures at the workplace (Ehrlich, 1985). These international health-based standards would not be overly burdensome to apply in South Africa. At the very least they would provide health protection presently not available to South Africans, and would be in line with the Constitution seeking to provide citizens with a right to an environment that is not harmful to health.

However, it is well recognised that the health-based limits are severely constrained in their ability to provide standards with adequate human and environmental protection in relation to the myriad existing and new pesticides entering the environment. For example, in the absence of adequate toxicological data to determine the presence of potential health effects, as is the case for the majority of pesticides, it has been argued that standards should be set at the level of detection (Whyatt, 1990). Consideration should therefore be given to exploring application of more stringent standards, such as those predicated on the precautionary principle and similar to those adopted by the EU. Such an approach should ideally be negotiated within the national chemicals profile initiative under DEAT as part of a coherent policy framework (DEAT, 2004). Notably, given the fact that pesticides are not appreciably removed during conventional water treatment processes unless activated carbon filtering (Barnes and Kalita, 2001) or one of a number of other catalytic processes such as ozonation, nano-filtration and ultra-violet processes is used, the costs of remediating pesticide contamination of water sources used for drinking are high enough to warrant concentration control at source.

Lastly, without the capacity to monitor the sale, application and environmental fate of pesticides it will be impossible to establish the basis for policy and regulation. Under the Rotterdam Convention, The Prior Informed Consent Procedure for International Trade of Hazardous Chemicals and Pesticides requires exporters to provide adequate information on human health or environmental risks, taking into account relevant international standards prior to export (United Nations Environment Programme, 2004). As most pesticides in South Africa are imported, this convention which came into force on 24 February 2004 provides a means of monitoring the sale of these chemicals. Environmental policy-makers will need to look to strengthening capacity at local levels to ensure that communities and local government are able to manage environmental threats to human health. Such measures would ensure consistency with recent developments in environmental management in South Africa that give primacy to a number of key environmental policy principles. A public health perspective should ensure that growing international concerns for long-term adverse health and environmental impacts arising from the presence of pesticides in water are adequately addressed in regulatory controls in South Africa.

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