Review Summary
on

The NRA review of

ATRAZINE

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Existing Chemicals Review Program

National Registration Authority
for Agricultural and Veterinary Chemicals

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FOREWORD

The National Registration Authority for Agricultural and Veterinary Chemicals (NRA) is an independent statutory authority with responsibility for the regulation of agricultural and veterinary chemicals.

The NRA's Existing Chemicals Review Program (ECRP) systematically examines agricultural and veterinary chemicals registered in the past to determine whether they continue to meet current standards for registration. Chemicals for review are chosen according to pre-determined, publicly available selection criteria. Public participation is a key aspect of this program.

In undertaking reviews, the NRA works in close cooperation with advisory agencies including the Department of Health and Family Services (Chemicals and Non-Prescription Drug Branch), Environment Australia (Risk Assessment and Policy Section), Worksafe Australia (Chemical Assessment Division) and State Departments of Agriculture.

The NRA has a policy of encouraging openness and transparency in its activities and community involvement in decision-making. The publication of evaluation documents for all ECRP reviews is a part of that process.

The NRA also makes these reports available to the regulatory agencies of other countries as part of bilateral agreements or as part of the OECD *ad hoc* exchange program. Under the OECD program it is proposed that countries receiving these reports will not utilise them for registration purposes unless they are also provided with the raw data from the relevant applicant.

This summary provides a brief overview of the review of atrazine that has been conducted by the NRA and its advisory agencies. The review's findings are based on information collected from a variety of sources, including data packages and information submitted by the registrant, information submitted by members of the public, questionnaires sent to key user/industry groups and government organisations, and literature searches.

The information and technical data required by the NRA to review the safety of both new and existing chemical products must be derived according to accepted scientific principles, as must the methods of assessment undertaken. Details of required data are outlined in various NRA publications.

Other publications explaining the NRA's requirements for registration can also be purchased or obtained by contacting the NRA. Among these are: *Ag Manual: The Requirements Manual for Agricultural Chemicals; Vet Manual: The Requirements Manual for Veterinary Chemicals* and Volume II of *Interim Requirements for the Registration of Agricultural and Veterinary Chemical Products*.

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ABBREVIATIONS AND ACRONYMS

ac	active constituent
ACPH	Advisory Committee on Pesticides and Health
ADI	acceptable daily intake (for humans)
ai	active ingredient
d	day
DACT	diaminochlorotriazine
EC_{50}	concentration at which 50% of the test population are affected
EEC	estimated environmental concentration
EU	European Union
FHRMG	Forest Herbicide Research Management Group
GAP	Good Agricultural Practice
GI	gastrointestinal
h	hour
ha	hectare
im	intramuscular
in vitro	outside the living body and in an artificial environment
in vivo	inside the living body of a plant or animal
ip	intraperitoneal
iv	intravenous
kg	kilogram
L	litre
LC_{50}	concentration that kills 50% of the test population of organisms
LD_{50}	dosage of chemical that kills 50% of the test population of organisms
LOEL	Lowest Observed Effect Level
m	metre
MAC	minimum algistatic concentration
mg	milligram
mg/kg bw/day	mg/kg bodyweight/day
min	minute
mL	millilitre
mM	millimolar
µg	microgram
MOE	margin of exposure
MRL	maximum residue limit
MSDS	Material Safety Data Sheet
NDPSC	National Drugs and Poisons Scheduling Committee
ng	nanogram
NHMRC	National Health and Medical Research Council
NOEC	No Observed Effect Concentration
NOEL	No Observed Effect Level
NOHSC	National Occupational Health and Safety Commission
OECD	Organisation for Economic Cooperation and Development
OH&S	occupational health and safety
P	product
PACC	Pesticides and Agricultural Chemicals Committee
po	oral
POEM	Predictive Operator Exposure Model
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinyl chloride
s	second
sc	subcutaneous
SUSDP	Standard for the Uniform Scheduling of Drugs and Poisons
TGAC	technical grade active constituent
US EPA	United States Environmental Protection Agency
WHO	World Health Organisation

SUMMARY

The NRA has reviewed the registration of atrazine. Atrazine is a selective, systemic herbicide which provides knockdown and residual action for control of many broad leaved weeds and some grasses in tree plantations and a variety of crops such as sorghum, maize, canola and sugarcane. Atrazine is one of the most widely used herbicides in Australian agriculture.

The review, conducted under the NRA's Existing Chemicals Review Program, found that atrazine continues to demonstrate the potential to contaminate ground and surface water and that safety margins for aquatic organisms are, in some circumstances, narrow. The NRA, therefore, recommends that measures be taken to reduce aquatic contamination, and that levels of atrazine and its major metabolites in the environment be monitored to determine trends in atrazine contamination of surface and ground waters and to establish whether current and future restrictions are effective in maintaining or improving safety margins.

Product details

Label directions for the majority of its uses in agriculture require atrazine to be applied pre-planting at rates between 1.8 and 3.0 kg active ingredient (a.i.) per hectare, depending on soil type, or 1.25 kg a.i. per hectare when used in combination with metalochlor. Lower rates are applied to other crops such as lupins and lucerne. Post-planting rates are 0.5 kg active ingredient per hectare.

Application is mostly by tractor- or 4WD vehicle-mounted boomspray, with some aerial application (fixed wing) occurring when soils are wet. Some application by helicopter occurs in plantation forestry. In plantation forestry, annual application rates are 4.5 kg a.i. per hectare for sandy and highly erodible soils and 8 kg a.i. per hectare for clay loams and heavier soils. For the home garden, label application rates are given as product (g) per m^2 and correspond to 2.5 and 5.0 kg atrazine /ha.

In Australia, 34 registrations for products containing atrazine and 4 approvals for active constituents currently exist.

Low hazard to members of the community and users

Atrazine is of low acute toxicity and is not a skin sensitiser in humans. Toxicological evidence suggests that atrazine is not a genotoxic carcinogen. In the Sprague Dawley (SD) strain of rats, the earlier onset of mammary tumours (a common tumour type in these rats, with a high background incidence in ageing females) observed in some toxicology studies at high doses of atrazine was due to a strain-specific hormonal effect. The pattern of oestrogen levels in ageing SD rats differs from that of other rat strains tested, and from that in humans. The atrazine effect in this particular strain of rats is not considered to be an appropriate model for the assessment of mammary tumour development in humans. Atrazine is not considered to be teratogenic or toxic to reproduction.

The 1992 Australian Market Basket Survey conducted assays for atrazine and simazine in meat and cereal foods. No residues of either herbicide were detected. This finding is in agreement with US data; in over 30 years of use, atrazine has not been detected in edible portions of plants or livestock nor has it been detected in market-basket surveys. Therefore, exposure of the population to atrazine in food is considered very unlikely.

Exposure to atrazine is more likely to occur through drinking water. It is estimated that intake at 10 ppb in water would result in an intake approximately 5.7% of the current acceptable daily intake (ADI) for atrazine.

Atrazine poses no undue hazard to most users. Predicted exposures and worker exposure studies, extrapolated to Australian conditions, indicate acceptable risk for the majority of users. Faggers involved in aerial spraying are considered to be at risk. The use pattern for atrazine indicates that workers entering treated areas will not be exposed to levels likely to have a detrimental effect on health.

Minor efficacy concerns

Minor issues concerning the efficacy of atrazine have been reported to the NRA. Reports of variable performance in the Northern Territory over the 1995-96 season have raised concerns over the possible development of resistance to atrazine by a major weed of sorghum and maize, *Penniseteum peddicellatum*. An unconfirmed report of resistance in Johnson grass (*Sorghum halepense)* has also been received in Victoria.

New uses

Consideration should be given to extending the registration of atrazine in certain areas, to reflect current use patterns. The area planted to triazine-tolerant (TT) canola is rapidly expanding, and atrazine use on this crop is currently allowed under NRA permit. Atrazine is used off-label on chick peas in north-west Victoria. Chick peas are a major pulse crop for Victoria with significant export potential. Atrazine registration for use on Parthenium weed in Queensland should be extended to other States now infested with the weed, namely parts of the Northern Territory and northern NSW.

Residue information incomplete

Information provided on residues indicated no change to the current residue definition of atrazine parent for crops and animal commodities is necessary. However, data are required on forage and fodder residues for sorghum, pastures and lucerne to confirm the primary animal feed commodity maximum residue limit (MRL) and those of animal commodities. Certain MRLs should be deleted because there is no current Australian use pattern.

Potential hazard to aquatic ecosystems

Atrazine is a mobile chemical with the potential to contaminate water at low levels as a result of normal use. Evidence indicates that, in the Australian aquatic environment, atrazine exposures are generally below the threshold for ecosystem effects, which is about 20 ppb. Groundwater samples often contain detectable levels of atrazine and its metabolites around the level of 1 ppb. Higher levels have been detected but these were known to be of point-source origin, arising from improper pesticide handling practices or accidents. General historical levels in natural surface waters are less than 10 ppb (and in most cases below 1 ppb) although higher levels may occur briefly in lower order streams receiving storm runoff. However, safety margins are narrow.

The NRA has already taken steps to eliminate some sources of aquatic contamination by restricting maximum annual application rates of atrazine and withdrawing certain uses with a high potential for aquatic contamination. The NRA has also established a broad-based taskforce to conduct a three-year program of trials and monitoring to establish whether revised conditions of use in plantation forestry will reduce aquatic contamination to acceptable levels. A number of trials are in progress.

Reducing potential hazard to the environment

While it is acknowledged that low level aquatic contamination by atrazine is unavoidable, due to its widespread use, every effort should be made to minimise its occurrence. Poor agricultural practices such as tailwater release from excessive irrigation, application shortly before heavy rains or storms or to waterlogged soils, and use in irrigation channels need to be stopped. Users should also be re-educated on the review recommendations to ensure they are adopted fully.

Monitoring levels of atrazine in surface and ground water

The NRA considers that monitoring of atrazine levels in the environment needs to continue to determine trends in atrazine contamination of Australian surface and ground waters. In addition, future monitoring needs to be conducted to investigate levels in natural waterways as well as the irrigation drainage systems that have been the main focus to date. Monitoring of residue levels in water should also be linked to biological monitoring to determine the ecological significance of atrazine levels found in Australian waterways. This monitoring will help determine whether current and future restrictions are effective in maintaining or improving current safety margins. The monitoring will initially include testing for metabolites, but only until more information has been obtained on the current levels of metabolites, as well as parent atrazine to metabolite ratios.

However, should monitoring be inadequate, or should it demonstrate that environmental safety margins continue to be narrow, the NRA will consider restricting the use of atrazine further.

Proposals for water quality guidelines

The current Australian Drinking Water Guideline is based on the measurement of atrazine alone. Metabolites, when measured, have commonly been detected at levels of the same order of magnitude as parent atrazine. Since the metabolites are, in general, no less toxic than atrazine, these metabolites should be considered in the standard. Therefore, while there is no basis for concern about human health effects at current, reported levels of contamination, consideration should be given to amending the standard to measure the combined total of atrazine plus its closely related metabolites. This action would have the equivalent effect of lowering the guideline value (currently 0.5 ppb) and the health value (currently 20 ppb) for atrazine alone since, in water samples in which atrazine is detected, one or more metabolites are commonly detected but disregarded in the current standard. This issue has been referred to the National Health and Medical Research Council (NHMRC) for consideration by a joint committee of the NHMRC and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

Australia has yet to establish a water quality guideline for protecting aquatic ecosystems, but the Environmental Research Institute of the Supervising Scientist (ERISS) is currently reviewing the Australian guidelines. A guideline value of 2 ppb for atrazine operates overseas and has been proposed locally. The NRA will provide a copy of its review of atrazine to ERISS to aid deliberations.

The NRA proposes that:

- certain measures be taken to minimise aquatic contamination by atrazine;
- atrazine levels in the environment be monitored to determine trends in atrazine contamination and whether the measures are effective;
- the definition of atrazine for the Australian Drinking Water Guideline be amended to include atrazine plus its major metabolites; and
- some registrations and MRLs be amended in line with current use patterns.

Full details of the review outcomes are available on pages 47-52 of this report.

1. INTRODUCTION

The National Registration Authority for Agricultural and Veterinary Chemicals (NRA) has reviewed the active ingredient atrazine, all products containing atrazine and associated labels.

The purpose of this document is to provide a summary of the data evaluated and of the regulatory decisions reached, as a result of the review of atrazine.

1.1 Regulatory information

Initiating a review

The NRA has statutory powers to reconsider the approval of active constituents, the registration of chemical products or the approval of labels for containers at any time. The basis for a reconsideration is whether the NRA is satisfied that the requirements prescribed by the Agricultural and Veterinary Chemicals Code (scheduled to the *Agricultural and Veterinary Chemicals Act 1994*) for continued approval are being met. These requirements are that the use of an active constituent or product, in accordance with the recommendations for its use:

- would not be an undue hazard to the safety of people exposed to it during its handling or people using anything containing its residues;
- would not be likely to have an effect that is harmful to human beings;
- would not be likely to have an unintended effect that is harmful to animals, plants or things or to the environment; and
- would not unduly prejudice trade or commerce between Australia and places outside Australia.

Obligations to submit data and other information on chemicals under review

On initiating a review, the NRA has to notify relevant approval holders and registrants of the matters it intends to reconsider and its reasons for doing so, and to invite them to make written submissions on those matters. These parties are also requested to submit all existing information and data (regardless of its age or confidentiality) on the chemical under review. The NRA also notifies the community of the review through national and local newspapers, inviting them to make submissions.

In addition to inviting public submissions, the NRA may consult with persons, organisations or government agencies with relevant knowledge or interests for the purposes of obtaining information or advice relating to the review.

Once a review is under way, the NRA may request additional information from approval holders and registrants. If such a request is denied, the NRA may suspend or cancel the relevant approval or registration.

Outcomes of reviews

There are three possible outcomes to an ECRP review:

1. The NRA is satisfied that the chemical under review continues to meet the prescribed requirements for the initial approval or registration and confirms the approval or registration.

2. The NRA is satisfied that the conditions to which the approval or registration is currently subject can be varied in such a way that the requirements for continued approval or registration will be complied with and varies the conditions of approval or registration.

3. The NRA is not satisfied that the conditions continue to be met and suspends or cancels the approval or registration.

The NRA must notify the approval holders, registrants and the community of the outcomes of these reviews.

1.2 Data protection

To grant protection to providers of certain information relating to agricultural and veterinary chemicals, the NRA introduced a program of data protection. The objectives of this program are:

- to provide an incentive for the development of products and data applicable to Australian or local conditions;
- to encourage the availability of overseas products and data; and
- to provide reciprocal protection for Australian products and data under overseas' data protection systems.

In general, the NRA designates information as 'protected registration information' for a 'protection period' of two to seven years if the information:

- is requested by the NRA for the purposes of reviewing a product;
- is relevant to the scope of the review; and
- relates to the interaction between the product and the environment of living organisms or naturally occurring populations in ecosystems, including human beings.

If the NRA proposes to use the same information to determine whether to register, or continue registration, of another chemical product, the NRA must not use the information until the parties come to an agreement as to terms for compensation, unless the protection period has expired or the NRA is satisfied that it is in the public interest to use the information.

1.3 Reasons for the atrazine review

Atrazine was selected for review by the NRA Board after scoring highly against the agreed selection criteria for public health, occupational health and safety, agriculture and environment. In summary, the concerns over the chemical were:

- human and animal carcinogen claims;
- its moderate potential chronic toxicity risk;
- its potential to contaminate ground and surface water;
- absence of MRLs for major commodities;
- reported problems with use in agriculture; and
- high level of public concern.

Whilst the selection process ranked atrazine highly due to certain issues, the review was not confined only to those issues, but covered **all aspects** of the conditions of registration and approval of atrazine.

1.4 Consultation activities

There was a high level of public interest in the NRA review of atrazine. In response to the widely publicised call for submissions on the review, 176 submissions were received from individuals, environmental and community groups and from the agricultural and plantation forestry industries. Submissions on similar topics were collated into groups and are presented below. A more detailed breakdown of responses can be found in the technical report. Where possible the words of the original submission have been maintained, therefore the information provide, and views expressed, are those of the authors of the submissions and have not been validated by the NRA.

Environment and public health

Water contamination

Atrazine is routinely used by the plantation forestry industry to suppress weed competition during plantation establishment. This produced several submissions regarding groundwater contamination resulting from such activity. Respondents stated that the persistence of atrazine in the environment and its mobility should preclude use where the chemical is likely to leave the site of application. Reports of contamination of water and aquatic ecosystems, despite use according to the label, were also received. All respondents felt that contamination should be minimised, with some regarding any contamination of water unacceptable, no matter how slight the risk to humans and aquatic life.

Several respondents cited the contamination of an area of north-west Tasmania as an issue of serious concern. In May 1993, atrazine and glyphosate were sprayed in this area. It was claimed that protest by local residents resulted in wider buffers along creeks, ground-based spraying and some chemical free areas. After heavy rain in July that year, the domestic water supply was said to be contaminated with atrazine at levels above the WHO standard of 2 ppb. Residents in the area reported that, 18 months later, levels were still above the EEC limit value of 0.1 ppb.

Other responses cited reports showing contamination of water from agricultural dams in Queensland, South Australia (levels up to 8.6 µg/L, mean of 2 µg/L) and Western Australia, and water from the Padthaway-Coonawarra region of Victoria and the Gunnedah region of NSW.

Overseas, atrazine is reported to have been banned in Germany and Italy in 1991 due to contamination of groundwater and high levels in drinking water.

Respondents were also concerned about the probability of primary produce being contaminated through ingesting (in the case of livestock) and irrigation (in the case of crops) with contaminated water. One response referred to a Department of Primary Industry study which showed that triazines show up in milk at almost the same levels as in the water the cows consume.

Two respondents were concerned about the effects of atrazine-contaminated water on local ecosystems. One concern was over the possibility that water draining from atrazine-treated sugarcane may affect plant life in the drains, adjacent wetlands and nature reserve into which it drained. The other referred to research findings in Tasmania which indicated long-term effects on algae at levels of 5 ppb and to a US study which found that aquatic animals are indirectly affected at concentrations above 20 ppb.

Other respondents provided information on water testing that had been carried out on or near their properties. Cattle and sheep graziers reported no atrazine in water used for their stock; turf growers reported that no atrazine was found in water following use in turf growing.

Respondents from the plantation forestry industry reported on monitoring studies conducted at various times after atrazine application. Results from one respondent for the 1994 season showed levels of atrazine never rose above the Australian Drinking Water Guideline (20 ppb). Ground bores tested in 1989, 1992 and 1994 showed atrazine levels rose above 2 ppb, in areas of sandy soils, during mid-winter when streams were in peak flow. The rest of the time, and in areas of clay soil, levels were below 2 ppb.

Toxicological effects

The major concerns in this category were the potential of atrazine to act as a hormone disrupter and produce cancer. Responses linked atrazine to ovarian tumours, non-Hodgkins lymphoma, and breast and testicle tumours. Atrazine was reported to be a class 2B carcinogen (possibly carcinogenic to humans), according to the WHO and considered by the US EPA as a possible human carcinogen. Atrazine was also reported to be converted to a mutagenic substance by corn plants which, in combination with nitrogen, produces dangerous synergistic effects.

Conversely, other respondents stated that atrazine was safe for people to use and safe to the environment. The use of low rates, once per year, were not viewed as posing a risk to human health. Users reported they were aware of no detrimental effects on their health. One respondent ensures annual blood tests are carried out on his employees. In 15 years, no signs of atrazine build-up in their blood have been detected.

Agriculture

Minimum tillage

Many responses were received from the farming community, supporting the continued use of atrazine. Atrazine is regarded as occupying an important role in weed control, especially with the move from mechanical cultivation towards minimum tillage. Without atrazine, farmers indicated they would need to return to environmentally damaging excessive cultivation. They stated that the use of atrazine produced the following benefits: improved soil structure and a subsequent decrease in soil erosion; decreased machinery use resulting in fuel savings; decreased water use through the retained stubble holding more moisture; improved profitability and greater utilisation of sloping land. Several responses cited studies showing decreased soil erosion and pesticide runoff arising from the switch to no-till cultivation.

A similar situation was reported by cane growers. One of the most important recent developments in their industry has been development of green cane harvesting where a blanket of leaf material is retained on the ground. This is not suitable for all cane growing areas but, where used, acts as a mulch to recycle nutrients into the soil, slows weed growth, retains moisture and helps prevent soil erosion. Studies were cited which showed no evidence of atrazine in leachate from cane fields or atrazine residues in sugar.

Runoff from irrigation channels and soils

One response stated that the incidence of atrazine in waterways in New South Wales is largely associated with tailwater runoff from irrigation areas. This was felt to be a problem that would decrease in the future due to the current move towards recycling tailwater and minimising its use.

Soil type and climate were reported to greatly affect the degree of atrazine leaching into waterways. It was reported that most of the sorghum and grain grown in Queensland is on high clay content soils where the movement of atrazine is minimal and groundwater contamination unlikely.

Minimising chemical use

Two farmer organisations stated that the proper use of chemicals such as atrazine in agriculture was compatible with high standards of environmental and occupational safety. Programs and policies introduced to achieve this aim were: code of practice for aerial spraying; education of users through accredited programs; Landcare programs to minimise the use of chemicals and promote environmental awareness; promotion of integrated pest management programs and increased liaison with advisers in the State agriculture departments. It was reported that this has resulted in a decrease in the use of chemicals over the past ten years.

Advantages of atrazine

Atrazine is viewed as an important herbicide for the control of a wide variety of broadleaf weeds and grasses. It has a role combating weeds resistant to other types of herbicides and its persistence in the soil gives control over long periods. Atrazine was reported, in some submissions, to be the only herbicide available to combat weeds resistant to other chemicals. Respondents reported no build up of atrazine residue in soils as a result of normal use. Use patterns varied but usually included rotation of an atrazine-resistant crop with one or more susceptible crops, limiting atrazine application to no more than one every three to five years on a particular area.

Several submissions supported the use of atrazine for canola crops, which is reported to be an expanding industry due to the introduction of atrazine-tolerant canola varieties. This has allowed canola to be grown in areas previously unavailable because of the unsuitability of any herbicide other than atrazine to control the weeds present in those areas.

Cost effectiveness

Atrazine was considered to be a cheap, broad spectrum herbicide. Alternatives were reported to be either more expensive or to control a narrower range of weeds. If atrazine were not available, respondents reported they would have to use other herbicides, costing up to five times more. This would disadvantage operations, affect livelihoods or cause more hardship to owners of properties already affected by drought or mice. The time and expense involved in registering new products was also seen as a disincentive to finding substitutes for atrazine.

The grass seed industry reported that a drop in yields of between 50 and 80 % could result if atrazine were no longer available. The grass seed produced would be sub-standard, contaminated with unwanted grass weeds and would no longer meet the government’s certification standards.

Improved yields through minimum tillage

Reports were received that the use of atrazine over the years had increased yields and decreased soil erosion. One respondent reported no crop failures in 16 years; another a yield of grain that was 0.5 to 2.0 tonnes/ha above that of neighbouring properties; and a third observed that the soil contained more biological activity such as earthworms.

Plantation forestry

Atrazine is reported to be the major preparatory herbicide for planting trees commercially, especially during the establishment period in the first two years. It is used to reduce competition from weeds and is also thought to stimulate tree growth. Figures provided showed that survival increased from 56 to 96% (at 52 weeks) for eucalypts on ex-pasture - no weed control versus atrazine weed control. It was also estimated that at least one year's tree growth was lost for each year herbaceous weeds were not controlled after planting.

The Tasmanian plantation forestry industry views atrazine as a way farmers can utilise marginal land, particularly steep areas. The trees also provide wind breaks and animal shelters.

In Victoria, one submission described how trials have been initiated to control woody weeds. Suitable sites are planted with legumes and grasses before tree planting. After planting, the trees are released from competition from the oversown species by spot herbicide application which decreases the area treated. This new approach is not considered possible without atrazine.

Without atrazine, respondents consider additional cost of $184/ha per year could be incurred. Substitutes are reported to have some level of phytotoxicity and poorer residual control. In New Zealand, terbuthylazine is used as an alternative to atrazine on pines, but this is not registered in Australia and is more expensive.

Several respondents also felt that it was premature for the NRA to make decisions on the fate of atrazine in the plantation forestry industry when the investigation of plantation forestry use by the Forest Herbicide Research Management Group is still in progress and the results of the success of the 1995 restrictions are not known.

Proposed outcomes

Comments on the possible outcomes of the review were wide ranging, including:

- atrazine should be deregistered and replaced by non-polluting means of weed suppression;
- aerial spraying should be banned;
- more restrictions on use should be implemented;
- no more off-label permits should be issued;
- research should be initiated into more environmentally acceptable ways of applying atrazine; and
- atrazine should be maintained under its current conditions.

Atrazine survey

The NRA also surveyed various groups involved as advisers, users and registrants of atrazine to gather information on use, performance, changed agricultural practices, adverse effects and trade and residues. The results form part of the efficacy report which appears in section 7 of this summary.

1.5 Chemical and product details

History of registration

Atrazine was reported and developed in the late 1950s by Ciba-Geigy. It was first registered in Australia in 1960-61 for the control of annual weeds and seedling grasses in broadacre crops such as maize, sweet corn, broom millet, sachalline, and non-agricultural situations such as along fence lines, irrigation channels, drains, driveways and footpaths. Registration was later extended, in 1977, to include the control of weeds around pine seedlings.

The toxicology of atrazine was first considered by the National Health and Medical Research Council (NHMRC) of Australia in 1985. It was subsequently evaluated and reviewed by the NHMRC on a number of occasions.

Maximum residue limits (MRLs) were established for corn, grain and fodder, sorghum, broom millet and established lucerne and sweet corn in 1983-84. An experimental MRL in cereal grains was also established at that time.

In 1993 the NRA investigated the issue of atrazine use and water contamination. This investigation resulted in a set of amendments to use patterns, including buffer zones from water courses, dams and wells, and maximum application rates. Previous uses in non-crop situations such as fence lines, rights of way and irrigation channels were discontinued at the end of December 1995 because of concerns for aquatic contamination. These discontinued uses generally involved much higher rates of application in situations conducive to off-target movement to water.

Another outcome of the 1993 investigation was establishment of the Forest Herbicide Research Management Group. The role of this group was and is to plan and review a water monitoring program and a series of trials on the impact of various atrazine use patterns on water quality. Interim recommendations from the Group are expected in 1997 with final recommendations by 1998-99.

Use pattern

Atrazine is a selective systemic herbicide which provides knockdown and residual action. It is mainly absorbed through the roots, then transported to the actively growing tips and leaves where it inhibits photosynthesis and interferes with other enzymatic processes in the plant to produce yellowing and death. Atrazine is used before and after the emergence of weeds to control some annual grasses and most broad-leaved weeds in a variety of crops and plantation forestry.

Atrazine is toxic to many crops, including most vegetables, potatoes and soya beans. Crops which are not tolerant to atrazine, should not be planted until the area is free of atrazine residues.

In Australia, atrazine is registered in 34 products and 4 technical grade active constituents (TGAC), produced by 13 companies (a full listing is available at Attachment 1). Atrazine products are available as liquids, granules, wettable powders and water dispersible granules. It is formulated alone and in combination with other herbicides such as ametryn, amitrole, hexazinone, metalochlor, glyphosate and dicamba.

Atrazine is one of the most widely used herbicides in Australian agriculture (estimated tonnage, a few thousand tonnes per annum). Major agricultural uses in Australia include summer crops such as sorghum and maize. It is also used on sugarcane and is widely used in Western Australia on lupins. Use on triazine-tolerant canola is a new, rapidly increasing use, allowed under NRA permit. Minor uses include lucerne, grass seed, pasture and potatoes. Off-label uses include chickpeas and faba beans. Main non-agricultural uses are in the establishment of pine and eucalypt plantations (the major use occurring in Tasmania) and Parthenium weed control in Queensland, parts of the Northern Territory and northern NSW.

Currently approved labels for products containing atrazine contain recommendations for use on the following crops:

broom millet	lupins	sacchaline	ryegrass seed crops	forage sorghum
Eucalyptus spp	maize	sorghum	sweet corn	lucerne
grass seed crops	potatoes	sugarcane	*Pinus radiata*	

Atrazine is also used for weed control in conservation tillage farming systems, for seedbed establishment prior to planting sorghum, or for fallow maintenance prior to wheat, peas or lupins. Weed control areas in the home garden include driveways, footpaths, fence lines, paved areas and tennis courts.

Application methods

Atrazine is applied as a coarse spray either pre- or post-emergence. The exception is potatoes, where atrazine is used as a harvest aid after the crop has matured. In general, ground-based application methods such as spot applications with a knapsack sprayer, strip or panel application and broadcast application by ground-based machinery predominate, but aircraft are commonly used in fallow situations and sugarcane, and helicopter application is widely used in plantation forestry.

Formulation

Atrazine technical grade active constituent is not manufactured in Australia. It is imported from the United States, Switzerland, Italy, South Africa and Israel.

Packaging

Container sizes for liquid products include 5L, 20L, 200L and 1000L. The granular product is packaged in 20 kg bags. The wettable powder is in 2.2 kg and 25 kg lots and the water dispersible granules are in 2.2 kg, 10 kg and 15 kg lots. Container sizes for home garden products include 100 g, 200 g and 1L packs.

1.6 Overseas regulatory status

Atrazine is registered in many countries, including the USA and the European Union (EU), but with various restrictions. Examples are reduced application rates in the USA and a ban on use on non-cropped land in the UK. Some EU member States (Germany, Italy, Norway and Sweden) have discontinued the use of atrazine because of its widespread presence in water. Atrazine and the closely related herbicide, simazine, are currently under special review in the USA because of concerns associated with their presence in drinking water and possible carcinogenic properties.

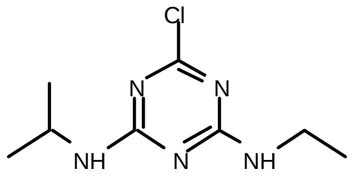
NB. The following assessments are summaries only and have been simplified to make them easier to understand **-** *this sometimes means using less precise descriptions. For full details of the assessments you should refer to the technical report.*

2. CHEMISTRY ASSESSMENT

2.1 Chemical identity

Common name: atrazine

Structural formula:



Purity: 92-95% minimum atrazine, 98% minimum active triazines (includes the symmetrical triazines simazine and propazine). Impurities include dichlorotriazines, tris(alkylamino)-triazines and hydroxy-triazines.

Empirical formula: $C_8H_{14}ClN_5$

Molecular weight: 215.7

2.2 Chemistry aspects

The chemistry aspects (manufacturing process, quality control procedures, batch analysis results and analytical methods) of the atrazine technical grade active constituents (TGAC) continue to meet current standards.

3. TOXICOLOGICAL ASSESSMENT

The toxicological database for atrazine and four of its metabolites, which consists primarily of toxicity tests conducted using animals, is extensive. In interpreting the data, it should be noted that toxicity tests generally use doses which are high compared to likely human exposures. The use of high doses increases the likelihood that potentially significant toxic effects will be identified. Toxicity tests should also indicate dose levels at which the specific toxic effects are unlikely to occur. Such dose levels as the No-Observable-Effect-Level (NOEL) are used to develop acceptable limits for dietary or other intakes at which no adverse health effects in humans would be expected.

3.1 Toxicokinetics and metabolism

The metabolism of atrazine is very similar in different species of mammals, although rates of metabolism may differ. Atrazine is almost completely absorbed from the gastrointestinal tract, rapidly metabolised in the liver, then excreted from the body (mainly in the urine), with no significant accumulation and without metabolism in other tissues.

3.2 Acute studies

When applied to the skin, under the skin, into the abdominal cavity and inhaled by laboratory test species, atrazine has low to very low acute toxicity. It may possibly be a mild eye irritant, but is not a skin irritant. Atrazine does not appear to be a skin sensitiser in humans, although conflicting results were obtained in animal studies.

3.3 Short-term repeat-dose studies

When young weanling rats were fed atrazine for two weeks, then allowed to recover for two weeks, bodyweights returned to almost normal and other effects were largely reversible, suggesting that atrazine delayed maturation but did not produce long-lasting effects. There was no evidence of permanent effects on the immune system, blood forming tissues or endocrine organs.

When Sprague-Dawley (SD) rats were fed by stomach tube at 200 mg/kg and above for two weeks, atrazine reduced levels of the hormone, oestrogen. This suggests that such effects could occur at lower doses in long-term studies, thus influencing mammary tumour development in a strain of rats already predisposed to developing them.

When applied to the skin of rabbits for 21 days, atrazine influenced bodyweight gain, food consumption and several other biochemical changes, indicating that atrazine is absorbed through the skin. When female SD rats were fed with diaminochlorotriazine (DACT) by stomach tube for at least 2 weeks, they appeared thin and hunched at the two highest doses. Oestrogen levels were lower at doses of 200 mg/kg/d and above. When beagles were fed DACT for 4 weeks, the NOEL was about 14 mg/kg bw/d on the basis of the faecal, bodyweight, food consumption and heart effects at 1000 ppm (21-27.2 mg/kg bw/d) and above. When a formulation containing 250 g/L atrazine and 130 g/L dicamba was applied to the skin of New Zealand White rabbits, it caused slight to moderate skin irritation, but no poisoning.

3.4 Subchronic studies

Rats and dogs fed atrazine for 3 months showed consistent effects of reduced bodyweight gain and food consumption and mild anaemia indicative of effects on blood-forming tissues. Reduced testicular weight/small testes occurred at high doses.

Feeding studies with desethylatrazine, hydroxyatrazine, desisopropylatrazine and DACT generally produced similar findings to atrazine. Additionally, desisopropylatrazine caused thyroid activation and enlargement of hormone-producing cells in the pituitary of rats and,hydroxyatrazine had some toxic effects on the kidneys. As with atrazine, DACT increased the length of the oestrous cycle in SD rats and the incidence of persistent oestrus.

3.5 Long-term studies

Twenty long-term toxicity studies on atrazine were examined, including 3 in mice, 14 in rats and 3 in dogs. In addition, long-term studies using DACT (one-year dietary study in dogs) and hydroxyatrazine (2-year dietary study in rats) were evaluated. It is not possible to cover the results of such a large range of studies in any detail in this summary but the main cancer findings are summarised in Table 1:-

Table 1: Summary of long-term toxicity studies on atrazine and its metabolites

Study	Tumourigenicity Finding
Mouse 18-month dietary	No cancer activity (two strains) at 82 ppm in the diet.
CD-1 mouse 21-22 month dietary	Possible small increase in lung cell tumours at the low- and mild-dose but not high-dose.
CD-1 mouse 91-week dietary	No cancer effects.
Albino rat (strain unknown) 2-year dietary	No cancer effects.
SD rat 2-year dietary	No increase in mammary tumours. (IBT study - not considered an adequate study).
SD rat 2-year dietary	Increased mammary tumours in females.

Study	Tumourigenicity Finding
SD rat 2-year dietary (animals taken from a 2-generation reproduction study, exposed in utero to the same dose levels)	No increase in mammary tumours in dosed females. (Apparent increase in pituitary tumours in high dose females but within historical controls. Incidences in other groups unexpectedly low).
Female SD rat 2-year dietary	Earlier incidence of mammary and pituitary tumours at the high dose (400 ppm) but no increase in overall incidence.
Female SD rat 2-year dietary	Earlier onset, but no increased incidence of mammary tumours at 400 ppm (high dose) & lower incidence than controls at 70 ppm (low-dose).
Female Fischer 2-year rat dietary	No effect on the onset or incidence of pituitary, ovarian mammary, or uterine tumours.
Fischer rat 2-year dietary	No effect at any dose on the onset or incidence of tumours.
Female SD rat 1-year	Small increase in mammary tumours at 400 ppm (high dose)
SD rat 2-year dietary - hydroxyatrazine	No effect on the time of onset of mammary tumours, but reduced incidence at the high dose.

Mild anaemia was sufficiently common to indicate that inhibition of blood production was an effect of atrazine treatment at higher doses, a reversible effect also noted after large acute doses. Anaemia, altered blood parameters and/or blood-forming tissue toxicity were noted in short-term repeat-dose studies (rabbits), subchronic studies (rats, dogs) and chronic studies (mice, rats, dogs).

Some non cancer findings in chronic studies after dietary atrazine administration included possible cardiovascular effects, possible kidney toxicity and pelvic stones. Reduced survival of females at the high doses of 1000 ppm and 3000 ppm in two mouse studies and in one of a number of rat studies was reported; in the other chronic rat studies, mortality rates were either not affected or there was a small increase in survival in males.

Some non cancer findings in chronic studies noted after feeding DACT included cardiovascular effects in dogs. In chronic studies with hydroxyatrazine in rats, the kidneys and lower urinary tract were target organs of toxicity.

3.6 Reproduction studies

In a study of reproduction in rats, the animals were given water representative of groundwater contaminated with pesticide/fertiliser mixtures at 1x, 10x and 100x actual concentrations (containing 0.5, 5 and 50 ng/mL atrazine). No significant adverse effects were seen. No developmental effects were noted in 2- and 3-generation rat dietary studies, at the highest doses tested, even though there was some maternal toxicity reported in the 2-generation study.

3.7 Developmental studies

No birth defects were noted in 2- and 3-generation reproduction studies with atrazine or in developmental studies with atrazine and each of its four metabolites.

3.8 Genotoxicity studies

In a large range of *in* vitro and *in vivo* studies, mostly negative results were obtained and the weight of evidence is that atrazine does not interact with genetic material. Tests for damage to genetic material in rats and mice dosed for 13 weeks with atrazine-containing drinking water (up to 100x the levels found in contaminated US water) were negative. Concerns have been expressed about the genotoxicity of N-nitrosoatrazine (NNAT) but available evidence points to rapid decomposition of synthetic NNAT in the environment; no data were cited to indicate that it was formed in the environment after atrazine use.

The four atrazine metabolites desethylatrazine, desisopropylatrazine, DACT and hydroxyatrazine were negative in gene mutation assays, *in vivo* chromosomal effects assays, and assays for DNA damage.

3.9 Immunotoxicity

In a specific study on the immunotoxic potential of atrazine, transient and reversible suppression of the immune response and stimulation of body cells that engulf foreign cells could not be attributed to sublethal exposure to an atrazine formulation.

3.10 Special studies

Several studies supported the hypothesis that atrazine speeds up reproductive ageing of the neuroendocrine (brain-hormone) system in female SD rats. This results in a longer oestrogen exposure period which produces an earlier onset of mammary tumours; a threshold exists for this effect.

Studies on the interaction of atrazine, simazine and DACT with rat uterine oestrogen receptors (ER) showed that these chemicals were about 100 000 less effective than oestradiol itself in competing with radio-labelled oestradiol ERs. Overall results of *in vitro and in vivo* studies suggest that these three triazines possess no intrinsic oestrogenic activity but can weakly inhibit responses in the SD rat uterus. It is possible that this weak oestrogen-stimulated, anti-oestrogenic activity may be caused by an indirect interaction with hormone signals.

Rats and mice given pesticide/fertiliser mixtures in their drinking water for 26 weeks, representative of established groundwater contamination in California and Iowa, showed no obvious adverse effects.

3.11 Effects in humans

No signs or symptoms of poisoning due to atrazine have been seen in humans and an antidote is neither known nor needed.

In a population study of white Kansas males (1982-86), the relative risk of non-Hodgkins lymphoma (NHL) associated with the exclusive use of triazines was not statistically significantly different from controls.

In a published case-control interview study (1993) conducted in 4 mid-western states of the USA, the combined odds ratio for NHL with atrazine use was 1.4 but, when adjusted for other pesticides (2,4-D and organophosphorous insecticides), the atrazine-NHL association was much reduced (to less than one in all but one State) i.e. these data provide little evidence that atrazine use is associated with NHL in white males.

In a case-control interview study (1990) of agricultural risk factors for leukaemia amongst white men in Iowa and Minnesota, there were slight but significantly elevated risks for farmers over non-farmers for all leukaemia (odds ratio 1.2) and for chronic lymphocytic leukaemia (odds ratio 1.4). However, when considering exposures to individual chemicals, there was no evidence of a link between atrazine use and leukaemia.

Mortality rates were studied in 1472 workers at a triazine manufacturing plant in Louisiana and compared with general population mortality rates. Overall, mortality of the workers was much lower than the general population. Cancer rates were normal (3 observed vs 3.7 expected cancer deaths). A significantly larger population follow-up study of workers at two atrazine production plants in the USA showed an increase of observed-over-expected levels of non-Hodgkin's lymphoma (NHL) and the cancer, soft tissue sarcoma, which was statistically significant. The actual numbers of cases were very low, however, and some of the workers concerned had only been recently employed at the plants.

Between 1980 and 1985 in Italy, 65 women with primary ovarian cancers were compared with 126 randomly-selected women. 'Exposed' individuals were defined as those involved in the preparation or use of triazine herbicides or who worked in corn cultivation which used herbicides, including triazines. Relative risks were 2.7 for 'definitely exposed' subjects, and 1.8 for 'possibly exposed' subjects. Actual triazine exposure was not measured. Although a number of reproductive factors for ovarian cancers were controlled, other known non-reproductive factors(e.g. obesity, smoking and alcohol) were not. Several critiques concluded that, on the basis of the statistics, classification of the exposed women, and possible confounders and biases, the case for an association between ovarian cancer and triazines was weak, and for a causal link, even weaker.

Ciba-Geigy conducted a population study at their Schweizerhalle plant. One hundred and fifty four pairs of employees were compared to determine if there was any increase in health disorders amongst those working with atrazine. The study did not find any changes in clinical signs measured. Stomach upsets were seen in more people exposed to atrazine but this was not linked to the duration of exposure. The researchers concluded it was unlikely that exposure to atrazine was causing this effect.

3.12 Conclusions for public health standards

Poisons scheduling

Atrazine is currently in Schedule 5 of the Standard for the Scheduling of Drugs and Poisons (SUSDP), and this is appropriate for a compound with the low acute toxicity of atrazine. Current safety directions on the product labels are appropriate for limiting exposure, and first aid instructions give satisfactory advice in the event of poisoning.

No observed effect level / acceptable daily intake

The lowest no-observed-effect level (NOEL) for atrazine is 0.5 mg/kg bw/d, based on results of a 2-year dietary rat study in which 10 ppm was taken as the no-effect-level for mammary tumours in female rats. While the mammary tumours are not considered to be relevant to human health, the response reflects an hormonal interaction and is, therefore, an appropriately conservative endpoint for assessing the acceptable daily intake (ADI).

The lowest NOEL reported for desethylatrazine was 3.5 mg/kg bw/d, based on reductions in bodyweight gain and food consumption, blood changes and an increase in liver weight and serum alkaline phosphatase -a marker of liver and bone disease (in a 3-month dietary study in rats) and possible heart and kidney effects (in a 3-month dietary study in dogs).

The lowest NOEL reported for desisopropylatrazine was 3.2 mg/kg bw/d, based on thyroid gland activation and enlargement of hormone-producing cells in the pituitary (male rats), unusual sites of blood cell formation in liver and spleen (female rats), and increases in liver weight (female rats, 3-month dietary study).

The lowest NOEL reported for DACT was 0.7 mg/kg bw/d, based on oestrous-cycle effects (3-month dietary study in rats).

The lowest NOEL reported for hydroxyatrazine, a plant metabolite of atrazine, was 0. 5 mg/kg bw/d, based on kidney toxicity in rats (2-year dietary study).

The current ADI for atrazine is 0.005 mg/kg/day, based on the NOEL of 0.5 mg/kg/d and using a safety factor of 100.

It is recommended that the current ADI value for atrazine stand, as a basis for controlling possible residues of atrazine in food. However, it is recommended that the Australian Drinking Water Guidelines be amended to include metabolites of atrazine together with parent atrazine in the definition of atrazine; this action will have the equivalent effect of lowering the Guideline Value* (currently 0.5 μg/L) for atrazine alone since, in water samples in which atrazine is detected, one or more metabolites are commonly detected but disregarded in the current guideline.

Therefore, this issue should be referred to the NHMRC for consideration by a joint NHMRC and ARMCANZ committee, which conducts ongoing reviews of the drinking water guidelines. The proposed atrazine drinking water guideline should be based upon a combined total of atrazine plus at least its three main chloro-metabolites, desethylatrazine, desisopropylatrazine and diaminochlorotriazine. Hydroxyatrazine may be included if Australian water monitoring studies show it to be a significant contributor to total triazine contamination.

* The level at, or above which, action should be taken to identify the source and prevent further contamination.

4. OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT

4.1 Existing regulatory controls for occupational health and safety

Hazardous substances

Atrazine is included on the National Occupational Health and Safety Commission (NOHSC) List of Designated Hazardous Substances. The updated European Union classification lists it as a category 3 carcinogen [substances which cause concern for humans owing to possible carcinogenic effects, but in respect of which the available information is not adequate for making a satisfactory assessment] and category 3 mutagen [substances which cause concern for humans owing to possible mutagenic effects, but in respect of which available information does not satisfactorily demonstrate heritable genetic damage] and allocates the following risk and safety phases:

R20/22	Harmful by inhalation and if swallowed.
R36	Irritating to eyes.
R40	Possible risk of irreversible effects.
R43	May cause sensitisation by skin contact.
S2	Keep out of reach of children.
S36/S37	Wear suitable protective clothing and gloves.
S46	If swallowed, contact a doctor or Poisons Information Centre immediately and show this container or label.

All the atrazine products under review are hazardous substances. Hazardous substances come under the controls for workers specified in NOHSC Control of Workplace Hazardous Substances.

Atmospheric monitoring

There is a NOHSC Exposure Standard for atrazine of 5 mg/m^3 time weighted average.

4.2 Toxicity and contamination relevant to occupational exposure

Under experimental conditions, atrazine has low oral and dermal toxicity and very low inhalation toxicity. It is a slight eye irritant and skin sensitiser in animals but these effects have not been demonstrated experimentally in humans. In a single dose, an average 60 kg worker would need skin contamination of more than 186 g atrazine, 372 mL of a 50% liquid product or 207 g of a 90% solid product, to reach the dermal LD_{50} (dosage of a chemical that kills 50% of a test population).

Information on the toxicity of atrazine following repeated exposure comes from long-term studies in animals. An oral no-observed-effect-level (NOEL) of 4.1 mg/kg bw/day, based on the earlier onset of mammary tumours in a one-year female rat dietary study, is selected as the most appropriate for the occupational health and safety risk assessment.

There is a human study of absorption of radioactive atrazine through the skin and excretion in urine and faeces. Excretion rates of 5.63% and 1.18% were achieved with a low dose and high dose, respectively. The value of 1.18% was selected as the dermal absorption factor in the risk assessment as the high dose most closely reflected the skin contamination found in end users.

Pharmacokinetic studies in Rhesus monkeys suggest that the atrazine metabolites, the chlorotriazines would be a suitable urinary biomarker for atrazine exposure in workers. Chlorotriazine residues are excreted in a predictable proportion in urine over a range of internal doses.

Using the rat oral NOEL and human dermal absorption factor, an average
60 kg worker would need daily skin contamination of more than 21 g atrazine, 42 mL of a 50% liquid product or 23 g of a 90% solid product, to experience the toxic effects of atrazine. These amounts correspond to 350 mL, 105 mL and 130 mL of the most concentrated atrazine sprays of 6% (agriculture use, ground spray), 20% (agriculture use, aerial spray) and 16% (plantation forestry), respectively.

The amounts of atrazine that may contaminate workers during routine spraying operations in agriculture and plantation forestry were estimated, to assess the likelihood of toxic effects. The rat oral NOEL and human dermal absorption were considered against estimated exposures, to give margins of exposure. The findings appear in later sections of this summary.

4.3 Reported atrazine effects

In Australia there are no reports of adverse health effects in workers linked to the use of atrazine.

In overseas reports, there are a few cases of deliberate atrazine ingestion, but no substantiated reports of atrazine causing acute systemic health effects in end users. A small number of published studies describe irritation, contact dermatitis and positive patch testing in farm workers using atrazine. The implications of long-term exposure to atrazine and other herbicides is under investigation as there are overseas reports associating an increase in certain tumour types with farming. Population studies, to date, are unable to prove or disprove an association between atrazine exposure and human cancers in manufacturing workers or farm workers.

4.4 Use pattern for atrazine in Australia

Handling prior to end use

Atrazine and some products are imported while other products are formulated in Australia. Formulators may be exposed to atrazine and the products.

Transport, storage and retail workers handle only the packaged active constituent or product, so should not become contaminated with atrazine unless the packaging is damaged.

Handling by end users

Atrazine may be applied to the same area more than once a year. It may be 2applied by air (fixed wing aircraft or helicopter), ground rig or hand-directed means. Individual operators or contractors may apply atrazine products.

Use pattern information was obtained from product labels, chemical industry submissions and the NRA Performance Questionnaires. It is used to estimate worker exposure under Australian conditions and is summarised in Table 2.

Table 2: End use parameters derived from NRA Performance Questionnaires used to estimate worker exposure and risk

Situation	Model	Application rate		
		kg a.i./ha (maximum per year)	spray L/ha (range)	ha/day (range)
Broadacre except lucerne/lupins	boom spray	3	50 - 400	12 - 270
Lucerne/lupins	boom spray	0.55	50; 140	12 - 270
Potatoes	boom spray	1.15	100	5 & 50
Sugar cane	boom spray	3	50 - 250	20
Plantation forestry	hand spray	8	50 - 200	6 (1); 1(2)
Plantation forestry	boom spray	8	50 - 1000	6 - 72

(1) used for hand-spraying from a trailer-mounted tank.

(2) based on supplementary information from the forestry industry for knapsack sprayers

The maximum atrazine concentration in working strength spray is 6% in agriculture ground sprays, 16% in plantation forestry ground sprays and 20% in aerial sprays. Concentrates may be added to the spray tank or premix tank by the open pour method, venturi device or direct transfer from bulk containers. One granular product used in plantation forestry, a combination of atrazine and hexazinone, is dispensed without dilution. Broadcast, strip or spot spraying is used as appropriate.

4.5 Occupational exposure and risk

End users may be contaminated with atrazine when mixing/loading, applying spray, cleaning up spills or maintaining equipment. Workers entering treated areas may become contaminated with sprayed soil or foliage. Workers handling soil contaminated produce may contact atrazine residues. The main means of contamination will be by skin exposure to the concentrate, spray mist and contaminated surfaces. Atrazine has low vapour pressure so inhalation of vapour from the concentrates is unlikely. However, as some atrazine products are formulated as wettable powders, granules or water dispersible granules, breathing in of product dust is possible. Sprayers may inhale spray mist.

It is possible for farm operators to be exposed to atrazine for periods of a few days in one or two episodes per crop in the early season. Contract sprayers for all crop types and plantation forestry uses would have regular exposure to atrazine over the treatment season. The duration would depend upon the crop area being serviced.

Measured worker exposure

The report assessed a number of worker studies of varying quality and applicability to the Australian use pattern. Where possible, extrapolations were made from similar use patterns in the studies for the agricultural and plantation forestry uses under assessment. Additional exposure data provided from the exposure database, PHED, was used in the risk assessment. The risk assessment used the maximum allowable application rate and the range of treatment areas summarised in Table 2. The estimations of exposure and risk from the worker studies indicated that applying atrazine by boomspray in agriculture and plantation forestry and by hand spray gun in plantation forestry was acceptable for workers wearing hand and body protective clothing. Contamination was reduced if sprayers were inside enclosed cabs. Workers manually spreading atrazine granules using a cranking handle however became visibly contaminated with dust and had unacceptable exposure and risk.

Predicted worker exposure

The measured worker exposure data was supplemented with exposure data generated by the UK Predictive Operator Exposure Model (POEM). POEM was used to estimate atrazine exposure for the Australian use pattern in agriculture and plantation forestry. Two application methods were chosen:

- boom spray, ie vehicle mounted (with cab) hydraulic nozzle boom spray (V-nozzle), and
- hand spray (knapsack), ie hand held outdoors hydraullic nozzles (H-nozzle)

The risk assessment used the maximum allowable application rate, the range of treatment areas summarised in Table 2, and 3 hours spraying time per day. When diluting the product, exposure was higher for workers diluting a liquid than a solid product. The formulation type has no influence on applicator exposure. Predicted exposure and risk were acceptable for most uses tested as long as workers involved in mixing/loading, spraying or the combined tasks of mixing/loading and spraying wore gloves and body protection, used enclosed cabs and used bulk containers where large volumes of atrazine concentrate were required. Certain low volume broadacre and plantation forestry boomspray use patterns had high exposure, however a comparison with the most relevant measured worker study indicated that the predicted exposures were an overestimate and the risk was acceptable. Exposure for boomsprayers using open cabs is not included in the model.

Predicted exposure was high and the risk unacceptable for plantation forestry workers using knapsack sprayers, however consideration of a simazine surrogate measured worker study indicated that the predicted exposure was an overestimate and the risk was acceptable.

Inhalation exposure over all uses ranged from 0.2 to 0.9% of total exposure for mixers/loaders/applicators wearing gloves and body protection.

Qualitative assessment - aerial operations

Hundreds of hectares may be treated per day by air in both agriculture and plantation forestry operations, using a high concentration of atrazine in working strength spray or by direct application of granules. There were no worker studies submitted for aerial sprayers, apart from PHED exposures. The predictive model is not designed for aerial spraying. Atrazine products are either poured into vats and pumped to the plane or directly pumped to the plane. To treat the required areas, bulk supplies of the liquid atrazine would be needed as using many small (ie 20 L) container sizes would be impractical. Direct transfer of bulk product should enable more effective control of exposure. Exposure during transfer of granules would be limited. Hand and body protective clothing will be needed for mixer/loaders. Pilots are protected against direct exposure to spray mist or directly dispensed granules.

The risk to mixer/loaders and pilots is acceptable.

Human flaggers involved in aerial spraying may become contaminated with spray mist. Limited information is available on flagger exposure. The risk to human flaggers is considered unacceptable, unless protected by engineering controls such as enclosed cabs.

Qualitative assessment - re-entry

No information or worker exposure studies covering re-entry into atrazine-treated areas were submitted for review. The use of atrazine in relation to crop tending activities indicates that for broadacre crops, sugar cane and plantation forestry, re-entry would neither be frequent nor of long duration. Atrazine is used to kill weeds in potato crops prior to harvest. However, as any treated weeds will have died by harvest, any residual atrazine will be low. Harvesting is a mechanical operation involving some handling for sorting purposes. Workers handling harvested potatoes may come into contact with atrazine soil residues. The degree of exposure is unlikely to create a risk for such workers.

4.6 Conclusions

The occupational health and safety risk assessment concludes that atrazine can be safely used in accordance with restrictions introduced in December 1995, subject to restrictions on certain manual activities. This conclusion is based on a quantitative risk assessment using measured (including surrogate) and predicted worker exposure and a qualitative risk assessment for uses where worker exposure data was not available.

This conclusion takes into account controls available for large scale use of atrazine, namely bulk handling and enclosed transfer methods, enclosed tractor cabs and aerial spraying.

The existing safety directions for atrazine do not contain sufficient personal protective clothing requirements for all products, based on the findings in the occupational health and safety risk assessment.

Given the current use pattern of atrazine in relation to crop tending activities, re-entry into treated areas or handling of produce contaminated with atrazine soil residues, does not place workers at risk.

5. ENVIRONMENTAL ASSESSMENT

Atrazine has a history of aquatic contamination which contributed to its selection for review.

5.1 Environmental exposure

Environmental monitoring

Because of its widespread use and environmental properties, atrazine is a commonly found contaminant of surface and ground waters in Australia, particularly within irrigated agriculture and plantation forestry areas. The NRA has revised use patterns to counter this contamination, with the phase out of most non-crop uses, including for irrigation channel hygiene, and the introduction of reduced rates in plantation forestry. However, a number of registrants and users appear to be unaware of, or are ignoring, these restrictions.

Atrazine has been found at concentrations in the order of 100 µg/L in irrigation drainage water from a rice growing area with some maize, and occurs commonly in natural surface waters, generally at concentrations below 10 µg/L and, in most cases, below 1 µg/L. Atrazine may be found in surface waters across Australia, with irrigation and drainage channels and forest areas recognised as key sources. A median concentration of 8.1 µg/L was found in Tasmanian streams draining forestry plantations on the day of application. Runoff from irrigated and dryland farming also contributes to aquatic contamination. Poor agricultural practices such as tailwater release from excessive irrigation and application shortly before heavy rains or storms or to waterlogged soils appear to be significant sources of environmental exposure.

Only limited monitoring of groundwater has been conducted, but atrazine is commonly detected at concentrations in the order of 1 µg/L, accompanied at some sites by the metabolite desethylatrazine.

Environmental chemistry and fate

Atrazine is a well studied herbicide, with environmental fate data available for the following areas.

Hydrolysis

Atrazine is transformed to hydroxyatrazine by hydrolysis (breakdown with water), but the reaction is very slow in sterile water. Transformation is more rapid in soils, where hydrolysis is believed to be catalysed by acidic groups within the soil organic matter.

Photolysis

Atrazine breaks down under the influence of sunlight to a range of dechlorinated and dealkylated products, but the reaction is slow with an estimated half-life (time required to reduce by one-half the concentration of a material) in water of about a year. Degradation is faster in the presence of humic acids as sensitiser, giving rise to an additional product (ammelide) from deamination. Half-lives of a few weeks on soil surfaces exposed to natural sunlight appear typical.

Metabolism

A broad range of studies was submitted, including standard metabolism and biodegradation studies conducted according to recognised test guidelines, and published papers examining specific issues such as increased mineralisation (complete breakdown) in the presence of enriched microbial cultures. The key points to emerge are that bioavailable atrazine is moderately persistent in the environment. Furthermore, atrazine tends to become non-bioavailable by forming non-extractable residues rather than degrading, with very limited mineralisation under normal environmental conditions.

Laboratory investigations indicate that atrazine degrades in soils through a combination of soil catalysed processes and microbial and plant metabolism, with the main reactions being hydrolytic dechlorination, side chain dealkylation, and subsequent deamination. The hydrolytic reaction, which is soil catalysed, appears to be favoured in acidic soils.

Half-lives from laboratory metabolism studies range between 1 and 8 months. These data should be interpreted as half-lives for loss of bioavailable atrazine as non-extractable residues have been excluded from their derivation. Non-extractable residues generally include significant proportions of unchanged atrazine, which considerably increases the half-life when considered in calculations. Half-lives can easily extend to more than a year when calculated on this basis.

Loss of atrazine from soils is mainly accompanied by the formation of non-extractable residues. Non-extractable residues break down in a similar way to extractable residues and release under environmental conditions may occur at a few percent per year through microbial or plant metabolism or decomposition of soil organic matter.

Mineralisation of atrazine in soils is a very inefficient process, except where soils have been artificially fortified with atrazine-mineralising bacteria. Intermediate metabolites such as cyanuric acid and ring opened products such as biuret and urea are not isolated.

Breakdown in aquatic systems follows similar pathways, with the hydrolytic reaction apparently catalysed by sediment. Aquatic sediment appears to have only limited capacity to attach atrazine. At low atrazine concentrations, half-lives of 2 months or more appear typical of freshwater systems, while break down in estuarine (tidal) systems shows half-lives of less than a month.

Mobility in soil

A broad range of studies was submitted to define the mobility characteristics of atrazine, including standard batch adsorption and column leaching studies conducted according to recognised test guidelines, and published articles dealing with mechanistic aspects and using less standard methods. It is evident from the papers submitted that atrazine undergoes only limited attachment to soils, although increasing amounts become associated with the soil over time. The mechanism of attachment has been closely investigated over short and long-terms but remains incompletely understood.

Considerably more data exist for atrazine than for other herbicides, and this review is not exhaustive. Results from the studies reviewed are broadly consistent and allow the following conclusions to be drawn.

Atrazine undergoes limited attachment to soils (reported soil organic carbon partition coefficients in the order of 100) and is highly mobile. A significant proportion of attached chlorotriazine residues is slow to release, and desorption coefficients (which indicate the strength of attachment) are indicative of moderate to strong attachment and low to moderate mobility. The difference between adsorption and desorption means that atrazine tends to be highly mobile soon after application. However, once adsorbed, the mobility of atrazine is highly influenced by soil desorption processes. The dealkylated metabolites desethylatrazine and desisopropyl-atrazine exhibit similar behaviour, but have slightly lower desorption coefficients than atrazine.

Attachment mainly occurs to organic matter in the soil, particularly if it contains high levels of humus. Soil organic matter has two attachment regions, partitioning and hole filling, the latter occupied more slowly and accounting for the bulk of residues in soils with a history of atrazine applications. There may be a lesser but significant contribution from clay minerals. Attachment may occur through two different mechanism; the relative significance of each appears to vary across different soils.

Desethylatrazine appears to be the most mobile metabolite, followed by atrazine, desisopropylatrazine and DACT, with hydroxytriazines significantly less mobile.

Persistence and mobility data suggests atrazine is a probable leacher. Similar studies indicate that the dealkylated metabolites desethylatrazine and desisopropyl-atrazine are more prone to leaching than atrazine.

Leachability is confirmed by column leaching studies. While atrazine and metabolites are largely retained on soil columns, significant amounts (in the order of 5% of applied) are recovered from leachate. Atrazine forms a slow-moving fraction in soils that can act as a source of long-term, low level leaching.

Atrazine is not particularly volatile, with losses of a few percent to evaporation in the few days following application.

Field dissipation

Atrazine residues were largely confined to the surface 20 cm of soils, declining from a few ppm soon after application to the low-mid ppb range over the course of a year. Note that these are extractable residues, and may be accompanied by significant amounts (over 80% of applied in one case some 9 years after application) of non-extractable residues. Atrazine concentrations in leachate collected at depths in the order of a metre generally remain below 10 µg/L although detections up to 54 µg/L have been recorded. Atrazine was found at 34 µg/L in leachate at 80 cm depth some 9 days after bare ground application at 5 kg/ha. Losses from conventional tillage appear generally to be smaller than from no-till plots, particularly the leaching component, because of preferential flow through wormholes and other macropores under the latter conditions.

Desethylatrazine is the most abundant and mobile metabolite. Hydroxyatrazine appears to be the most persistent metabolite and also the least mobile primary metabolite.

Lysimeter studies gave similar results, with around 1% of applied radiolabeled atrazine leaching to depths of 2-4 m over a year. Concentrations were in the low ppb range with peak levels around 20 µg/L at a depth of 90 cm).

Volatility losses represent a few percent of atrazine applied, although higher estimates exist. Because of its widespread use, atrazine is a commonly detected contaminant of fog and rainwater.

Accumulation and bioaccumulation

Atrazine has the potential to accumulate as non-extractable residues (a reversible but slow-moving fraction) in soils, given that as much as 83% of the original radiolabel can still be found in soil nine years after application. However, the rate of release of these accumulated non-extractable residues is thought to be low (no more than a few percent annually).

Bioaccumulation in fish is low, and accumulated residues are rapidly eliminated when fish are returned to clean water.

Conclusion

Considerably more data exist for atrazine than for other herbicides as it has been very intensively studied. This review is not exhaustive but based mainly on data provided by the principal registrant, together with key selected papers from the recent scientific literature. Data submitted are considered complete with no significant data gaps, although a number of aspects remain incompletely understood. In particular, understanding of attachment mechanisms remains incomplete with some results apparently in conflict, although this probably reflects the existence of a variety of mechanisms, the significance of which varies with soil properties.

Although precise mechanisms are not fully understood, it is evident that the endurance of atrazine in the environment, together with its limited attachment to soil, significant water solubility and widespread use, are disadvantageous from the environmental perspective as they lead to long-term, low level contamination of surface and groundwater. This is exemplified by contamination of irrigation drainage water in the Murrumbidgee irrigation area at levels above 1 µg/L throughout the summer cropping season, with peak levels in the order of 100 µg/L. High peak levels have also been reported in streams draining forestry plantations in Tasmania, reflecting a combination of moderate to high application rates, steep terrain, heavy rainfall, cool winter temperatures, application to wet soils, and particularly weak soil attachment in the few days following application.

The use of atrazine requires careful management and strict adherence to good farming practice if levels of aquatic contamination are to be maintained within acceptable bounds. It is particularly important that new restrictions on use introduced by the NRA are adhered to. Some registrants and users appear to remain unaware of the current restrictions and continue to promote or use atrazine in situations that can lead to aquatic contamination, such as for weed control in irrigation channels and non-agricultural situations.

5.2 Environmental effects

Toxicity tests for a broad range of species have been submitted. Data submitted are considered complete with no significant data gaps. Some of the older tests were conducted more than two decades ago, but it appears that all have been conducted satisfactorily according to accepted international guidelines such as those of the US EPA and OECD. With the exception of some of the aquatic multi-species studies, test reports have generally not been published.

Birds

Acute oral

Recent tests on Japanese quail and mallard ducks fed atrazine showed it to be practically non-toxic (LD50 > 2000 mg/kg). Occasional deaths occurred at doses above 125 mg/kg, particularly in male birds. Symptoms of intoxication included depressed food consumption, lethargy and uncoordinated movement, with some regurgitation observed in mallards. No observed effect levels were 15 mg/kg in Japanese quail and 31 mg/kg in mallards.

Earlier feeding studies showed slight toxicity to bobwhite (LD50 = 940 mg. kg^{-1}), Japanese quail (LD50 = 1660 mg/kg) and chickens (LD50 = 830 mg/kg). The relative insensitivity of Peking ducks (LD50 > 10000 mg/kg) appears to reflect regurgitation, which occurred just after administration in adult ducks and within 10 minutes in ducklings at higher doses.

The metabolite desethylatrazine was moderately toxic (LD50 = 464 mg/kg) when fed to bobwhite, with death generally occurring within a day of dosing.

Dietary

When Japanese quail chicks were fed atrazine (5 days exposure and 3 days recovery) it was found to be practically non-toxic (LC50 > 5000 ppm). Birds showed symptoms of intoxication (depressed food consumption, lethargy and hunched posture) above the no observed effect level of 1250 ppm. Older studies in Japanese and bobwhite quail returned similar results.

Reproduction

When atrazine was fed to 18 week old bobwhite quail for 20 consecutive weeks, the no observed effect level was 225 ppm based on egg viability. Similar results were obtained from an equivalent test in mallards.

Aquatic organisms

Fish acute toxicity

Atrazine was slightly toxic to rainbow trout (LC50 = 11 mg/L), common carp (LC50 = 19 mg/L) and sheepshead minnow (LC50 = 19 mg/L) in 96 hour acute testing. No observed effect concentrations were 1.8 mg/L in trout (based on erratic swimming, loss of equilibrium and pigmentation), 3.2 mg/L in carp (based on loss of equilibrium) and 3.2 mg/L in sheepshead minnow (based on lethargy and erratic swimming).

Fathead minnow, kept in still water for 7 days, with daily renewal of about 80% of the test water, showed no change in survival or growth of freshly hatched larvae at a test concentration of 4.9 mg/L.

The toxicity of desisopropylatrazine to rainbow trout (96 hour LC50 = 17.2 mg/L) is similar to that obtained for atrazine under similar conditions. The completely dealkylated metabolite DACT is practically non-toxic (96 hour LC50 > 100 mg/L) to this organism.

Rainbow trout, exposed for a short period of time to sub-lethal concentrations (1.4-2.8 mg/L) of atrazine, showed reduced movement, balance disturbances and darkening of the body surface, as well as structural changes to the kidneys.

Fish chronic toxicity

Rainbow trout fingerlings (mean weight 0.6 g), exposed for 21 days under flow-through (running water) conditions to 1.0 mg/L atrazine, showed a 40% mortality rate. The no effect concentration based on mortality was 60 µg/L. The ratio of acute to chronic no observed effect concentrations is relatively high at 300.

Sublethal effects in rainbow trout (minor alterations of kidney corpuscles and kidney tubules) were apparent at much lower concentrations (5-40 µg/L) following chronic exposure.

Fathead minnows were continuously exposed to atrazine under flow-through conditions for 274 days; initially as embryos, (mean measured concentrations between 0.15 and 2.0 mg/L) with exposure of offspring continued for 30 days post-hatch. The no observed effect level based on growth reduction in both generations was 0.25 mg/L.

Aquatic invertebrate acute toxicity

Acute toxicity results for atrazine are tabulated below.

Test	Species	Result
24 hour acute	*Daphnia magna*	LC50 = 87 mg/L
48 hour acute	*Ceriodaphnia dubia*	NOEC = 4.9 mg/L
96 hour acute	*Chironomus tentans*	LC50 > 28 mg/L
96 hour acute	*Mysidopsis bahia*	LC50 = 5.4 mg/L
96 hour acute	*Acartia tonsa*	LC50 = 94 µg/L
96 hour acute	*Acartia tonsa*	LC50 = 4.3 mg/L
96 hour acute	*Neopanope texana*	LC50 > 1000 mg/L
96 hour acute	*Uca pugilator*	LC50 > 29 mg/L

Results indicate atrazine is slightly toxic to *Daphnia magna* (the no effect concentration was 18 mg/L) and *Ceriodaphnia dubia* although, in the latter, an LC50 could not be obtained as no effects were noted at the highest test concentration.

Atrazine is slightly toxic to midge (*Chironomus tentans*). The midge test used flow-through conditions, and deviated from the protocol in that the test organisms were fed to allow survival through 96 hours. The no observed effect concentration was 5.5 mg/L based on 15% mortality at 10 mg/L.

Atrazine is moderately toxic to the marine species, mysid shrimp (*Mysidopsis bahia)*. The no observed effect level was 1.7 mg/L based on sub-lethal effects (darkened pigmentation, lethargy, erratic swimming behaviour).

Atrazine is moderately toxic to the marine copepod, *Acartia tonsa* although anomalous results in the first of the two tests listed above appear to reflect experimental irregularities. Dose dependent mortality was observed at all treatment levels, and the no observed effect concentration in the second flow-through test was below 2.9 mg/L.

Adult crabs are insensitive to atrazine. Mud crabs (*Neopanope texana*; mean carapace width 15 mm) and fiddler crabs (*Uca pugilator*; 11-14 mm) were tested in still water with results expressed as nominal concentrations. No effects are apparent within atrazine's solubility limit.

The toxicity of desisopropylatrazine to *Daphnia magna* (48 hour EC50 = 126 mg/L) is similar to that of atrazine under similar conditions. The completely dealkylated metabolite DACT is also practically non-toxic (48 hour EC50 > 100 mg/L) to this organism.

Aquatic invertebrate chronic toxicity

A 21 day still water reproduction test on *Daphnia magna* showed a no effect concentration, based on increased number of progeny at 7 and 14 days, of 0.012 mg/L. No effects were noted on adults, or on the cumulative number of offspring at 21 days, at the highest test concentration of 0.12 mg/L. The ratio of acute to chronic no effect concentrations is 1500 based on increased progeny at 7 and 14 days, reducing to 150 or less based on observations at 21 days.

A 7 day still water renewal test in *Ceriodaphnia dubia* found a significantly reduced number of offspring per female at concentrations of 2.5 and 4.9 mg. L^{-1}. The no observed effect concentration was 1.2 mg/L. Adult survival was unaffected.

Algal toxicity

Algal toxicity data are tabulated below.

Test	Species	Result
72 hour	*Scenedesmus subspicatus*	EC50 = 43 µg/L
120 hour	*Microcystis aeruginosa*	MAC = 440 µg/L
120 hour	*Selenastrum capricornutum*	MAC = 200 µg/L
120 hour	*Chlorella pyrenoidosa*	MAC = 520 µg/L
120 hour	*Dunaliella tertiolecta*	MAC = 1100 µg/L
120 hour	*Skeletonema costatum*	MAC = 85 µg/L
120 hour	*Isochrysis galbana*	MAC = 88 µg/L
120 hour	*Porphyridium cruentum*	MAC = 780 µg/L
96 hour	*Selenastrum capricornutum*	EC50 = 130 µg/L
120 hour	*Selenastrum capricornutum*	EC50 = 55 µg/L
96 hour	*Skeletonema costatum*	EC50 = 55 µg/L
120 hour	*Anabaena flos-aquae*	EC50 = 230 µg/L
120 hour	*Navicula pelliculosa*	EC50 = 60 µg/L
120 hour	*Dunaliella tertiolecta*	EC50 = 170 µg/L

Algal growth was determined by counting the number of algal cells. Results for the first 8 species listed (3 freshwater and 5 marine) are expressed as nominal concentrations, and show that atrazine is highly toxic to algae. Lowest observed effect concentrations were generally about a quarter of the minimum algistatic concentrations (concentrations that allow no net growth during exposure but with at least partial recovery in clean media).

The following three algal results also indicate high to very high toxicity, and are expressed as mean measured concentrations that cause 50% growth inhibition.

The remaining three algal results, for freshwater blue-green algae, freshwater diatoms and marine chlorophytes respectively, confirm the high toxicity of atrazine to such organisms. The algicidal concentration (at which no recovery occurred) was 3.2 mg/L (the highest test concentration) for the marine chlorophyte and above this concentration for the two freshwater algal species.

The toxicity of desisopropylatrazine to *Scenedesmus subspicatus* (72 hour EC50 = 1.39 mg/L) indicates moderate toxicity, compared with the high toxicity recorded for atrazine under similar conditions. The completely dealkylated metabolite DACT was not toxic (72 hour EC50 > 100 mg/L) to this organism.

Aquatic macrophyte toxicity

Duckweed, a floating freshwater vascular plant, was as sensitive as algae to atrazine in 5 day still water and 7 day still water-renewal tests (EC50s of 170-180 µg/L) as may be expected given that atrazine inhibits photosynthesis. The 5 day phytostatic concentration (frond counts) was 1.72 mg/L, and the 7 day no observed effect level 57 µg/L.

Potamogeton perfoliatus, an estuarine submersed vascular plant, appears to be similarly sensitive (24 hour IC50 = 80 µg/L) based on inhibition of photosynthesis as determined from measurements of dissolved oxygen.

Multi-species studies

A variety of model ecosystems studies have been conducted, and are described in the full technical report. In general, these studies find effects at concentrations around 20 µg/L, but no lasting ecosystem damage. At concentrations around 100 µg/L, irreversible changes to algal and macrophyte communities are apparent. Atrazine persists in the water column in these studies, particularly in still water systems.

Terrestrial invertebrates

Atrazine is slightly to moderately toxicity to a broad range of terrestrial invertebrates.

Atrazine was moderately toxic (LD50 = 78 mg/kg) to the earthworm *Eisenia foetida* in a 14 day artificial soil test, with significant weight loss observed at the lowest test concentration of 60 mg/kg.

Atrazine was slightly toxic to honey bees (48 hour LD50 > 100 µg per bee) exposed by contact and oral routes.

Survival and feeding of carabid beetles were unaffected by exposure to atrazine application as an aqueous spray at a rate equivalent to 1.5 kg/ha.

A reduction in survival to adulthood (about a week) and fertility of 1 day old protonymphs of the predatory mite *Typhlodromus pyri* occurred following exposure to atrazine as an aqueous spray at 1.5 kg/ha. The overall reduction of beneficial capacity was 61%, indicating slight toxicity to this species.

No inhibitory effects were noted on respiration and ammonification/ nitrification in sand and silt soils containing 6 or 60 mg/kg atrazine. Sewage microorganisms are similarly insensitive with no significant inhibition of respiration for activated sludge exposed to nominal concentrations of atrazine up to 100 mg/L for 3 hours.

Mammals

No mammalian studies were submitted for environmental assessment, but the acute toxicity of atrazine to mammals appears, from summary data, to be slight (similar to avian toxicity).

Non-target vegetation

Atrazine is toxic to a broad range of terrestrial vegetation. The dealkylated metabolites desethylatrazine and desisopropylatrazine are as phytotoxic (toxic to plants) as atrazine, but hydroxy metabolites are not toxic to plants. Germination and seedling emergence are relatively unaffected by atrazine, but early growth and plant vigour are affected in a broad range of crops (soybean, lettuce, carrot, tomato, cucumber, cabbage, oat, ryegrass and onion) at application rates above 30 g/ha. The exception is corn, which tolerates applications of 4.5 kg/ha.

5.3 Environmental hazard

Atrazine is applied as a pre- or post-emergence spray at moderate rates for control of a broad range of weeds. The main use is in coarse grains, with application occurring mainly in late spring and early summer. A notable exception is plantation forestry, where atrazine is mostly applied during winter, including after rain when soils are at field capacity.

Atrazine is expected to become mainly associated with the soil and water between the soil particles following application, but significant amounts are likely to be lost to surface and groundwater through runoff and leaching.

Terrestrial hazard

Application at the maximum rate for field crops of 3 kg/ha would leave predicted residues of 640 ppm on short grass and 360 ppm on broadleaf vegetation. These residues are not expected to present an acute toxic hazard to birds or mammals that may eat the grasses or vegetation given the low toxicity of atrazine (recorded dietary LC50s above 5000 ppm and NOECs above 1000 ppm).

The agricultural rate of 3 kg/ha equates to 0.03 mg/cm. The amount of atrazine landing on 1 cm^2 is more than 1000 times below the LD_{50} for bees, indicating a very low hazard to these organisms.

If dispersed through 10 cm of soil (density 1.2) the above rate equates to 2.5 mg/kg, well below the LD50 for earthworms of 78 mg/kg.

The increased application rates in plantation forestry areas increase the hazard to terrestrial organisms slightly but not to significant levels.

Overall, the hazard of atrazine to terrestrial fauna appears low. However, atrazine is highly toxic to a range of plants, and may impact on non-target vegetation if used carelessly. The US EPA noted that non-target plants may be periodically exposed through spray drift, as well as from the widespread presence of atrazine in soil, water and the atmosphere, and may suffer some adverse effects.

Aquatic hazard

A realistic exposure scenario is for contamination through runoff or spray drift, which may deliver around 10% of a direct application. In this situation, the predicted environmental concentration in 15 cm water receiving 300 g/ha atrazine in agricultural situations would be 0.2 mg/L, increasing to 0.3-0.5 mg/L for plantation forestry. This does not give rise to concerns for direct toxicity to aquatic fauna, but is sufficiently high to affect aquatic vegetation and impact indirectly on aquatic fauna.

The above estimates represent worst case peak concentrations at discrete sites immediately following pollution events, rather than general levels in the aquatic environment. Furthermore, any detections at or above this level are expected to be transient, and prolonged exposure to concentrations that may damage the ecosystem is not anticipated. Monitoring data for Australia indicate that most aquatic exposures to atrazine are likely to be in the low ppb range, around 100 times below the estimated level. General historical levels in natural surface waters are less than 10 µg/L, and revisions to use patterns such as the cessation of most non-crop use including in irrigation channels should help reduce contamination of Australian waterways. Higher exposures may occur in irrigation drainage systems, and in streams draining forestry plantations. Contamination of groundwater appears from limited data to be widespread, with concentrations generally in the order of 1 µg/L.

In most situations, atrazine exposures will be below the threshold for ecosystem effects of about 20 µg/L determined in multi-species aquatic toxicity testing and in literature reviews. However, safety margins may be narrow, and there is clearly a need to minimise concentrations of atrazine leaving the site of application in runoff or as spray drift. This need is particularly acute in plantation forestry situations where atrazine may enter streams in concentrations likely to be damaging to aquatic ecosystems if heavy rain occurs soon after application to wet soils. There is also a need to publicise the cessation of use in irrigation channels, as atrazine appears to remain the product of choice in such situations and many users appear unaware that such use is now prohibited.

An Australian guideline has yet to be developed for protection of aquatic life from atrazine. Guidelines are presently being reviewed. The Griffith Office of the NSW EPA has proposed an interim guideline of 2 µg/L. This is the same as the value adopted by Canada, including a tenfold safety factor based on the concentration of about 20 µg/L shown to be the threshold for adverse effects in various aquatic ecosystem studies. Off-target movement of atrazine must be minimised if such guidelines are to be met.

5.4 Conclusions

Atrazine is a mobile chemical that is likely to contaminate water at low levels as a result of normal use. This is a general property of most herbicides. Unlike many herbicides, however, atrazine can remain in soils and aquatic systems for longer periods of time. The US EPA has noted that the pervasiveness of the triazine family (to which atrazine belongs) in the environment is the result of their massive use combined with their mobility and persistence.

At the present time, exposure of the Australian environment to atrazine generally occurs at levels below those that may cause ecosystem damage. Evidence reviewed indicates this threshold to be in the order of 20 µg/L, with current exposures in natural surface waters generally below 10 µg/L and, in most cases, below 1 µg/L. However, safety margins are clearly narrow.

Australia has yet to establish a water quality guideline protecting aquatic ecosystems, but Australian guidelines are under review. A guideline of 2 µg/L operates overseas and has been proposed locally. If the continued use of atrazine is to be defended, it is clear that every effort must be made to minimise aquatic contamination. Poor agricultural practices such as tailwater release from excessive irrigation, application shortly before heavy rains or storms or to waterlogged soils, and use in irrigation channels, need to be stopped.

To further minimise aquatic contamination, agricultural methods need to be developed that reduce reliance on synthetic chemical inputs by including herbicide use in integrated weed management programs that make maximum possible use of mechanical and biological methods, and crop rotation and competition.

A number of registrants and users appear to remain unaware of, or are ignoring the restrictions to atrazine use patterns, such as prohibition on use in irrigation channels, that came into force in December 1995. These restrictions must be fully implemented and enforced. Labels should be upgraded to include the following additional restraints:

- Do NOT apply under meteorological conditions or from equipment which could be expected to cause drift of this product or spray mix onto adjacent areas, particularly wetlands, waterbodies or watercourses.
- Do NOT apply to waterlogged soil.
- Do NOT apply if heavy rains or storms that are likely to cause surface runoff are forecast within two days of application.
- Do NOT irrigate to the point of runoff for at least two days after application.

Information on use patterns is the essential basis for assessment of environmental exposure to chemicals. Information on volumes of use of atrazine in Australia has not been disclosed, except by the principal registrant. Provision on an annual basis of current and projected sales volumes should be made a condition of continued registration for all atrazine registrants. This should include information on geographical areas in which atrazine products are sold and used, and estimates of use on individual crops.

Monitoring of atrazine levels in the environment needs to continue to determine trends in atrazine contamination of Australian surface and groundwaters, and whether current and proposed restrictions are effective in maintaining or improving current safety margins. In some areas, monitoring efforts need to be expanded. For example, monitoring of storm runoff from dryland farms needs to be conducted to determine the significance of this source to general aquatic contamination. In addition, future monitoring needs to investigate levels in natural waterways as well as the irrigation drainage systems (such as the Murrumbidgee irrigation area) that have been the main focus to date. Monitoring of residue levels should be linked to biological monitoring to determine the ecological significance of atrazine levels found in Australian waterways. Responsible registrants will commit resources to such environmental monitoring as a demonstration of their commitment to product stewardship.

Should this not occur, or should monitoring demonstrate that safety margins continue to be narrow, it is strongly recommended that further restrictions be implemented.

6. AGRICULTURAL ASSESSMENT

6.1 Efficacy

The past two decades have seen a major change in farming practices from intensive mechanical cultivation towards reduced till systems using herbicides such as atrazine to control weeds. This has been accompanied by a change in crops grown with a general move away from continuous wheat cropping to crop rotations involving a range of winter and summer crops.

Atrazine has made it possible for many growers to introduce crops such as lupins and peas into the wheat and pasture rotations. The recent introduction of triazine-tolerant (TT) canola has produced a rapid increase in canola cropping. In some districts TT canolas are the only varieties that can be grown because of the weed, wild radish. Other growers find TT canola the only profitable break rotation crop for wheat since the demise of lupins due to lupin root diseases.

Atrazine is registered for use on Parthenium weed in Queensland, but the area infested with this weed now covers parts of the Northern Territory and northern NSW

Atrazine is regarded as the chemical of choice for most growers and advisers, mainly because of its broad spectrum of activity, residual nature and cost-effectiveness. It is also regarded as easy to use with clear label instructions. Some growers found wettable granules were occasionally difficult to mix and could leave a residue in the mixing tank. In plantation forestry, dry granules tend to be preferred because of the ease of handling, easy clean up after spills, low volume of drift from the target site and increased residual effect.

Growers and commodity organisations, supported by State departments of agriculture, all agree that atrazine is still highly effective. The recommended timing of application is still found to be appropriate and some users have experienced greater effectiveness over the years which they attribute to a better knowledge of optimal application rates and timing of application.

Minor issues concerning the efficacy of atrazine have been reported. There may be problems in applying this herbicide no-till, particularly on lighter soils, because of the reliance on rainfall for incorporation and run-off into seed furrows. Reports of variable performance in the Northern Territory over the 1995/96 season has raised concerns over the development of resistance to atrazine by a major weed of sorghum and maize, *Penniseteum peddicellatum*. An unconfirmed report of resistance in Johnson grass (*Sorghum halepense*) has been received in Victoria.

6.2 Trade

Atrazine is not considered to present a risk to Australia's trade with other nations. Atrazine is used pre-plant or very soon after planting and, because of the long time interval between planting and harvest, there should not be any residues at harvest when used according to the label - a nil residue situation. For this reason, MRLs have been set at the limit of detection for approved crops.

The National Residue Survey has not done any monitoring of atrazine due largely to the fact residues are not expected in harvested crops. The 1992 Australian Market Basket Survey (published in 1994 by the National Food Authority) conducted assays for atrazine and simazine in meat and cereal foods. No residues of either herbicide were detected. Because of their use pattern it was considered unlikely that residues would be present in food. This finding is in agreement with US data; in over 30 years of use, atrazine has not been detected in edible portions of plants or livestock nor has it been detected in market-basket surveys.

6.3 Residues

Animal metabolism

As the lactating goat metabolism studies presented either contained no experiment results or did not use atrazine as a test substance, the fate of atrazine in farm animals could not be reviewed. All further conclusions regarding animal commodities are based upon direct feeding studies.

Plant metabolism

In young corn plants treated with atrazine at a rate similar to those used commercially, atrazine residues were between 0.003 and 1.23 mg/kg in 30 day forage samples and less than 0.02 mg/kg in silage stage forage and mature fodder. Levels of chlorometabolites (desisopropylatrazine, desethylatrazine and diaminochlorotriazine) of atrazine were less than 0.02 mg/kg in the 30 day forage. In mature fodder, residues of these metabolites were less than 0.01 mg/kg. The major metabolite identified was desisopropylatrazine , present in amounts of up to 0.27, 0.33, 0.005, and 0.14 mg/kg in 30 day forage, mature fodder, mature grain, and silage stage forage, respectively.

In a similar study, atrazine residues in young sorghum plants treated with atrazine at rates similar to those used commercially, were between 0.02 and 2.66 mg/kg in 30 day forage samples and less than 0.1 mg/kg in silage stage forage and mature fodder. Levels of chlorometabolites of atrazine were less than 0.05 mg/kg in the 30 day forage. In mature fodder, residues of these metabolites were less than 0.01 mg/kg. The major metabolite identified was desisopropylatrazine, present in amounts of up to 0.48, 0.14, 0.019, and 0.06 mg/kg in 30 day forage, mature fodder, mature grain, and silage stage forage respectively.

When growing sugarcane was given 4 applications of atrazine at rates similar to those used commercially, the atrazine level in the leaves 207 days after sowing and approximately 90 days after the third treatment was 0.16 ppm. Chloroatrazine residue levels were between 0.15 and 5.7 mg/kg. At harvest (approximately 137 days after the fourth and last treatment), atrazine levels in the sugarcane and its leaves were 0.007 and 0.017 mg/kg respectively. Chlorometabolite residues were between 0.015 and 0.4 mg/kg in the leaves and 0.009 and 0.06 mg/kg in the cane.

The metabolism studies support the current atrazine MRLs for maize and sorghum grains. For sugar cane, inclusion of the chlorometabolites in the residue definition indicates consideration of the current MRL of *0.1 mg/kg could be desirable. The studies also demonstrate that forage and fodder could contain measurable residues of atrazine and its chlorometabolites and that establishment of fodder and forage MRLs also needs consideration.

Analytical methods

Analytical methods presented for determination of atrazine and its chlorometabolites in forage, fodder, grain, grain fractions, animal tissues, milk and eggs are satisfactory. The methods have sufficient sensitivity and recoveries at low residue levels (0.05 for grains, fodder and forage, and 0.01-0.05 mg/kg for animal commodities) and are based on extraction of the residues from the commodity and determination by gas liquid chromatography.

Residue definition

The animal transfer studies point to the need to consider amendment of the present residue definition for atrazine to include reference to its chlorometabolites. The USA has done this but has not applied the atrazine plus chlorometabolites residue definition to most commodities (including animal commodities) - there are very good practical reasons for such a course of action.

From a residue viewpoint, determination of atrazine residues only appears practical and relevant in the light of the plant metabolism studies. However, if there are toxicological reasons for it, or if these metabolites are included in the residue definition of major trading partners, inclusion of the chlorometabolites in the residue definition may need to be considered further.

This issue was referred to the Advisory Committee on Pesticides and Health. The Committee appreciated the need to take into account toxicologically significant metabolites from an exposure risk assessment perspective. However, it was considered that the inclusion of the metabolites in the atrazine residue definition for food would be impractical for the following reasons:

- parent atrazine is likely to form a major component of the residues;

- some of the metabolites are common to other triazine herbicides which could present enforcement difficulties;

- it would unnecessarily complicate regulatory analyses which may compromise routine residue monitoring.

Animal transfer studies

When laying hens were fed atrazine for 28 days at levels of 0.5, 1.5 and 5 ppm in the feed, no residues of atrazine or its chlorometabolites except for diaminochlorotriazine were detected in any tissues (<0.01 mg/kg or <0.05 mg/kg for liver). Diaminochlorotriazine was present at levels of 0.02-0.03 mg/kg in muscle and skin at the 5 ppm feeding level and in eggs at ≤0.01 mg/kg at the 0.5 and 1.5 feeding levels and between <0.01 and 0.07 mg/kg at the 5 ppm feeding level.

In dairy cattle fed atrazine in the diet for 28 consecutive days at levels of 3.75, 11.25 and 37.5 ppm in the diet, no atrazine residues (<0.01 mg/kg) were found in any tissues or milk samples. Apart from diaminochlorotriazine , residues of other chlorometabolites were less than 0.05 mg/kg. The diamine was present in tissues and milk at all feeding levels. In tissues the maximum values of the diamine were 0.02 mg/kg in loin muscle at the 3.75 ppm level, 0.06 mg/kg in round muscle at the 11.25 ppm level and 0.12 mg/kg in liver at the 37.5 ppm level. Maximum milk values were 0.03, 0.12 and 0.41 mg/kg respectively.

When dairy cattle were fed atrazine in the diet for 9 consecutive days at levels of 0.0085, 0.0747 and 0.764 ppm, average total residue concentrations in the milk were 0.00016, 0.0019, and 0.012 mg/kg respectively. diaminochlorotriazine was the major metabolite identified with residue levels of 0.0001, 0008, 0.008 mg/kg found at the three feeding rates.

The animal transfer studies show that measurable residues of atrazine are unlikely to occur in animal commodities at atrazine levels in the feed of approximately 40 ppm.

Animal feed commodities

There are currently no Table 4 entries in the MRL Standard. Information on crop residues (specifically sorghum, lucerne and pasture) will be necessary to set animal feed commodity MRLs.

6.4 Conclusions

The Australian use patterns of atrazine generally provide for nil or low residues occurring in crops and animal tissues. The animal transfer studies evaluated show that measurable residues of atrazine are unlikely to occur in animal commodities at atrazine levels in the feed of at least 40 ppm.

However, there are currently no Table 4 entries in the MRL Standard. And as a consequence, information on crop residues (specifically sorghum, lucerne and pasture) will be necessary to set animal feed commodity MRLs.

No change to the current residue definition of atrazine parent for crops and animal commodities is warranted. Reconsideration of the residue definition (atrazine as parent only) has confirmed the current definition, primarily to ensure that monitoring will occur and that such monitoring will only refer to atrazine and not other related herbicides.

The following MRLs are recommended for deletion due to no current Australian use pattern:

Citrus fruits	*0.1 mg/kg
Grapes	*0.1 mg/kg
Pineapple	*0.1 mg/kg

The following MRL’s are to be modified:

Edible offal (mammalian)	*0.1 mg/kg
Meat (mammalian)	*0.01 mg/kg
Milks	*0.01 mg/kg

The following new MRLs are recommended:

Primary animal feed commodities	T40 mg/kg
Edible offal (mammalian)	T*0.1 mg/kg
Meat (mammalian)	T*0.01 mg/kg
Milks	T*0.01 mg/kg

T refers to MRLs that will expire in three years after this review is finalised.
* at the limit of detection

Applicants are required to provide forage and fodder residue data for sorghum, pastures and lucerne to confirm the primary animal feed commodity MRL and those of animal commodities. In addition, these data should permit confirmation or appropriate change to withholding periods for grazing of these crops. These trial data must be consistent with the Australian use patterns for atrazine-containing agricultural products.

7. OVERALL DISCUSSION AND CONCLUSIONS

7.1 Summary

In determining the outcomes of the atrazine review, the NRA has to be satisfied that the registration and approval of atrazine meets current regulatory requirements. The main findings of the review areas follows:

Technical grade atrazine continues to meet current standards. Atrazine is not considered to present a risk to Australia’s trade with other nations. Atrazine is used before or very soon after planting and, because of the long time interval between planting and harvest, there should be no residues at harvest when used according to the label - a nil residue situation. For this reason, MRLs have been set at the limit of detection for approved crops.

Atrazine is of low acute toxicity and is not a skin sensitiser in humans. Toxicological evidence suggests that atrazine is not a genotoxic carcinogen and that in the Sprague Dawley (SD) strain of rats, the earlier onset of mammary tumours (a common tumour type in these rats, with a high background incidence in ageing females) observed in some studies at high doses of atrazineis due to a strain specific hormonal effect. The pattern of oestrogen levels in ageing SD rats differs from that of other rat strains tested, and from that in humans. The atrazine effect in this particular strain of rats is not considered to be an appropriate model for the assessment of mammary tumour development in humans. Atrazine is not considered to be teratogenic or toxic to reproduction.

No change to the current no observed effect level (NOEL) of 0.5 mg/kg bw/day is warranted. However, the current acceptable daily intake (ADI) of 0.005 mg/kg bw/day should be based upon a combined total of atrazine plus its closely related metabolites, rather than atrazine alone, as is the case at present. This is because the atrazine metabolites are at least as toxic as parent atrazine.

The current Australian Drinking Water Guideline is based on the measurement of atrazine alone. Metabolites, when measured, have commonly been detected at levels in the same order of magnitude as parent atrazine. Since the metabolites are, in general, no less toxic than atrazine, these metabolites should be considered in the standard. Therefore, while there is no basis for concern about human health effects at current, reported levels of contamination, consideration should be given to amending the standard to measure the combined total of atrazine plus its closely related metabolites. This action would have the equivalent effect of lowering the Guideline Value (currently 0.5 ppb) and the Health Value[1] (currently 20 ppb) for atrazine alone since, in water samples in which atrazine is detected, one or more metabolites are commonly detected but disregarded in the current standard. This issue has been referred to the National Health and Medical Research Council (NHMRC) for consideration by a joint committee of the

[1] Level which can be safely consumed over a life-time

NHMRC and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

No change to the poisons scheduling for atrazine (currently S5 of the SUSDP) is warranted and no data have been provided which would give any grounds for amending the First Aid Directions. Safety Directions, however, should be amended slightly as a result of the occupational health and safety assessment.

The 1992 Australian Market Basket Survey conducted assays for atrazine and simazine in meat and cereal foods. No residues of either herbicide were detected. Because of their use pattern (just before or after crop emergence) it was considered unlikely that residues would be present in food. This finding is in agreement with US data; in over 30 years of use, atrazine has not been detected in edible portions of plants or livestock nor has it been detected in market-basket surveys. Therefore, exposure of the population to atrazine in food is considered very unlikely.

Exposure to atrazine is more likely to occur through drinking water. It is estimated that intake at 10 ppb in water would result in an intake approximately 5.7% of the current ADI for atrazine.

Information reviewed indicates that atrazine poses no undue hazard to users. Atrazine can be safely used by workers, subject to restrictions on certain manual activities. The risk is unacceptable for workers using dust-prone hand dispensers in plantation forestry and for unprotected human flaggers in aerial spraying operations. Safe use for other workers takes into account the options available to control exposure such as bulk handling, enclosed transfer methods, enclosed tractor cabs, aerial spraying and protective clothing. The uses of atrazine indicate there is little need for workers to re-enter treated areas. However, if workers do need to re-enter treated areas, they are unlikely to be exposed to levels that would have a detrimental effect on health.

Minor issues concerning the efficacy of atrazine have been reported to the NRA. Reports of variable performance in the Northern Territory over the 1995-96 season have raised concerns over the possible development of resistance to atrazine by a major weed of sorghum and maize, *Penniseteum peddicellatum*. An unconfirmed report of resistance in Johnson grass has also been received in Victoria.

Use on triazine tolerant canola is a relatively new and rapidly expanding use for atrazine. Although this use is not yet registered, it is allowed under NRA permit. Another non-registered use is on chick peas in north-west Victoria, in a mix with simazine. Chick peas are a major pulse crop for Victoria with significant export potential. Atrazine is registered for use on Parthenium weed in Queensland, but the area infested with this weed now covers parts of the Northern Territory and northern New South Wales

Information provided on residues indicated no change is necessary to the current residue definition of atrazine parent for crops and animal commodities. However, data are required on forage and fodder residues for sorghum, pastures and lucerne to confirm the primary animal feed commodity MRL (maximum residue limit) and those of animal commodities. In addition, these data should permit confirmation or appropriate change to withholding periods for grazing of these crops. Certain MRLs, for which there are no current Australian use patterns, should be deleted.

Atrazine is a mobile chemical with the potential to contaminate water at low levels as a result of normal use. Evidence indicates that, in the Australian aquatic environment, atrazine exposures are generally below the threshold for ecosystem effects, which is about 20 ppb. Groundwater samples often contain detectable levels of atrazine and its metabolites around the level of 1 ppb. Higher levels have been detected but these were known to be of point-source origin, arising from improper pesticide handling practices or accidents. General historical levels in natural surface waters are less than 10 ppb and, in most cases, below 1 ppb, although levels above this may occur briefly in lower order streams receiving storm runoff. However, safety margins are narrow.

Steps have already been taken to eliminate some sources of aquatic contamination through restricting maximum annual application rates of atrazine and withdrawing certain uses with a high potential for aquatic contamination. The NRA has also established a broad-based taskforce to conduct a three-year program of trials and monitoring to establish whether revised conditions of use in plantation forestry will reduce aquatic contamination to acceptable levels. A number of trials are in progress.

While it is acknowledged that low level aquatic contamination by atrazine is unavoidable, due to its widespread use, every effort should be made to minimise its occurrence. Poor agricultural practices such as tailwater release from excessive irrigation, application shortly before heavy rains or storms or to waterlogged soils, and use in irrigation channels need to be stopped. Users should also be re-educated on the review recommendations to ensure they are adopted fully.

The NRA considers that monitoring of atrazine levels in the environment needs to continue to determine trends in atrazine contamination of Australian surface and ground waters. In addition, future monitoring needs to be carried out to investigate levels in natural waterways as well as the irrigation drainage systems that have been the main focus to date. Monitoring of residue levels in water should also be linked to biological monitoring to determine the ecological significance of atrazine levels found in Australian waterways. This monitoring will help determine whether current and future restrictions are effective in maintaining or improving current safety margins.

However, should monitoring be inadequate, or should it demonstrate that environmental safety margins continue to be narrow, the NRA will consider restricting the use of atrazine further.

Australia has yet to establish a water quality guideline for the protection of aquatic ecosystems, but the Environmental Research Institute of the Supervising Scientist (ERISS) is currently reviewing the Australian guidelines. A guideline value of 2 ppb for atrazine has been proposed locally and operates overseas. The NRA will provide a copy of the atrazine report to ERISS to aid deliberations.

Taking all of the available information into account, the NRA believes atrazine, products containing atrazine and associated labels can continue to meet current registration and approval standards, provided the recommendations which follow on pages 47 to 53 are implemented.

7.2 Review Recommendations

Recommendation	Implementation Date
1. Restrictions on use and labelling	
(a) All current labels to be audited by the NRA to ensure they fully comply with the restrictions introduced in December 1995, which are:	**Audit by 31 December 1997**
• no mixing/loading or application within 20 m of any well, sink holes, intermittent or perennial stream	**As above**
• no application within 60 m of natural or impounded lakes or dams	**As above**
• no use in channels and drains	**As above**
• maximum annual rate of application of 3 kg ai/ha in all crops except plantation forestry. In plantation forestry, the maximum rates will be 4.5 kg ai/ha per year in sandy soils and those defined as "highly erodible", and 8 kg ai/ha per year in clay loams and heavier textured soils.	**As above**
• use in industrial and non-agricultural situations (includes home-garden) to be cancelled.	**31 December 1998**
* Cancellation of sale and supply.	**31 December 1998**
* Application of stocks held by users allowed until..	**30 June 1999**
(b) The following restrictions to be included on the label to minimise the risk of aquatic contamination from storm runoff:	**31 December 1998**
• Do NOT apply under meteorological conditions or from equipment which could be expected to cause drift of this product or spray mix onto adjacent areas, particularly wetlands, waterbodies or watercourses.	**As above**
• Do NOT apply to waterlogged soil.	**As above**
• Do NOT apply if heavy rains or storms that are likely to cause surface runoff are forecast within two days of application.	**As above**
• Do NOT irrigate to the point of runoff for at least two days after application.	**As above**

Recommendation	Implementation Date
(c) Deficiencies exist in the current atrazine entries in the *Handbook of First Aid Instructions and Safety Directions for Agricultural and Veterinary Chemicals* (1996). Safety directions in the handbook and on labels should be revised as follows:	**31 December 1998**
• Workers handling the concentrate (liquid, wettable powder, granule, water dispersible granule) and spray should wear elbow length PVC gloves, hat and cotton overalls.	**As above**
• Hand directed sprayers require, in addition, waterproof trousers and boots.	**As above**
• Hand directed granular applicators require, in addition, chemical resistant footwear.	**As above**
• Atrazine products, in a mixture with amitrole, ametryn, dicamba, glyphosate, hexazinone or metolachlor to be covered by handbook entries.	**As above**
(d) other additions to current labelling directions	
• Do not dispense atrazine via dust-prone methods e.g. hand-operated cranking handles. Only use applicators specifically designed to dispense granular product with minimum dust eg. the *Weed-A-Metre* granular dispenser, the Swissmex manual applicator, the Forest Mac applicator.	**31 December 1998**
• No human flaggers in aerial spraying unless protected by engineering controls such as enclosed cabs.	**31 December 1998**
• A minimum ground spray volume of 50 L per hectare (without supporting data or argument for specific uses).	**31 December 1998**
• All existing atrazine product labels to refer to the material safety data sheet.	**31 December 1998**
2. Extensions of use	
(a) Consideration of applications for registration for use on canola, and the establishment of an appropriate MRL, should be made a priority.	**in time for the canola plantings in April/May 1998**
(b) Consideration be given to registering atrazine for use on chick peas in Victoria by registrants.	**in time for the chick pea plantings in April/May 1998**

Recommendation	Implementation Date
(c) Registration for the use of atrazine on Parthenium weed to be extended to the Northern Territory and New South Wales.	**31 March 1998**
3. Maximum residue limits (MRLs)	
(a) The following MRLs to be amended/deleted:	**31 March 1998**
(i) deletion due to no current use pattern Citrus fruits *0.1 mg/kg Grapes *0.1 mg/kg Pineapple *0.1 mg/kg	
(ii) modification (for new MRL see below) Edible offal (mammalian) *0.1 mg/kg Meat (mammalian) *0.01 mg/kg Milks *0.01 mg/kg	
(iii) addition of the following new MRLs: Primary animal feed commodities T40 mg/kg Edible offal (mammalian) T*0.1 mg/kg Meat (mammalian) T*0.01 mg/kg Milks T*0.01 mg/kg	
T refers to MRLs that will expire in three years after the review is finalised. * at the limit of detection	
(b) Applicants are required to provide the NRA with forage and fodder residue data for sorghum, pastures and lucerne to confirm the primary animal feed commodity MRL and those of animal commodities. In addition, these data should permit confirmation or appropriate change to withholding periods for grazing of these crops. This trial data must be consistent with the Australian use patterns for atrazine-containing agricultural products.	**data submitted by 30 June 2000**
4. Reporting requirements	
(a) Registrants to provide the NRA with information, on annual sales (in tonnage terms and broken down by geographical area and crop) for the previous financial year, (1 July to 30 June) and estimates for the following financial year.	**Annually**
(b) Registrants must provide the NRA with information, on any reported incidents of atrazine resistance and follow-up investigations.	**Annually**

Recommendation	Implementation Date
(c) The NRA will obtain information, from registrants, State departments of agriculture, and CSIRO on reported incidents of atrazine resistance and follow-up investigations.	**Annually**
(d) Future participation by registrants in a program to monitor atrazine levels in water in certain areas will be mandatory	**To be advised**
5. Definition of atrazine	
(a) No change to the current residue definition of atrazine parent for crops and animal commodities is warranted.	
The current ADI of 0.005 mg/kg bw/day should be based upon a combined total of atrazine plus its closely related triazine metabolites.	**31 December 1998**
6. Water Quality Guidelines	
(a) Consideration should be given to amending the Australian Drinking Water Guidelines to include at least three of the four metabolites with parent atrazine in the definition of atrazine. To aid deliberations on the Australian Water Quality Guidelines for Fresh and Marine Waters, a copy of the atrazine review report will be provided to the Environmental Research Institute of the Supervising Scientist (ERISS)	**31 December 1998**
7. Material safety data sheets (MSDS)	
(a) All registrants formulating atrazine products in Australia to label technical grade atrazine and produce a material safety data sheet for atrazine, in accordance with hazardous substances regulations. These are to be submitted to the NRA.	**30 June 1998**
(b) All registrants of current atrazine products to produce a product material safety data sheet. These are to be submitted to the NRA.	**30 June 1998**
8. Forest Herbicide Research Management Group	
(a) The interim recommendations of the Forest Herbicide Research Management Group to be incorporated into the conditions of use for atrazine products, where appropriate.	

Advice to Users

Formulations

When a large amount of product is needed and bulk containers are not an option, solid formulations should be used in preference to liquid formulations.

Source reduction

To avoid weed problems in paddocks, users should carefully clean all equipment and manage weeds along boundaries and channels.

Source reduction of atrazine needs to be achieved through agricultural methods that reduce reliance on synthetic chemical inputs. Integrated weed management programs that make maximum possible use of herbicides together with mechanical and biological methods of weed control, and crop rotation and competition, should be pursued.

Management of off target movement

Off-target movement of atrazine should be minimised. One measure which would help to achieve this objective is to install drainage recirculation systems to capture irrigation water and at least the first flush of storm runoff. The practice of irrigating until tile drains begin to flow should be discouraged, particularly soon after application of atrazine.

Growers of sorghum and maize should consider whether pre-emergence applications can be replaced by post-emergence applications.

Application, particularly by aircraft, should not occur in high winds or under inversion conditions. Growers should consider planting trees along boundaries to help intercept any spray drift that may arise.

Advice to registrants

Registrants need to re-educate users about the use restrictions for atrazine, particularly the removal of use in drains.

Monitoring of atrazine levels in the environment needs to continue, and in some areas to expand, to determine trends in atrazine contamination of Australian surface and groundwaters, and whether the new restrictions imposed are effective in maintaining or improving current safety margins. Provision of the results of this monitoring to the NRA and State agriculture and environment agencies will enable them to develop better management practices through technology transfer and regulation. Responsible applicants will commit resources to such environmental monitoring as a demonstration of their commitment to product stewardship.

8. PROTECTED INFORMATION STATUS OF SUBMITTED DATA

All data considered as protected registration information by the NRA are identified in the bibliographies of the full review report with a letter “**P**” placed next to them in the left hand margin.

ATTACHMENT 1: PRODUCTS AND TGAC's AFFECTED BY THIS REVIEW

Product	Registrant
Atradex WG Herbicide	Crop Care Australasia Pty Ltd
Atramet Combi SC Herbicide	Makhteshim-Agan (Australia) Pty Ltd
Atranex 500 SC Herbicide	Makhteshim-Agan (Australia) Pty Ltd
Atranex Atrazine Wettable Powder Herbicide	Makhteshim-Agan (Australia) Pty Ltd
Ausgen Atrazine Flowable Herbicide	Artfern Pty Ltd
Betta Grower Total Herbicide	Betta Grower Fertilisers Pty Ltd
Ciba-Geigy Atrazine Granules 900 WG Herbicide	Novartis Crop Protection Australasia Ltd[2]
Crg Bantox Aa Weedspray	Chemical Recovery Co Pty Ltd
Crop Care Atrazine 500 SC Herbicide	Crop Care Australasia Pty Ltd
Crop King Atragranz Herbicide	Crop Care Australasia Pty Ltd
Crop King Flowable Atrazine 500 SC Selective Herbicide	Crop Care Australasia Pty Ltd
Cydan Weedacyde Liquid Herbicide	Hampic Pl Trading As Cyndan Chemicals
Davison Atrazine 500 Flowable Herbicide	Davison Industries
Davison Atrazine 900 WDG Herbicide	Davison Industries
Farmco Atrazine Flowable Liquid Herbicide	Nufarm Ltd
Farmoz AA Combi 500 Flowable Herbicide	Farmoz Pty Ltd
Farmoz Farmozine 900 WDG Herbicide	Farmoz Pty Ltd
Farmozine 500 Flowable Herbicide	Farmoz Pty Ltd
Flowable Gesaprim 500 SC Liquid Herbicide	Novartis Crop Protection Australasia Ltd
Gesapax Combi 500 SC Liquid Herbicide	Novartis Crop Protection Australasia Ltd
Gesapax Combi 800 WG Herbicide Granules	Novartis Crop Protection Australasia Ltd
Gesaprim Granules 900 WG Herbicide	Novartis Crop Protection Australasia Ltd
Macspred Forest Mix Granular Herbicide	Macspred Pty Ltd
Marksman Herbicide	Novartis Crop Protection Australasia Ltd
Novartis Atrazine Flowable 500 SC Liquid Herbicide	Novartis Crop Protection Australasia Ltd
Novartis Atrazine Granules 900 WG Herbicide	Novartis Crop Protection Australasia Ltd
Nufarm Flowable Nu-Trazine Liquid Herbicide	Nufarm Ltd
Nufarm Flowable Nu-Zinole AA Liquid Herbicide	Nufarm Ltd
Nufarm Nu-Trazine 900 DF Herbicide	Nufarm Ltd
Nufarm Nu-Trazine Herbicide	Nufarm Ltd
Nufarm Nu-Zinole AA Total Herbicide	Nufarm Ltd
Primextra Herbicide	Novartis Crop Protection Australasia Ltd

[2] Formerly Ciba-Geigy Australia Ltd

Product	Registrant
Summit Atrazine 500 Herbicide	Sumitomo Australia Ltd
Summit Atrazine 900 DF Herbicide	Sumitomo Australia Ltd
Total Weed Killer	David Gray & Co Pty Ltd

TGAC	Approval Holder
44047	Makhteshim-Agan (Australia) Pty Ltd
44367	Novartis Crop Protection Australasia Ltd
45076	Farmoz Pty Ltd
48797	Sipcam Pacific Australia Pty Ltd

ATTACHMENT 2: SUMMARY OF PUBLIC COMMENTS FOLLOWING RELEASE OF DRAFT REPORTS

A draft report of the NRA's review of atrazine was made available for public comment via a number of sources: direct mail to review participants, advertisement in the *NRA Gazette* and *NRA News*, media interviews and via the internet. All responses received (32), were taken into consideration in revising the draft document to produce this final report.

From the responses received, seven key issues could be identified, all of which dealt with the review recommendations. All responses were considered by the NRA in consultation with the relevant agencies.

The key issues raised are listed below, with the respondents' views on the particular recommendation noted under the heading 'comments'. Decisions on whether to incorporate the respondents' comments into this report, are noted under 'Outcome', as well as the reasons for these decisions.

A KEY ISSUES

1. Recommendation: No knapsack use in plantation forestry operations

Comments

The draft report contained a proposed recommendation to ban knapsack application. Many respondents argued strongly that banning of atrazine application by this method in the plantation forestry industry should not occur. It was stated that knapsack spraying is important, especially in areas where application via other methods is not practical due to the terrain. Knapsack spraying is used in the industry only for small jobs, and not on a daily basis for all weed control operations. There were concerns that the recommendation to eliminate knapsack spraying was based on the modelling of an application method other than the type actually used in the industry.

An argument was made for retention of knapsack application as it resulted in substantially less atrazine being used than if it were applied using broad-scale application techniques.

The area estimated to be covered by knapsack spraying used in the assessment model, was also considered to be incorrect. A more accurate estimate of the area sprayed using this method of application would be 0.6-0.72 ha per day and not 6 ha per day.

Outcome

The Worksafe Australia initial evaluation relied upon information provided by industry and end users and used predictive values to cover data gaps.
During the public comment period, further data on the use of knapsack spraying and the level of worker exposure was submitted by the registrant. Worksafe Australia evaluated this additional data and concluded that knapsack application could be supported.

In light of this, the recommendations made have been amended to allow the continued use of knapsack spraying.

2. Recommendation: Do not irrigate to the point of run off for at least 2 days after application, do not apply if heavy rains or storms that are likely to cause run-off are forecast within two days of application

Comments

Respondents felt that this recommendation would be impossible to comply with due to the unpredictability of rain, and to make this practice mandatory is impractical. Reasonably accurate forecasts are currently received; however, the actual amount of rain that is likely to occur is harder to forecast. For a farmer to ensure that run-off would not occur would mean that they would need to know the moisture status of all soil types on their property, which is not feasible. It was proposed that this recommendation be advisory rather than mandatory.

Different plantation regions and different crops need to accommodate different seasonal rainfall patterns during site preparation, and the use of 'windows of opportunity' in weather conditions is an important part of this practice. No single set of label directions will necessarily be appropriate for all situations.

Many producers in the sugarcane industry rely on the use of flood irrigation. If flood irrigation does not occur shortly after application of herbicide, it was considered that there is an increase in the likelihood of weed control failure. It was also noted that 45% of growers have recycling pits in place to capture run-off water following this irrigation and thus preventing the entry of the chemical into waterways.

Outcome

Environment Australia evaluated these comments, noting that the majority of growers do not have the facilities available on farm to capture run-off water and chemical following irrigation.

It was considered that meteorology is sufficiently advanced to generally be able to predict the event of heavy rains within a 48 hour period. This label requirement is a way of improving use practices by advising users to not apply the chemical at this time. While it is appreciated that this may not be possible in every situation, the intent is to discourage application of atrazine when there is a high likelihood of rain occurring.

It was, however, considered appropriate to modify the recommendation to: 'Do not apply if heavy rains that are likely to cause **surface run-off** are forecast within 2 days of application'. The aim of this recommendation was to avoid contamination of water bodies which mainly arises in storm situations when surface run-off causes erosion and transport of contaminated soil/sediment into waterways. Sub-surface runoff is of less concern as it lacks the erosive power of surface run-off.

3. Recommendation: Relaxation of "Interim" environmental guidelines for atrazine for protection of aquatic life.

Comments

It was suggested that proposals to establish a water quality guideline of 2 µg/L (2ppb) for protection of aquatic life were too conservative, and that a guideline value of 20 µg/L would offer sufficient protection.

Outcome

Environment Australia considered the comments regarding the setting of water quality guidelines for protection of aquatic life, noting that ANZECC water quality guidelines were being revised and that the guideline for atrazine remained under development. Guideline development would use both assessment factor and statistical evaluation approaches in a hierarchical framework, including scope for site-specific assessments rather than uncritical reliance on a single national value. Environment Australia noted that the 2 µg/L proposal was based on an assessment (safety) factor approach, and that a general level of 20 µg/L could not be supported as it would not include a safety factor.

4. Recommendation: Amendment of the drinking water guidelines to include at least three of the four metabolites.

Comments

It was considered by many respondents that no changes to the drinking water guideline be made until the results of the Forest Herbicide Research Management Group (FHRMG) studies are finalised.

The proposal to include metabolites in the requirements for testing was thought to be likely to result in an increased cost to the user because of higher analytical costs. Testing was considered to be desirable but essentially voluntary. It is restricted to those who can afford it. With the requirement to test for metabolites, this will further reduce the likelihood of testing being undertaken due to the higher associated costs.

Outcome

It was agreed that the inclusion of metabolite testing into the guideline should not be finalised until the results of the FHRMG are available.

5. Recommendation: A minimum spray volume of 50L per hectare (without supporting data or argument for specific uses)

Comments

A number of respondents felt that the proposed increase in spray volume to be applied per hectare, from 30L/ha to 50L/ha, was not necessary. The current usage level of 30L/ha is effective, and any increase was considered not to be warranted. The higher level was considered not to be economical or necessary for weed control. Therefore, maintenance of an upper limit of 30L/ha for economic application was proposed.

Outcome

Worksafe Australia commented on this proposal for the minimum spray to remain at a volume of 30L/ha. This level relates to ground boom spraying. Label spray volumes were accepted for aerial spraying. The OH&S risk assessment based on predictive exposure, indicated that atrazine used by low volume spraying (i.e. 50L water) would result in a high atrazine concentration and unacceptable worker exposure and risk. However extrapolations of this information to field exposures were acceptable. Therefore spray volumes of less than 50L water per hectare for ground spraying cannot be supported unless specific data are provided for assessment.

6. Recommendation: Workers handling the concentrate and spray should wear elbow length PVC gloves, hat and cotton overalls. Hand directed sprayers require, in addition, waterproof trousers and boots

comments

A number of respondents indicated that the recommendations for the type of protective clothing to be worn when dealing with the chemical are not practical, especially during times of high temperatures as are common in Queensland. Additional information was provided to Worksafe by Novartis, noting the outcomes of their trial work with atrazine and hand-directed sprayers. This indicated that waterproof trousers were not required as noted in the recommendation.

outcome

Worksafe Australia considered the concerns which were expressed over the requirements for certain protective clothing. The OH&S risk assessment indicated that hand and leg protection was needed for workers using hand-directed liquid sprayers. It was considered that atrazine users in warm locations may need to adopt other strategies, such as use of granular products (where registered), alternative herbicides, restricted spraying times, task rotation or spraying in cooler times of the day. It was concluded that the recommendation should stand.

7. Recommendation: ***Maximum annual rate of application 3kg/ha/annum in all crops except plantation forestry. In plantation forestry maximum level would be 4.5kg***

ai/ha per year in sandy soils and those defined as highly erodible, and 8 kg ai/ha per year in clay loams and heavier textured soils.

Comments

It was the opinion of many respondents that the application rate should be expressed as ‘amount per year’ rather than ‘per application’.

One respondent noted that often two applications are required during the early stages of establishment of the plantation period in the forestry industry. At the above specified levels, there would not be effective control of broadleaf weeds, and resistance problems would become more prevalent. It was proposed by the respondent that the recommendation be amended to read:

> “A second application of atrazine is allowed for plantation forestry during the first year of establishment provided that the total amount applied within a two year period does not exceed 9kg a.i/ha in sandy soils and those defined as ‘highly erodible’, and 16 kg a.i/ha in clay loams and heavier textured soils”.

Outcome

Environment Australia evaluated the above suggestions, and considered that the original recommendations should remain until the outcomes of the Forest Herbicide Research Management Group (FHRMG) studies are available. It was considered that multiple applications per year were contrary to the spirit of current restrictions, but the environmental acceptability of these practices would be considered further in light of data generated through FHRMG.

B COMMUNITY CONCERNS

Concerns were raised by a number of community groups, many from Tasmania, as to how a number of issues had been dealt with in the review. It was felt by these groups that the results played down the potential implications that the use of atrazine has on both the environment and public health.

Worker exposure following chemical handling, drinking water contamination, residues in food commodities and the effects that atrazine may have on endangered aquatic species were all raised by respondents who felt that the recommendations made did not adequately reduce atrazine use.

All of these comments were forwarded to the assessing agencies for comment.

Worksafe Australia responded to concerns about the effects of atrazine on worker safety by saying that they would be in favour of health checks for workers and that there is provision for these under hazardous substances regulations. Apart from a general medical examination, there does not appear to be specific health surveillance parameters that could be used to predict adverse health effects for atrazine. Exposure to atrazine can be documented through urinary metabolites and, at present, these can loosely be linked to dose and risk.

The OH&S risk assessment defined risk to workers using the conventional comparison of measured or predicted worker exposure data (where available) and a repeat dose no effect level. Where the risk was not acceptable, the use was not supported. Other uses were supported where the risk was shown to be acceptable, or with the understanding that use would be on a small scale, or if on a large scale, that engineering controls would apply.

The Department of Health and Family Services, noted that the concerns as to the validity of the statement *".. no basis for concern re human health at current levels of contamination"*, are not warranted. This statement was made in light of a reasonable amount of monitoring of atrazine and several of its metabolites in various locations in Australia. Further monitoring of water taking into account parent atrazine, its chlorometabolites and hydroxyatrazine is being conducted to assist in determining the most appropriate ones for future monitoring.

From the toxicology assessment little evidence was found to support the concerns that atrazine is likely to be a carcinogen to humans, and the evidence also suggests that neither atrazine nor its metabolites are genotoxic. The concern that atrazine could affect the metabolism of oestradiol, thus favouring the formation of genotoxic metabolites, is not supported by any data.

The response from Department of Health to the concern that long-term exposure was not sufficiently dealt with was that the current ADI of 0.005 mg/kg bwt/day is the acceptable level of ingestion over a lifetime that could be permitted without any risk to the consumer. This was set at 100 times lower than the lowest 'no observable effect level', ascertained in long-term studies in animals.

There have been no signs or symptoms of acute atrazine poisoning reported in humans. Thus, no additional restrictions are warranted on the basis of the atrazine components of formulations. In terms of long-term exposure, there is little epidemiological evidence of adverse health effects in those exposed to atrazine for longer periods of time.

The review was considered by one respondent to be unsatisfactory due to the lack of investigation of the unforeseen synergistic effects in the environment. At this stage, there is no established methodology to predict these effects nor to predict the potential interactions of each agricultural chemical with all other chemicals potentially being used at the same time.

A program is to be developed to monitor atrazine in agricultural situations. It will cover a number of geographical areas, and thus a range of different enterprises where atrazine is used. The program is to be set up following concerns from community groups about the level of atrazine in drinking water. This monitoring scheme will build on the program set up by the Forest Herbicide Research Management Group.

It was noted by a number of respondents that any water monitoring program should also include testing for the presence of atrazine metabolites. It was recommended by one agency that good Australian data be collected on atrazine and its metabolites in water monitoring programs. There was no objection to including atrazine and its chlorometabolites into the water quality guidelines, but inclusion of the metabolite hydroxyatrazine was not recommended. The addition of this last metabolite would apparently result in a different analytical method being used, which would in turn render routine monitoring expensive and time consuming. The future monitoring for hydroxyatrazine will ultimately depend on the results of water monitoring for this compound at different sites around Australia.

There were also concerns that the level of atrazine will, in fact, increase following the review recommendation, particularly owing to the extensions of use. The level of use should be detected through the monitoring program and any subsequent increases will need to be reassessed.

One concern raised suggested that metabolites be included into the residue definition of atrazine in foodstuffs. This was not supported due to the fact that several different triazines have common metabolites, and this could lead to control difficulties in the event of residue violations.

C MISCELLANEOUS ISSUES

A number of other amendments to the draft report were also suggested, including:
- re-wording of some areas to make the information clearer;
- amendment of some figures; and
- inclusion of additional wording to clarify some points.

These amendments have been incorporated into the document to ensure clarity and accuracy of reported information. The figures that were amended were mostly typographical errors in the original report.

The common issues raised by the plantation forestry industry were that:
- plantation forestry should be classified as an agricultural rather than a non-agricultural industry;
- extensions of use of atrazine should also include extensions to all crop tree species;
- any recommendations arising from this review should not be finalised until the outcomes of the FHRMG work had been finalised;
- figures and information quoted in the public comments section of the report were not correct. These figures and information have not been validated. It is noted that the primary purpose of this section was to highlight the range of views resulting from public consultation, not to assess the validity of this information. However all review conclusions and recommendations were devised from valid data generated according to sound scientific principles.

- Other concerns raised by respondents concerning the long-term effects of the recommendations related to extensions to use. It was considered that these would increase the overall use of the chemical.

All of these additional comments have been considered in finalising this report.