EMBARGOED until 2pm Thursday 3 March 2022

Knowing what's out there

Regulating the environmental fate of chemicals

March 2022

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

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Overview

This review asks how well our regulatory system understands the environmental fate of chemical contaminants and takes that into account in imposing conditions on their use. Unless a chemical is so toxic that it is banned, decisions to approve a chemical's use will involve judgements about what level of risk is acceptable after taking into account the advantages it offers and conditions on the *way* it is used and *where* it is used.

This report is **not** about how those risks are weighed up. It is **not** about how risk-averse our regulatory system is or should be in worrying about environmental impacts. It is concerned with two prior questions:

- **Are regulators consistently in possession of adequate information about the likely environmental fate of the chemicals they regulate?**
- **Are questions about environmental impact consistently asked?**

As such, this report joins others I have issued questioning the adequacy of the information on which we base important environmental decisions.

What you don't know *can* hurt you

Almost 35 years ago, the first inventory of pollution was assembled by the United States. Since then, every developed country except New Zealand has constructed what are known as pollution release and transfer registers (PRTRs). A PRTR is a national platform for collecting data on known discharges to the environment. They enable countries to join the dots between permitted discharges of potentially harmful substances to the environment and environmental monitoring that picks up traces of contaminants.

In theory there shouldn't be many surprises. If chemicals are used in the way that they are approved for use (and the approval process has taken into account their likely environmental fate), then what we see and find in the environment should be at acceptable levels. If those levels throw up problems, the conditions for use can be adjusted. Furthermore, if we know how much they are being used and where, we will have a pretty good idea of the extent of the problem.

New Zealand investigated the possibility of establishing a PRTR in 1998 but it didn't get a green light. In 2019 I suggested that the Minister for the Environment re-examine the case for such a register.[1] But rather than drop the matter there, I decided to dig more deeply and find out just what our regulatory system does – and doesn't – know about the environmental fate of chemicals in New Zealand.

In 2018, New Zealanders were informed that a chemical used in firefighting foams – per- and polyfluoroalkyl substances (PFAS) – had caused extensive contamination of groundwater in a number of locations. The chemicals in the foam had been in widespread use since the 1950s – but their use was not monitored even though they were known to pose risks to both human health and the environment. Those risks led to certain PFAS compounds being prohibited from use in firefighting foams in 2006. The contamination did not become a concern until well after that. That led to a scramble to try to work out how much had been used and where.

While it might be tempting to claim that the environmental risks posed by these foams meant they should never have been used in the first place, that reaction relies very much on the benefits of hindsight. What *was* completely foreseeable was the fact that if a problem arose, knowing what had been used and where would enable targeted monitoring and a swift response. Hence this review: Do we ask the right questions about the possible environmental effects of chemicals, and then, having used the answers to impose conditions on sensible, safe use, do we monitor what enters the environment so that we can, if necessary, change course?

The structure of this report

To help answer those questions, the report provides an overview of the science of environmental fate and impact (chapter two) and the current shape of the regulatory system, including how Māori are engaged in the process (chapter three).

At one end of the regulatory labyrinth stands the Hazardous Substances and New Organisms Act 1996 (HSNO Act). It is under this statute that chemicals are approved for use, their risks are assessed, and controls are imposed. At the other end is the Resource Management Act 1991 (RMA), under which conditions are placed on discharges to the environment.

Chapter four describes the main ways in which chemicals enter the environment and how those sources and pathways are managed. Knowing where chemicals enter the environment is easy when the source is a modern landfill or a wastewater treatment plant. The hard bit is controlling what substances have entered these systems – assuming that they are even known. On the other hand, when the entry point to the environment is diffuse – such as agrichemical use – we may know what is being used but know little about where and how it is reaching the environment and in what quantities.

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[1] PCE, 2019b.

And when it comes to something like stormwater that runs off roads and built-up areas and is piped into creeks and coastal areas at numerous points, we know little about what chemicals are being discharged to the environment and where they reach it.

The different pieces of guidance and legislation in place add up to a complex picture of regulation from importation through to release into receiving environments. It is a mosaic of approval, guidance, consenting and monitoring that does not always capture the environmental fate of some contaminants and in other cases misses them entirely.

Finally, to give a sense of how this regulatory framework works in practice, four chemical substances were selected and followed through the lifecycle of their use and disposal (chapter five). The case studies illustrate the way the regulatory system intervenes – or does not – to limit the impact of these chemicals on the environment. The four chemicals chosen are: the **neonicotinoid** class of insecticides, the **tetracycline** antibiotics, the herbicide **terbuthylazine** and the metal **zinc**.

Each of the four chemicals poses some hazard to the environment. But in most respects they are very different, representing different use patterns (agricultural, industrial and household), different likely receiving environments (surface water, soils, groundwater and coastal environments) and different degrees of knowledge about the impacts of the chemical.

Each case study highlights different approaches to the management and level of monitoring of each substance. The selected chemicals are not representative of all chemicals approved and used in New Zealand, and their selection is *not* an indication of any priority for regulatory review or control. They simply provide the reader with illustrative examples of the different ways the environmental fate of chemicals is managed by New Zealand's regulatory system. Chapter six asks whether those different approaches – and in particular some of the data and knowledge gaps – can be justified.

Asking the right questions about the things that matter

Nothing is easier to recommend than better information. But how much and about what? There are roughly 150,000 substances approved for use in New Zealand, made up of an estimated 30,000 chemicals. The number of chemicals in use globally is north of 100,000. The vast majority of these have been the subject of some scrutiny by regulators in other large economies, so New Zealand does not start with a blank sheet. But the particular features of our environment and the particular use we make of certain substances means that we cannot simply adopt the judgements of other countries without further question.

We have developed a very complex system for approving and managing chemicals spanning multiple government agencies. For all that, only about 3,500 substances have ever been the subject of individual approvals, and only a few hundred have been fully reassessed. This is the legacy of a mass transfer of chemicals to the system created by the HSNO Act that took place in 2005 using 'group standards' for the bulk of substances. The reasons for this are explained in chapter three. It has left some enduring consequences in its wake.

Firstly, group standards delegate responsibility to assign approval status to an importer or manufacturer. This is a very hands-off approach to regulation. While records of this assignment must be kept, the Environmental Protection Authority (EPA) as the national regulator does not typically receive this information unless a compliance issue arises, so it provides little oversight.

Secondly, at the time of transfer there was no formal risk assessment weighing up the risks, costs and benefits and effectiveness of individual substances because of the sheer size of the task. While group standards and transfer notices provided new controls, evidence of the risks, costs and benefits of individual substances was not evaluated and won't be unless the chemicals are formally reassessed. That is a costly business, and the EPA has never had anywhere near the resources to conduct more than a handful of reassessments per year.

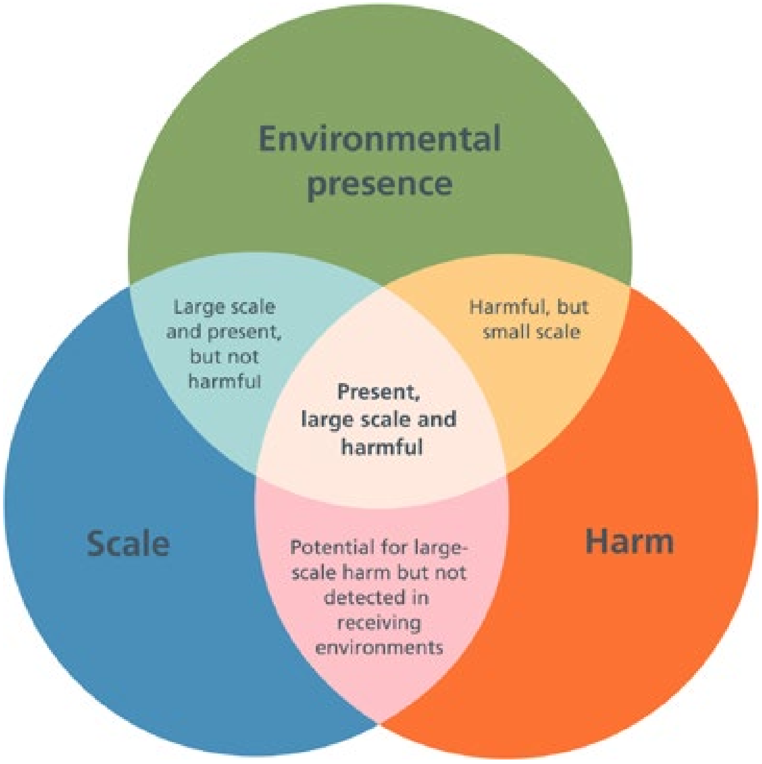
When it comes to regional council monitoring for the presence of chemicals in receiving environments, fewer than 200 chemicals are the subject of regular monitoring in receiving environments. While not all of the chemicals used in New Zealand will pose a high level of concern, there are many unknowns.

With respect to environmental risks, our chemical management system needs to be able to target its regulatory effort to those contaminants and uses that raise the most serious issues. It currently lacks a framework making sure that happens. For that reason, my principal over-arching recommendation is that **all the agencies dealing with chemicals need to develop a common framework to prioritise their efforts to consider, and manage, the environmental impacts of chemical use.** The design of any such framework should involve Māori.

That framework needs to be based on the intersection of three factors:

- the **scale** on which a chemical is being used
- the potential environmental **harm** that it could cause
- the extent to which the contaminant's **presence** is being detected in the environment.

The following figure summarises the way information about each of these factors can help regulators ask the right questions about the most important risks.



Source: PCE

Figure 6.1: A framework to help focus regulation and monitoring on the most important environmental contamination risks.

It would clearly make sense for the greatest focus to be on chemicals that fall within the centre of the figure: those that are used on a large scale, which are known to cause harm, and whose presence is detected in the environment. But beyond that, the existence of two of the three factors (scale, harm and presence) can indicate the need for taking a focused interest.

For instance, things that are widely used and not believed to be particularly harmful may still merit monitoring. Good quality information enables us to see if their environmental contamination and impact is as predicted. Furthermore, if new information comes to hand about emerging risks, we have a baseline to start from. Similarly, if something known to be harmful is used on a small scale within specified limits, monitoring the ongoing scale of use will be vital to ensure that the level of environmental risk remains at a manageable level. And if concerns arise, we know where to start looking.

Beyond having a common framework for focusing on the most important environmental risks posed by chemical contamination, there are some specific information gaps that need to be filled. For a start, we need better information on the amount of chemicals that are used and therefore potentially released into the environment. Keeping track of the quantities of chemicals imported, manufactured, or sold would provide this information. New Zealand’s regulatory system does not do this.

To obtain a full picture of the physical flows of the four chemicals we chose as case studies was a difficult, time-consuming process. To put together information across the lifecycle of their importation, use and disposal, information had to be sought from a wide variety of public and industry sources. Yet this sort of information is commonly collected by many of our large trading partners.

In addition to knowing what quantities are being made available for use and where, we need better information on where they are actually being released. To the extent that this information exists, it is in the hands of local government consenting agencies and private businesses and is often of limited accessibility. Something like a PRTR would provide this information. Clearly we don't need it for every single substance. Rather, we need it for the things that are most widely used in the New Zealand economy and whose use we may wish to monitor because the scale of their use and the potential for harm means we want to keep an eye on them. Starting with a few of the most important would be a pragmatic way of making progress.

My specific recommendation is that **the Ministry for the Environment should develop regulations to require and empower the EPA to collate, collect and report on the quantity and use of chemicals in New Zealand.** In particular, the EPA should:

- require importers and manufacturers to report to the EPA the annual quantities of chemicals imported and manufactured, respectively, with the EPA publicly reporting the information as aggregated figures
- require those selling chemicals to report regional sales quantities to the EPA, with the EPA publicly reporting the information as aggregated figures
- collect data on use and environmental fate with a focus on priority releases
- develop a data platform that connects the dots of import, sale, release and evidence of environmental fate gathered from monitoring.

If we knew what was being used and the regional distribution of that use, we could then organise our environmental monitoring to match those use patterns.

Beyond monitoring, we need to do a better job of providing numeric limits for what is an acceptable level of contamination. Numeric limits can be set either as guidance or as regulations and are used at both national and regional levels. There are problems at both levels.

At the national level, the EPA can set environmental exposure limits (EELs). However, these are rarely set or subject to compliance monitoring. The EPA does not currently have an operational policy in place covering the use of EELs. A detailed method for deriving EELs was set out in regulations, but these were revoked in 2017 and have not been replaced.

The legislation is not helpful to the EPA. It can only impose EELs on a substance-by-substance basis. But many substances contain the same ingredients. A more practical approach would be to set an EEL for an *active ingredient* at the first approval of a substance containing that ingredient, or during a reassessment, which would subsequently apply to all approvals containing that ingredient.

A further problem is that, in practical terms, the EPA, regional councils and other enforcement agencies struggle to enforce breaches of EELs. To do so, they would have to identify sources and their respective contribution to an exceedance. This could be challenging detective-work in a catchment-based context. Instead, the EPA commonly sets maximum application rates to manage environmental risks. But without setting an EEL in conjunction with an application rate, there is no imperative to measure concentrations in the environment and therefore assess the efficacy of this control in terms of environmental impact.

In the absence of a functional EEL system, regional councils routinely rely on the use of New Zealand and overseas-developed risk-based guidelines, where these exist, in issuing consents under the RMA. As chapter six explains, the existing guidelines are in varying stages of currency and there are gaps. But even if guidance exists, it may not be applied by regional councils. This is particularly so in respect of those chemical uses – such as pesticides – that are diffuse. Permitted uses are not generally subject to any compliance monitoring. The absence of EELs makes it even harder to make the link between the adequacy of national controls and what is occurring on the ground.

I am recommending that **the Ministry for the Environment should develop guidance on best practices to be followed in monitoring the environmental fate of chemicals covering both EPA and regional council roles.**

Specifically, that guidance should include advice on:

- who is responsible for setting guideline values and monitoring against these values
- how monitoring effort and guideline value development should be prioritised
- the scope of receiving environments to be monitored and the frequency of monitoring
- the way national and regional levels of regulation should support one another, including:
    - how national-level data on where and how much a chemical is used should assist regional councils to target their monitoring
    - how regional-level monitoring data should be fed back to the EPA to improve national-level regulatory controls
- adapting to new information about chemical pressures (by increasing/decreasing priority for monitoring)
- how best to support the development and implementation of Māori cultural monitoring as a vehicle for providing cultural perspectives and data that could be incorporated into the determination of threshold values.

The EPA should give higher priority to the development and use of environmental exposure limits (EELs). In particular, the EPA should:

- develop and publish a policy, including a methodology, for setting EELs
- provide guidance to enforcement agencies for requirements for monitoring and reporting to demonstrate compliance
- set EELs for priority chemicals of national concern. This may be particularly important for chemicals that arise from diffuse discharges that are not routinely monitored through consent-based monitoring at a local scale.

Some specifics in need of attention

While the HSNO Act and the RMA are the principal statutory scene setters, chapter three describes a more crowded landscape that includes regulation-making powers under the Health and Safety at Work Act 2015 and a special code for the agricultural sector called the Agrichemical Compounds and Veterinary Medicines Act 1996. Then there is the Medicines Act 1981 dealing with medicines and pharmaceuticals for human consumption.

Finished products under the Medicines Act are specifically excluded from oversight by the EPA despite the fact that once ingested they will end up contributing to the cocktail of chemicals found in wastewater treatment plants. The same happens with animal waste. For instance, each year about seven tonnes of tetracycline antibiotics are given to animals, of which about 80 per cent find their way into the environment.

The number of chemicals and the mosaic of legislation governing their use makes it almost inevitable that the environmental fate of chemical contaminants from some sources and pathways is overlooked. On other occasions, the lack of oversight is a conscious decision *not* to ask questions. Manufactured articles present a particularly difficult challenge. Many products containing highly problematic compounds such as PFAS present no immediate risks given their intended use as items of clothing or other finished goods. But what happens when they are discarded and start to break down is another matter.

Sometimes, the decision to treat something as a finished item rather than a chemical can have far-reaching effects. The case study on neonicotinoids provides an arresting example of this. The EPA has up until now regarded seeds treated with neonicotinoids as manufactured articles and therefore outside its jurisdiction. As a result, pesticides that are specifically designed to be introduced into the environment in very significant quantities fall outside the scrutiny of the regulatory system.

A seed and its neonicotinoid coating cannot be considered separate items. But it is a product that is designed to be used in a way that will inevitably free the chemical to leave the product and enter the environment. The EPA's willingness to essentially ignore the hazardous properties of the combined product is questionable. But it draws attention to the way in which a system dedicated to ensuring that environmental impacts are taken into account and then monitored for can end up omitting significant quantities of substances that have the potential to cause harm.

In chapter four, I refer to 'outliers' – forms in which chemicals are found that may contaminate the environment but, along with specific pathways, are not neatly captured under the current regulatory regime. I am recommending that **the EPA should develop policies to address specific pathways and other forms in which chemicals may contaminate the environment such as animal wastes, accumulation of contaminants in agricultural soils, human pharmaceuticals in wastewater, some manufactured articles, and by-products.**

Specifically, as a result of this investigation, **the EPA should expedite an update of its policy regarding treated seed as a manufactured article to ensure appropriate regulation before its current reassessment of neonicotinoids is finalised.**

Cultural impacts

In the current approval process for chemicals, cultural impacts are only considered at a national level. The EPA has a Kaupapa Kura Taiao team that develops Māori impact assessments. While this system appears to work well, its national focus means that it does not always mesh well with the concerns of tangata whenua, which are more likely to be localised and place-based.

The assessments undertaken by Kaupapa Kura Taiao often describe a range of issues and impacts that are generic to Māori and serve as a placeholder for submissions from whānau, hapū and iwi rather than being informed by them.

To bridge this gap, I am recommending that **the EPA Kaupapa Kura Taiao team considers focusing some of its resources on providing 'friends of submitters' services to Māori (whānau, hapū, iwi and other Māori entities).**

In conclusion

Our reliance on industrial, manufactured chemicals is ubiquitous. They underlie a modern economy and much that represents convenience in modern life. They also carry risks that are more or less well understood. If the risks of harm materialise, their replacements will often raise new risks. There is a constant stream of new products that runs alongside a pipeline of environmental monitoring information that informs us about the adequacy of previous assessments of risk. Linking risk assessment with the setting of regulations and monitoring for compliance and environmental impact is a hugely complex affair no matter how a regulatory system is designed.

New Zealand's regulatory system is complex – whether it needs to be as complex as it is, is not something I am venturing a view on. But accepting its structure as for the time being a given, the question is whether it asks the questions that, from an environmental perspective, need to be asked. My conclusion is that it doesn't always do so and that it needs a basis for providing better scrutiny of the chemicals New Zealand uses a lot of and which have the potential to cause harm.

That means being prioritised and adaptive. In terms of priorities, we have to be alert to the fact that the marginal cost of learning more about things we know a lot about may not be worth it if we aren't asking any questions about other things. In terms of being adaptive, we need to be sufficiently agile to incorporate new findings from research and monitoring into regulations as they come to hand. The fact that a chemical is 'caught' by the system doesn't mean that today's settings will always be suitable.

I am hopeful that if a common framework to prioritisation based on scale, harm and presence is implemented and some of the information, monitoring and regulatory gaps I have identified are remedied, policymakers will be able to answer the question "Are we asking the right questions about the things that matter?" in the affirmative.

Simon Upton

Parliamentary Commissioner for the Environment

Loxogramme dictyopteris

Tirohanga whānui

Ko te pātai a tēnei arotake he pēhea te mārama a tēnei pūnaha whakarite i te otinga o ngā tāhawa matū, ā, ka aro atu ki tēnā ina whakature ana i ngā āhuatanga mō te whakamahi. Hāunga te matū e aukatia ana e te tāoke rawa, ko ngā whakataunga ki te whakaae i te whakamahi o te matū e hāngai ana ki te taumata whakamōrea e whakaaetia ana i muri i te aro atu ki ana painga me ngā āhuatanga o te *ara* e whakamahia ana, ā, *kei hea* e whakamahia ana.

Ehara te kaupapa o tēnei pūrongo i te āhua ine i aua whakamōrea. **Ehara hoki** te kaupapa i te karo-whakamōrea o tā mātou pūnaha whakarite ina maharahara ana mō ngā pānga taiao. E aro kē ana ki ngā pātai e rua nō mua:

- **He riterite te whiwhi a ngā kaiwhakarite ki ngā mōhiohio tika mō te otinga ā-taiao ka tūponohia ki ngā matū e whakaritea ana e rātou?**
- **He riterite rānei te pātai mo te whakaaweawe ā-taiao?**

Nā reira, e hono ana tēnei pūrongo ki ētahi atu kua tukuna e au e uiui ana i te tika o ngā mōhiohio ka noho hei tūāpapa mō ngā whakataunga taiao hira.

Ka taea ngā mea kāore i te mōhiotia te patu i a koe

E tata ana ki te 35 tau i mua, i whakaemitia te whakarārangitanga tuatahi o te parakino e Amerika. Mai i taua wā, kua hanga ngā motu ao tuatahi katoa, hāunga a Aotearoa, i ngā mea e kīia ana he rēhita parakino tuku me te whakawhiti (ngā PRTR). Ko te PRTR tētahi atamira ā-motu hei kohikohi raraunga mō ngā whakaruke ki te taiao e mōhiotia ana. Ka whakaaetia ngā motu ki te whakapiri i ngā ira i waenganui i ngā whakaruke tika o ngā matū whakakino pea ki te taiao me te aroturuki taiao e kite ana i ngā paku tāhawa.

E ai ki te ariā, ehara tēnei i te mea ohorere. Mēnā e whakamahia ana ngā matū i runga i te āhuatanga e whakaaetia ana mō te whakamahinga (ā, kua aro atu te hātepe whakaae ki te otinga ā-taiao ka tūponotia), ko tērā e kitea ai e tātou i roto i te taiao, ka noho i raro i te taumata e whakaaetia ana. Ki te puta mai he raruraru i aua taumata, ka taea te whakarerekē i ngā āhuatanga whakamahi. Waihoki, ina mōhio ana mātou he pēhea te nui o te whakamahi, ā, ki hea, e mōhio ana mātou ki te whānuitanga o te raruraru.

Ka tirohia e Aotearoa te whakatū i te PRTR i te tau 1998, engari kāore i whakaaetia. I te tau 2019, ka marohi au me tiro anō te Minita mō te Taiao i te take mō te rēhita pēnā.[1] Engari, kāore i mutu au i reira, i whakaaro au ki te āta rapu kia mōhio i te tino mahi o te pūnaha whakarite – me te kore mōhio hoki – mō te otinga ā-taiao o ngā matū i Aotearoa.

I te tau 2018, i whakamōhiotia ngā tāngata nō Aotearoa ko tētahi matū e whakamahia ana i roto i ngā huhuka – ko ngā matū per- me ngā poly-fluoroalkyl (PFAS) – i tino tāhawa i te wai whenua i ētahi wāhi. He whānui te whakamahi o ngā matū i roto i te huhuka mai i ngā tau 1950 – engari kāore i aroturukihia te whakamahi, ahakoa e mōhiotia ana he whakamōrea pea ki te hauora tangata me te taiao. Nā aua whakamōrea i whakahēngia te whakamahi i ngā pūhui PFAS i roto i ngā huhuka whakaweto ahi i te tau 2006. I muri i taua wā ka puta mai te āwangawanga mō te tāhawa. Kātahi ka āta whakaarohia he pēhea te nui i whakamahia, ā, ki hea.

Ahakoa, ka kī ētahi nā ngā whakamōrea o aua huhuka e tika ana kia kaua rawa e whakamahia mai i te tīmatanga, engari nā te tirohanga whakamuri taua whakaaro. Ko te mea *i taea ai* te matapae mēnā ina puta mai te raruraru, ki te mōhio he aha i whakamahia, ā, ki hea, e taea ai te āta aroturuki me te urupare tere. Nā reira i hua ai tēnei arotake: He tika rānei ā tātou pātai mō ngā whakaaweawe taiao ka tūponohia pea o ngā matū, ā, nā te whakamahi i ngā whakautu ki te whakature i ngā herenga ki te whakamahi tika, haumaru hoki, ka aroturuki rānei mātou i tērā e uru ana ki te taiao kia taea ai, mēnā e hiahiatia ana, te panoni?

Te anga o tēnei pūrongo

Hei āwhina ki te whakautu i aua pātai, ka whakarato te pūrongo i te tirohanga whānui o te pūtaiao o te otinga ā-taiao me te pānga (upoko tuarua) me te āhua onāianei o te pūnaha whakarite, tae atu ki te whāi wāhi atu o ngāi Māori i roto i te hātepe (upoko tuatoru).

I tētahi pito o te pona whakarite ko te Ture Hazardous Substances and New Organisms Act 1996 (Ture HSNO). Ka whakaaetia ngā matū i raro i tēnei ture kia whakamahia, ka aromatawaia ngā whakamōrea, ā, ka whakaturea ngā whakahaere. Ki tētahi atu pito ko te Ture Resource Management 1991 (RMA), e whakaturea ana ngā herenga mō ngā whakaruke ki te taiao.

Ka tautuhi te upoko tuawhā i ngā ara matua e uru ai ngā matū ki te taiao, ā, he pēhea te whakahaere i aua mātāpuna me ngā ara. He ngāwari te mōhio ki te wāhi e uru ai ngā matū ki te taiao mēnā ko te mātāpuna te ruapara hou, te wāhi whakamaimoa waipara rānei. Ko te mea uaua ko te whakahaere i ngā matū kua uru ki ēnei pūnaha – ina mōhiotia ana rānei aua mea. Engari, mēnā he matawhānui te urunga ki te taiao – pērā i te whakamahi i te matū pāmu – ka mōhio pea mātou he aha e whakamahia ana, engari kāore i te mōhio ki hea, ā, he pēhea te wāhi uru ki te taiao, ā, he aha te nui.

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[1] PCE, 2019b.

Ā, e pā ana ki te wai āwhā e heke mai ana i ngā rori me ngā wāhi hanganga, ā, i tukuna mā te pū ki ngā awaiti me ngā takutai moana ki ngā wāhi huhua, he iti tō mātou mōhio ki ngā matū e whakarukea ana ki te taiao, ā, ko hea ngā wāhi e pāngia ana.

Ina tāpirihia ngā wāhanga rerekē o te ārahitanga me te ture kua whakatinanahia he whakaahua whīwhiwhi o te whakarite mai i te whakaurunga mai tae atu ki te tuku atu ki ngā taiao e whiwhi ana. He whakakōingoingotanga o te whakaaetanga, ārahitanga, whakaaetanga ā-ture me te aroturukitanga kāore i te hopu i te otinga ā-taiao o ētahi o ngā tāhawa, ā, i ētahi wā kāore i kitea.

Ka mutu, kia āhua mōhio ki te whakatinanatanga o tēnei anga whakarite, i kōwhiria ngā pūmatū e whā, ā, ka whāia mō te hurihanga katoa o te whakamahi me te porowhiu (upoko tuarima). Ka whakaahuatia e ngā mātai kēhi i te ara wawao o te pūnaha whakarite – kāore i te pērā rānei – ki te whakaiti i te whakaaweawe o ēnei matū ki te taiao. Koinei ngā matū i kōwhiritia: ko te rōpū **neonicotinoid** o ngā patu pepeke, ko ngā rongoā paturopi **tetracycline**, ko te patu otaota **terbuthylazine** me te kongaku **zinc**.

Kei tēnā matū, kei tēnā matū o ēnei matū e whā he mōrearea ki te taiao. Engari i te nuinga o te wā he tino rerekē, e whakakanohi ana i ngā tauira whakamahi rerekē (ahuwhenua, ahumahi me ngā kāinga), he rerekē ngā taiao e whiwhi ana (wai papa, oneone, wai wheua me ngā taiao takutai moana) me te rerekētanga o te mōhio mō te pānga o te matū.

Ka miramira ia mātai kēhi i ngā ahunga rerekē ki te whakahaere me te taumata o te aroturuki o ia matū. Ehara ngā matū i kōwhiritia i te whakakanohitanga o ngā matū katoa kua whakaaetia me te whakamahia ki Aotearoa, ā, *ehara* te kōwhiringa i te tohu o tētahi whakaarotau mō te arotake, te whakahaere rānei ā-whakaritenga. He tauira whakamārama noa iho o ngā ara rerekē e whakahaeretia ana te otinga ā-taiao o ngā matū e te pūnaha whakarite o Aotearoa. Ka pātai te upoko tuaono mēnā e tika ana aua ahunga rerekē – otirā ētahi o ngā āputa raraunga me te mōhiotanga.

Te pātai tika mō ngā mea hira

Kāore he mea ngāwari atu i te tūtohu i te mōhiohio pai ake. Engari e hia, ā, mō te aha? He āhua 150,000 ngā matū kua whakaaetia kia whakamahia i Aotearoa, nō ngā matū e 30,000. Neke atu i te 100,000 te maha o ngā matū e whakamahia ana ā-ao. Ko te tino nuinga o ēnei kua tirohia e ngā kaiwhakarite i ētahi atu ohaoha nui, nā reira me kaua a Aotearoa e tīmata ai ki te tīmatanga. Engari ko te tikanga o ngā āhuatanga taketake o tō tātou taiao me tā mātou whakamahi motuhake i ētahi matū kāore e taea e mātou te whai noa i ngā whakataunga o ētahi atu motu me te kore uiui.

Kua whakawhanaketia e mātou te pūnaha whīwhiwhi ki te whakaae me te whakahaere i ngā matū e whakawhiti ana i ngā tari kāwanatanga huhua. Ahakoa tērā, e 3,500 noa iho ngā matū kua tirohia e ngā whakaaetanga takitahi, ā, rua rau pea kua aromatawaia anōtia. Koinei te tukunga iho o te whakawhiti nui rawa o ngā matū ki te pūnaha i auahatia e te Ture HSNO i mahia i te tau 2005 mā te whakamahi i ngā 'paerewa ā-rōpū' mō te nuinga o ngā matū. Ka whakamāramatia ngā take mō tēnei i roto i te upoko tuatoru. Kua waihotia ētahi tukunga iho.

Tuatahi, ka tuku ngā paerewa ā-rōpū i te kawenga ki te hoatu i te tūnga whakaae ki tētahi kaihoko whakaroto, kaiwhakanao rānei. He ahunga haumaruru ki te whakaritenga. Ahakoa me mau tonu ngā mauhanga o tēnei hoatutanga, kāore Te Mana Rauhī Taiao (EPA), te kaiwhakarite ā-motu i te whiwhi i ēnei mōhiohio hāunga e whakarewahia ana te take whakaaetanga, nā reira he iti te tirohanga whānui.

Tuarua, i te wā o te whakawhiti kāore he aromatawai whakamōrea ōkawa e ine ana i ngā whakamōrea, ngā utu me ngā painga me te whaitake o ngā matū takitahi nā te nui rawa o te mahi. Ahakoa ka whakarato ngā paerewa ā-rōpū me ngā pānui whakawhiti i ngā whakahaere hou, kāore i aromātaihia te taunakitanga o ngā whakamōrea, ngā utu me ngā painga o ngā matū takitahi, ā, kāore e pērā ki te kore e aromātaihia ōkawatia anōtia ngā matū. He nui te utu o tēnei, ā, kāore te EPA i te whai i ngā rauemi ki te whakahaere i ngā aromatawai anō ruarua i ia tau.

E pā ana ki te aroturuki a ngā kaunihera ā-rohe mēnā kei reira ngā matū i roto i ngā taiao e whiwhi ana, iti iho i te 200 ngā matū e āta aroturukihia riteritehia ana i roto i ngā taiao e whiwhi ana. Ahakoa kāore he whakamōrea nui nō ngā matū katoa e whakamahia ana i Aotearoa, he nui ngā mea kāore i te mōhiotia.

E pā ana ki ngā whakamōrea ā-taiao, me āhei te whai a te mahi a tā mātou pūnaha whakahaere ki ngā tāhawa me ngā mahi e whakaputa ana i ngā take tino nui. Kāore he anga hei whakatūturu i tēnei āhuatanga. Nā reira, koinei taku tino tūtohi matua me whakawhanake ngā tari kāwanatanga **katoa** e whakamahi ana i ngā matū **i te anga ki te whakaarotau i te whakapau kaha ki te aro, me te whakahaere, i ngā pānga ā-taiao o te whakamahi matū.** Me whai wāhi atu ngāi Māori ki te hoahoa o te anga pērā.

Me aro atu te tūāpapa o te anga ki te pūtahitanga o ngā āhuatanga e toru:

- te **rahi** o te whakamahi o te matū
- te **whakakino** ka puta mai pea
- te whānuitanga o te kitea o te **whakatinanatanga** o te tāhawa i roto i te taiao.

Ka whakarāpopoto te hoahoa i raro iho i te āwhina a ētahi mōhiohio mō ēnei tūmomo āhuatanga i ngā kaiwhakarite te uiui tika mō ngā whakamōrea hira rawa.

Mātāpuna: PCE

Hoahoa 6.1: He anga hei arotahi i ngā whakaritenga me te aroturuki o ngā whakamōrea tāhawa taiao nui rawa.

E mārama ana kia tino arotahi ki ngā matū kei waenganui o te hoahoa: ngā mea e whakamahia rahitia ana, e mōhiotia ana te whakakino, ā, ka kitea te whakatinanatanga i roto i te taiao. Engari, i tua atu i tēnā, ka tūtohu pea te whakatinanatanga o ngā āhuatanga e rua o ngā āhuatanga e toru (rahi, whakakino, me te whakatinanatanga) i te hiahia kia āta arotahitia.

Hei tauira, me aroturuki tonu pea ngā mea e whakamahia nuitia ana ahakoa e whakaarohia ana ehara i te tino whakakino. Mā ngā mōhiohio kounga pai mātou e kite mēnā he ōrite te tāhawa me te pānga ā-taiao i tērā i matapaetia ana. Waihoki, mēnā ka tae mai ngā mōhiohio mō ngā whakamōrea e puta mai ana, he tīmatangata tā mātou. Waihoki, mēnā he iti te whakamahinga o tētahi mea whakakino i roto i ngā tepenga i whakaritea, he mea nui kia aroturuki i te rahi o te whakamahi e haere tonu ana kia whakatūturu ka noho tonu te taumata o te whakamōrea taiao ki te taumata tika. Ā, mēnā ka puta mai he āwangawanga, ka mōhio matou ki hea rapu ai.

I tua atu i te anga ōrite hei arotahi ki ngā whakamōrea taiao hira o te tāhawa matū, tērā ētahi āputa mōhiohio hei whakakī. I te tuatahi, me whai mātou i ngā mōhiohio pai ake mō te nui o ngā matū e whakamahia ana, ā, nā reira e tukua ana ki te taiao. Ka whakarato te haurapa i te rahi o ngā matū e kawea mai ana, e hangaia ana, e hokona ana rānei i ēnei mōhiohio. Kāore e pēnei ana te pūnaha whakarite o Aotearoa.

Kia kite i te whakaahua whānui o ngā rerenga ā-tinana o ngā matū e whā i kōwhiria e mātou hei mātai kēhi, he hātepe uaua, whakapau wā hoki. Ki te tuitui i ēnei mōhiohio puta noa i te huringa o te hoko whakaroto, te whakamahi me te porowhiu, me rapu ngā mōhiohio nō te huhua o ngā mātāpuna tūmatanui, ahumahi hoki. Engari e kohikohia ana ēnei mōhiohio e te maha o ā mātou hoa hokohoko nui.

I tua atu i te mōhio ki ngā rahi e tukuna ana kia whakamahia, ā, ki hea, e hiahia ana mātou ki ngā mōhiohio pai ake e pā ana ki te wāhi e tukuna atu ana ēnei mea. Mēnā he mōhiohio, kei ngā ringaringa o ngā tari kāwanatanga whakaae o ngā kāwanatanga ā-rohe me ngā pakihi tūmataiti, ā, he uaua te whakatapoko. Ka whakarato tētahi mea ōrite ki te PRTR i ēnei mōhiohio. E mārama ana kāore i te hiahiatia mō ngā matū katoa. Engari, e hiahiatia ana kia āta tirohia ngā mea e whakamahia whānuitia ana i roto i te ohaoha o Aotearoa, ā, e hiahiatia kia aroturuki nā te rahi o te whakamahi me te tūponotanga pea o te whakakino. Ko te tīmata ki ngā mea hira rawa tētahi ara ki te ahu whakamua.

Ko taku tūtohi motuhake kia **whakawhanakete Manatū Taiao i ngā waeture kia herea, kia whakamanahia hoki te EPA ki te whakaemi, kohikohi me te pūrongorongo mō te rahi me te whakamahi o ngā matū i Aotearoa.** Otirā, me pēnei te EPA:

- whakature kia pūrongorongo ngā kaihoko whakaroto me ngā kaiwhakanao ki te EPA te rahinga i ia tau o ngā matū e hokona whakarato, e whakanaohia hoki, ā, me te pūrongorongo tūmatanui a te EPA i ngā mōhiohio hei tau whakakotahi
- whakature i te hunga e hoko ana i ngā matū kia pūrongorongo i ngā rahinga e hokona ana ā-rohe ki te EPA, me pūrongorongo tūmatanui a te EPA i ngā mōhiohio hei tau kotahi
- kohikohi i ngā raraunga mō te whakamahi me te otinga ā-taiao me te arotahi ki nga tukunga whakaarotau
- whakawhanake i te atamira raraunga e tūhono ana i ngā ira o te hoko whakaroto, te hoko, te tuku me te taunakitanga o te otinga ā-taiao i kohikohia i te aroturuki.

Mēnā i mōhio mātou he aha e whakamahia ana me te tohatoha ā-rohe o taua whakamahi, ka taea e mātou te whakahaere i tā mātou aroturuki ā-taiao kia rite ki aua tauira whakamahi.

I tua atu i te aroturuki, me pai ake te mahi o te whakarato i ngā tepenga ā-nama o te taumata tika mō te tāhawa. Ka taea te whakarite i ngā tepenga ā-nama hei ārahitanga, hei whakaritenga rānei, ā, e whakamahia ana ki ngā taumata ā-motu, ā-rohe hoki. He raruraru ki ngā taumata e rua.

Ki te taumata ā-motu, ka taea e te EPA te whakarite i ngā tepenga huranga ā-taiao (EELs). Heoi anō, he iti te whakaritenga o ēnei, te wā rānei e aroturukihia ana mō te tūtohutanga. Ināianei, kāore he kaupapahere whakahaere a te EPA mō ngā EELs. I whakaritea te tikanga āmiki mō te hanga EEL i roto i ngā whakaritenga, engari i unuhia ēnei i te tau 2017, ā, kāore anō kia whakakapia.

Kāore te ture i te āwhina i te EPA. Ka taea te whakature i ngā EEL ki tēnā matū, ki tēnā matū. Engari, kei roto i ēnei matū ngā mea whakauru ōrite. Ko te ahunga whai kiko pea kia whakarite i te EEL mō te *mea whakauru hohe* i te whakaaetanga tuatahi o te matū me taua mea whakauru kei roto, i te wā o te aromatawai anō rānei, ka hāngai i muri ki ngā whakaaetanga katoa e mau ana i taua mea whakauru.

Ko tētahi atu raruraru, i te ao nei, he uaua kia whakauruhi te EPA, ngā kaunihera ā-rohe me ētahi atu tari kāwanatanga whakauruhi i ngā whatinga o ngā EEL. Ki te pēnā, me tautuhi i ngā mātāpuna me te nui o te tāpaetanga ki te pahika. He mahi uaua kia kite i te horopaki hōpua. Engari, ka whakarite kē te EPA i ngā papātanga pānga nui rawa ki te whakahaere i ngā whakamōrea taiao. Engari, ki te kore e whakarite i te EEL i te taha o te pāpātanga pānga, kāore he take kia ine i ngā whakahihiwatanga i roto i te taiao, ā, nā reira te aromatawai i te pai o tēnei whakahaere e pā ana ki te pānga ā-taiao.

Nā te kore o te pūnaha EEL e mahi ana, ka aro kē ngā kaunihera ā-rohe ki te whakamahi o ngā ārahitanga nō Aotearoa, nō tāwāhi hoki, mēnā tērā ētahi, ina tuku ana i te tohu whakaaetanga i raro i te RMA. Pērā i te whakamārama o te upoko tuaono, he rerekē te whakahoutanga o ngā ārahitanga onāianei, ā, tērā ētahi āputa. Engari ahakoa he ārahitanga, kāore pea e taea te whakatakoto e ngā kaunihera ā-rohe. E tino kitea ana tēnei e pā ana ki ngā whakamahinga o ngā matū – pērā i ngā paturiha – he matawhānui. Kāore i te aroturukihia ā-ture ngā whakamahinga e whakaaetia ana. Nā te korenga o ngā EEL he uaua rawa ki te tūhono i te tika o ngā whakahaere ā-motu me tērā e mahia ana i ia rā.

E tūtohi ana au **me whakawhanake te Manatū Taiao i te ārahitanga mō ngā tikanga pai rawa kia whāia ina aroturuki ana i te otinga ā-taiao o ngā matū e uhi ana i ngā mahi a te EPA me ngā kaunihera ā-rohe.**

Otirā, me whai taua ārahitanga i te kupu āwhina pēnei:

- ko wai e noho haepapa ana mō te whakarite i ngā uara ārahitanga me te aroturuki ki ēnei uara
- he pēhea te whakaarotau i te mahi aroturuki me te whakawhanake uara ārahitanga
- te rahi o ngā taiao e whiwhi ana kia aroturukihia me te auau o te aroturuki
- te āhua o te tautoko o ngā taumata whakarite ā-motu, ā-rohe hoki, tētahi i tētahi, tae atu ki:
    - he pēhea te āwhina o te raraunga taumata-ā-motu mō te wāhi me te nui o te whakamahi o te matū i ngā kaunihera ā-rohe kia whakahāngai i te aroturuki
    - he pēhea te raraunga aroturuki taumata-ā-rohe e whakahokia atu ana ki te EPA ki te whakapai ake i ngā whakahaere whakaritenga taumata-ā-motu
- te urutau ki ngā mōhiohio hou mō ngā pēhanga matū (mā te whakapiki/whakaheke i te whakaarotau mō te aroturuki)
- he pēhea e tautoko ai i te whakawhanaketanga me te whakatinanatanga o te aroturuki tikanga Māori hei waka ki te whakarato i ngā tirohanga ahurea me ngā raraunga ka taea te whakauru ki te whakataunga o ngā uara taumata.

Me kaha ake te whakaarotau o te EPA ki te whakawhanaketanga me te whakamahinga o ngā tepenga huranga taiao (EEL). Otirā, me pēnei te EPA:

- whakawhanake me te pānui i te kaupapahere, tae atu ki te tikanga, mō te whakarite i ngā EEL
- whakarato i te ārahitanga ki ngā tari kāwanatanga whakauruhitanga mō te aroturuki me te pūrongorongo ki te whakaatu i te whakatutukitanga
- whakarite i ngā EEL mō ngā matū whakaarotau e hira ana ā-motu. He mea hira pea tēnei mō ngā matū e puta mai ana i ngā whakaruke matawhānui kaore i aroturukihia ana mā te aroturuki nō te tohu whakaaetanga ki te rahinga ā-rohe.

Ko ētahi mea tauwhāiti e hiahiatia ana kia arohia

Ahakoa ko te Ture HSNO me te RMA ngā mea tīmatanga, ka tautuhi te upoko tuatoru i te horanuku e kīkī ana me te mana hanga whakaritenga i raro i te Ture Health and Safety at Work 2015 me te waehere motuhake mō te wāhanga ahuwhenua e kīia ana ko te Ture Agrichemical Compounds and Veterinary Medicines Act 1996. Tērā hoki te Ture Medicines 1981 e aro atu ana ki ngā rongoā me ngā pūroi hei kai mā te tangata.

Ka āta awerehia ngā otinga whakamutunga i raro i te Ture Medicines i te tirohanga o te EPA, ahakoa ina kainga ka tāpae atu ki te huhua o ngā matū e kitea ana i roto i ngā wāhi whakamaimoa waipara. He ōrite mō te para kararehe. Hei tauira, i ia tau e tata ana ki te whitu tana o ngā rongoā paturopi tetracycline e tukuna ana ki ngā kararehe, ā, e 80 ōrau e tae atu ana ki te taiao.

Ko te tikanga o te nama o ngā matū me te whakakōingoingotanga o te ture e whakahaere ana i te whakamahi kāore e kore ka mahue te otinga ā-taiao o ētahi o ngā tāhawa matū i ētahi mātāpuna, ara hoki. I ētahi atu wā, i āta whakaarohia kia *kaua* e uiui te take o te kore tirohanga. He tino wero tō ngā mea e whakanaotia ana. Kāore he whakamōrea tō ngā otinga maha me ngā pūhui kino kei roto pērā i te PFAS nā te tikanga o te whakamahi hei tūemi kākahu, ētahi atu otinga rānei. Engari he pēhea i te wā ka whiua atu, ā, ka tīmata ki te wetewete.

I ētahi wā te whakataunga kia whakaarohia he otinga tētahi mea, kaua ko te matū, ka tuku i ngā whakaaweawe nui. He tauira nui tō te mātai kēhi mō ngā neonicotinoids i tēnei. Tae noa ki tēnei wā kua whakaarohia e te EPA ko ngā kākano e pāngia ana e ngā neonicotinoids hei otinga, ā, nā reira kei tua i tana tirohanga. Nā reira, ko ngā paturiha e āta hoahoatia ana ki whakaurua ai ki te taiao ki ngā rahinga nui rawa, kāore e noho ana i raro i te tirohanga o te pūnaha whakarite.

Kāore te kākano me tana uhinga neonicotinoid e whakaarohia ana hei tūemi rerekē. Engari he otinga e hoahoatia ana kia whakamahia i te ara kāore e kore ka tukuna te matū kia wehe i te otinga me te uru ki te taiao. He raruraru tō te rata o te EPA kia kore e tiro atu ki ngā āhuatanga mōrearea o te otinga whakatōpū. Engari ka whakaatuhia te ara e warewaretia ana he wāhanga nui o ngā matū ka whakakino pea i roto i te pūnaha e tāuke ana ki te aro atu ki ngā pānga taiao me te aroturukihia.

I roto i te upoko tuawhā, ka kōrero au mō ngā 'mea rerekē' – he āhua o ngā matū e tāhawa ana pea i te taiao, engari, tae atu ki ngā ara tauwhāiti, kāore i te tino hopukia i raro i te tikanga whakarite onāianei. E tūtohi ana au **me whakawhanake te EPA i ngā kaupapahere ki te aro atu ki ngā ara tauwhāiti me ētahi āhua e tāhawa ai ngā matū i te taiao pērā i ngā para kararehe, te whakatōpūtanga o ngā tāhawa i roto i ngā oneone ahuwhenua, ngā pūroi tangata i roto i te parawai, ētahi mea whakanao, me ngā otinga whakaputa.**

Otirā, hei hua nō tēnei whakatewhatewha, **me tere whakahou te EPA i tana kaupapahere e pā ana ki te kākano whakamaimoatia hei otinga whakanao ki te whakatūturu i te whakaritenga tika i mua i te whakaotinga o te aromatawai anō onāianei o ngā neonicotinoids.**

Ngā whakaaweawe ahurea

I roto i te hātepe whakaae onāianei mō ngā matū, ka arohia anake ngā whakaaweawe ahurea ki te taumata ā-motu. He tira Kaupapa Kura Taiao tō te EPA e whakawhanake ana i ngā aromatawai whakaaweawe Māori. Ahakoa, te āhua nei he pai te mahi a tēnei pūnaha, nā te arotahi ā-motu, kāore e tino tau ana ki ngā āwangawanga o ngā tāngata whenua, e hāngai ana ki te rohe, ki te takiwā hoki.

Ka tautuhi ngā aromatawai e whakamahia ana e te Kaupapa Kura Taiao i te whānuitanga o ngā take me ngā pānga e pā ana ki ngāi Māori katoa, ā, ka noho hei rīwhi mō ngā tāpaetanga a ngā whānau, ngā hapū, me ngā iwi, kaua ko te whaimōhio ki a rātou.

Hei whakapuru i tēnei ango e tūtohi ana au **kia whakaaro te tira o te EPA Kaupapa Kura Taiao kia arotahi ētahi o ana rauemi ki te whakarato i ngā ratonga 'hoa whakatāpae' ki ngāi Māori (whānau, hapū, iwi me ētahi atu rōpū Māori).**

Hei whakakapinga

He whānui tā mātou whakawhirinaki ki ngā matū ahumahi, whakangao. Ka noho hei tūāpapa mō te ohaoha hou, ā, te hāneanea i roto i te ao hou. E mau ana hoki i ngā whakamōrea e āhua mōhiotia ana. Mēnā ka whakatinanahia ngā whakamōrea o te whakakino, ka whakarewa ngā whakakapinga i ētahi atu whakamōrea hou. He rerenga riterite o ngā otinga hou e noho ana ki te taha o te rārangi pū o ngā mōhiohio aroturuki taiao e whakamōhio atu ki a mātou mō te tika o ngā aromatawai mua o te whakamōrea. He mahi whīwhiwhi rawa te tūhono i te aromatawai whakamōrea ki te whakarite i ngā whakaritenga me te aroturuki mō te whakatutukitanga me te pānga taiao ahakoa he pēhea te hoahoa o te pūnaha whakarite.

He whīwhiwhi te pūnaha whakarite o Aotearoa – mēnā me pērā rawa te whīwhiwhi, kāore au i te tuku i taku whakaaro ināianei. Engari, mēnā ka whakaae koinā te anga, ko te urupounamu mēnā ka pātaihia ngā pātai e hiahiatia ana mō te tirohanga taiao. Ko taku whakatau kāore e pērā rawa ana i ngā wā katoa, ā, me whai i te tūāpapa hei whakarato i te āta tirohanga o ngā matū e whakamahia nuitia ana e Aotearoa, ā, ka whakakino pea.

Ko te tikanga me whakaarotau, me urutau hoki. E pā ana ki ngā whakaarotau, me mōhio mātou kāore he take kia ako mō ngā mea e mōhiotia ana e mātou ki te kore mātou e uiui mō ētahi atu mea. Mō te urutau, me tāwariwari mātou kia whakauru i ngā kitenga hou i te rangahau me te aroturuki ki ngā whakaritenga ina kitea ai. Ahakoa ka 'hopukia' te matū i te pūnaha, ehara i te mea ka tika ngā whakaritenga onāianei i ngā wā katoa.

Ko te tūmanako ki te whakatinana i te anga whānui mō te whakaarotau i hanga i runga i te rahi, te whakakino me te whakatinanatanga, ā, e whakatikahia ai ētahi o ngā āputa mōhiohio, aroturuki me te whakarite kua tautuhia e au, ka taea e ngā kaihanga kaupapahere te whakautu i te pātai "E uiui ana mātou i ngā pātai tika mō ngā mea hira?" ki te āe.

Simon Upton

Te Kaitiaki Taiao a Te Whare Pāremata

1


Todea barbara

Introduction

Global chemical use

More than 100 million chemical substances are currently listed in the Chemical Abstracts Service database, and about 4,000 new ones are added every day.[1] Estimates of the number of chemicals registered for use range from 30,000 to 50,000 in Europe to over 235,000 individual chemicals listed on national chemical inventories globally.[2] The chemical industry is one of the world's largest, with sales (including pharmaceuticals) of around USD 5,680 billion in 2017 projected to grow to around USD 21,750 billion by 2060.[3]

Over the last couple of decades, some chemicals have been subject to global regulatory action due to health and environmental concerns. Examples include some pesticides, industrial chemicals and by-products listed under the Stockholm Convention on Persistent Organic Pollutants that came into force in 2004, and the antifouling agent tributyltin banned by the International Maritime Organization in 2008. Although many of these chemicals have been phased out, challenges remain in ensuring that their remnants are appropriately disposed of. There are many other chemicals that are currently being scrutinised under the Stockholm Convention process that may, over time, be found to present significant risks.

Globally, most chemicals enter the environment from the mining, agriculture, energy generation, chemical production and product manufacturing industries, as well as from direct use, disposal and wastewater treatment. Given the sheer numbers of chemicals that end up in the environment (both naturally occurring and synthetic) it is impossible to monitor every contaminant, where these contaminants end up, and whether their presence in the environment is causing problems.

Many of these chemicals, such as pharmaceuticals and personal care products, are of emerging concern, especially as new information becomes known about their effects and movement through our environment.[4] While the sorts of chemicals that end up in the New Zealand environment are very similar to those found globally, there are some important differences. New Zealand is, largely, an importer rather than a producer of chemicals. Furthermore, unlike many countries, a larger share of chemical contaminants find their sources in land-based industries.

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[1] Dulio et al., 2018.

[2] Dulio et al., 2018; Wang et al., 2020, p.2578.

[3] American Chemistry Council, 2018, cited in OECD, 2019, p.6.

[4] Wastewater treatment plants are only partially effective at removing pharmaceuticals from wastewater (Owens, 2015, and Beek, 2016, cited in UNEP, 2019, p.101).

Objectives and scope of this review

The quality and breadth of information that informs the development of appropriate environmental policy has been the subject of ongoing scrutiny, nationally and internationally.[5] In New Zealand, it is well established that there are significant data gaps in our understanding of waste and pollution, including chemical contamination.[6]

In 2018, I initiated a small piece of work looking at what is known about releases of chemicals in New Zealand's receiving environments.[7] This led to my writing a letter to the Minister for the Environment suggesting that the Ministry re-examine the merits of establishing a Pollutant Release and Transfer Register (PRTR) in New Zealand. New Zealand remains the only Organisation for Economic Co-operation and Development (OECD) member country that does not possess such a policy tool.

At the time I made my suggestion, New Zealanders were coming to grips with the knowledge that a chemical used in firefighting foams had caused extensive contamination of groundwater in a number of locations. The contaminant was one of a large group of chemical compounds called PFAS (per- and poly-fluoroalkyl substances), which take multiple forms. Some of the chemicals in this group, including PFOS (perfluorooctanesulfonic acid) and PFOA (perfluorooctanoic acid), pose potential dangers to the environment and to human health. They are both listed under the Stockholm Convention.[8]

In New Zealand, releases of PFOS and PFOA were not monitored at the time, and contamination only became a concern *after* their use in firefighting foams had actually been prohibited in 2006.[9] They became the focus of an all-of-government enquiry in 2018, which led to investigations taking place at a number of sites.[10] Because their importation and release had not been monitored, defining the extent of the problem was a much more difficult task.

Firefighting foams are just one example of a large number of approved chemicals that find their way into New Zealand's receiving environments, including soils and ground, surface and coastal waterbodies. PFAS-based compounds are relatively new, and understanding of their toxicity and impacts is in the early stages. But they join many other substances with established environmental risk profiles that have been in use for decades. New Zealand's experience with the firefighting foam problem raises the question of whether our regulatory system has a sufficient understanding of the potential for environmental contamination posed by chemicals – new or old.

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[5] OECD, 2017; PCE, 2019a.

[6] Data gaps include the interacting and cumulative effects of water pollution and other pressures on ecosystem health in rural areas, the impact of pollution on ecosystems and cultural values, and the cumulative impact of multiple pollutants and other pressures (e.g. habitat modification) in urban areas (PCE, 2019a, pp.28–30).

[7] PCE, 2019b.

[8] See http://chm.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx.

[9] In New Zealand, firefighting foams containing PFOS or PFOA were specifically prohibited under the Fire Fighting Chemicals Group Standard when it was originally issued in 2006 (EPA, 2020b, p.3).

[10] See https://environment.govt.nz/what-government-is-doing/areas-of-work/land/per-and-poly-fluoroalkyl-substances-pfas/pfas-investigations/#about-pfas-investigations and https://landandgroundwater.com/story/pfas-in-new-zealand-current-knowledge-the-steps-forwards [accessed 8 December 2021].

This report considers what questions are being asked about the environmental fate of chemical contaminants at key points in the regulatory system, from authorisations at the national level through to subsequent discharge-permitting at the regional level. It canvasses advances that have been made in our understanding of environmental fate and impacts of chemical contaminants, as well as the limitations of that knowledge. It asks how this information is factored into assessments, and on what terms. It ultimately considers whether our current regulatory system facilitates or impedes the incorporation of a robust understanding of environmental fate and impact into regulatory decision making.

The report covers both organic and inorganic chemicals associated with rural, industrial and urban settings. It covers chemicals whose toxicity and presence in the environment are relatively well understood, as well as to those that are of emerging concern.

Chemical contaminants have the potential to impact on the wellbeing of tangata whenua, and regulatory agencies within the system must consider Te Tiriti o Waitangi when performing their roles. I have looked into the way Māori are engaged by the regulatory system and the extent to which cultural impacts are considered in the process.

The environment, as defined under the Environment Act 1986, incorporates ecosystems and their constituent parts as well as people and communities. Ecological health, human health, the wellbeing of tangata whenua and the nation's economic wellbeing are values that are intimately connected. Each stands to benefit from, or be harmed by, chemicals in the thousands of different applications offered by modern chemistry and industrial processing. An investigation of all chemical contaminants on all of these aspects would be vast. The focus of this investigation has therefore been narrowed along the following dimensions.

First, while it is clear that pollutants may cause harm to human health either through direct exposure to chemicals or via consumption of food from commercial sources or mahinga kai (food gathering places), the primary focus of this report is on the potential impact to biota and ecosystems within New Zealand's receiving environments. It gives particular focus to freshwater ecosystems (surface water and groundwater), coastal environments and soils, and the biota and flora that these host.

Second, the report does not focus on nutrients and bacterial contaminants. While they are important environmental contaminants, these have received considerable policy focus over recent decades. Freshwater policy reform processes have resulted in national-level limit-setting under the National Policy Statement for Freshwater Management 2020.

Third, this report uses four case study chemicals to illustrate how the regulatory system for chemicals operates as a whole. All of these chemicals have important applications ranging from industrial processes through to healthcare. The investigation does not attempt to undertake an environmental risk assessment, nor weigh up the risks, costs and benefits of the use of any specific chemical. This is the responsibility of the Environmental Protection Authority (EPA).

Fourth, this report focuses on present-day, legally authorised releases, rather than legacy contamination concerns.

Finally, noting the recent work of the Hazardous Substance Compliance System Technical Working Group appointed by the EPA and the Ministry for the Environment, the review does not set out to comprehensively evaluate the performance of the compliance and enforcement regime. Some of its findings, however, may resonate with those of the Technical Working Group.[11]

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[11] Hazardous Substance Compliance System Technical Working Group, 2019.

Approach to the investigation

To generate insights on the regulatory system throughout the lifecycle of chemical use and disposal, four case studies have been used to put a spotlight on how well-informed regulators are about the environmental fate of chemicals. The case study chemicals were chosen to represent different use patterns and receiving environments. Clearly, the case studies can only be illustrative, not exhaustive. However, they have been selected to illustrate a range of settings – urban and rural, point source and diffuse pollution – and cover a wide range of receiving environments.

The case study chemicals are:

- **neonicotinoids**, an insecticide used in the pastoral, arable and timber treatment sectors
- **tetracyclines**, an antibiotic used in human and veterinary medicines
- **terbuthylazine**, a herbicide used in forestry and agricultural settings
- **zinc**, a metal that is found in a broad array of substances and may be found in stormwater, wastewater and agricultural settings.

In addition to inhouse research, two specific pieces of external work were commissioned to provide insights on specific lines of enquiry.

The first is a review of chemical contaminants monitored by regional councils in wastewater, stormwater and landfill leachate as key sources of contaminants into receiving environments. The report by Jacobs New Zealand Ltd is titled *Chemical contaminants in Aotearoa: State of knowledge, management and risks*.[12]

The second report provides quantitative estimates of zinc from available data mobilised from coal mines, calculated by Verum Group and titled *Assessment of zinc mobilisation from coal mines*.[13] This study was needed to reduce uncertainty associated with zinc leaching from coal mines in making an assessment about the total quantity of zinc released into the receiving environment.

Both consultancy reports are available at pce.parliament.nz.

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[12] Conwell, 2021.

[13] Pope and Christenson, 2021.

2

Hymenophyllum malingii

The science of environmental fate and impact

Introduction

The way we have come to live depends on the use of manufactured chemicals. They are in everything from medications and personal care items to coatings on fabrics, roofing materials and cleaning products. The convenience of these products comes with a cost. Environmental chemistry and ecotoxicology have shown that chemical production and use usually have an impact, whether that be on human or environmental health. Many of the substances produced and used by humans have contaminated air, water and soil, and their waste and disposal are creating unanticipated problems.[1]

This chapter provides an overview of the scientific knowledge that helps us to understand the fate and impact of chemicals in the environment. It provides some insights on the methods and approaches used to inform the regulation of chemicals in New Zealand.

The emergence of ecotoxicology

Although the effect of toxicants on people has been known for centuries, the purely human focus in science shifted to a more holistic one in the 1950s, with the realisation that humans are part of the natural environment and depend on other living organisms. This awareness emerged from a series of humanitarian and environmental disasters. Of particular infamy was the prolonged discharge of methylmercury from an industrial chemical plant into Minamata Bay on the west coast of Kyūshū in Japan.[2] The prolonged effects of this discharge became apparent by 1956, and it is now acknowledged as one of the world's worst cases of mercury poisoning. But it was not just people who were affected. Bioaccumulation of methylmercury throughout the marine food web resulted in the death of shellfish, fish, birds and even cats.

Rachel Carson's 1962 book *Silent Spring* brought the consequences of extensive pesticide use to public attention. In it she examined several notable impacts of pesticides (DDT in particular) on birds in the United States, such as the thinning and collapse of eggshells, which led to the decline of some bird populations.[3] This work exposed widespread environmental effects to a public that had previously held a benign view of the environmental use of chemicals.[4]

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[1] Sánchez-Bayo, 2011.

[2] Harada, 1995.

[3] DDT is the acronym for dichlorodiphenyltrichloroethane, an organochlorine used as an insecticide.

[4] Carson, 1962.

Carson's book and emerging evidence of environmental degradation contributed to a paradigm shift in the perception of pollution. The 'dilution' paradigm, understood as 'the solution to pollution is dilution', rapidly shifted to a 'boomerang' paradigm that recognised that what we throw away can come back to hurt us. This shift and a growing awareness of the consequences of inattention to pollutants in the environment were pivotal for the development of the ecotoxicology field. Ecotoxicology, a term used for the first time in 1969, studies the toxic effects of natural or synthetic pollutants on ecosystems, animals (including humans), plants and microbes in an integral way.[5]

Chemicals in the environment- the nature of the problem

Chemicals can occur naturally, such as metals present in rock that may be released when disturbed by mining or volcanic activity, or can be intentionally produced by humans, such as plastics or pharmaceuticals. When chemicals of natural or synthetic origin get into environments they are not usually present in, or in quantities greater than their naturally occurring amounts, they can cause problems for the things living in these environments.

There are two key aspects to understanding the problems that chemicals might cause in the environment: firstly, how they get into the environment (and in what form and quantity), otherwise known as environmental fate; and secondly, how they cause harm to the things living in these environments, and their level of toxicity.

What happens to chemicals in the environment?

The sources of chemical pollution can be categorised as point source and non-point source or diffuse pollution. As the name suggests, point source pollution comes from a single place (e.g. a wastewater outlet). It is generally easier to identify and address than diffuse pollution, which can come from many dispersed sources at the same time (e.g. leaching of phosphorus from fertilisers applied to multiple fields).

Once a chemical is in the environment, its physical and chemical properties will determine where it ends up and whether it will have any toxic effects on organisms and ecosystems exposed to it. Physical properties are those that can be observed or measured without changing the chemical's identity, such as molecular weight, tendency to evaporate (volatility), boiling point, and ability to bind to soil (sorption) or be dissolved in water. Chemical properties, on the other hand, are those characteristics of a substance that will result in a change to a chemical's identity, such as occurs in a chemical reaction (e.g. flammability, acidity) (see Figure 2.1).

Based on these physicochemical properties and observational work, scientists have developed tools to measure how long a chemical remains in the environment (its persistence), how much it can move around, and how much is likely to be available to organisms to take up (bioavailability).

The persistence of a chemical in the environment will depend on how easily it degrades. Persistence is often measured in terms of a chemical's half-life – the amount of time a chemical takes to degrade to one-half of its initial concentration.[6] Degradation is a complex process whereby a chemical is broken down into other chemicals by physical, chemical and biological processes into a range of transformation products. Also called breakdown products or metabolites, some of these transformation products can continue to be toxic but might have different modes of action to the parent compound.

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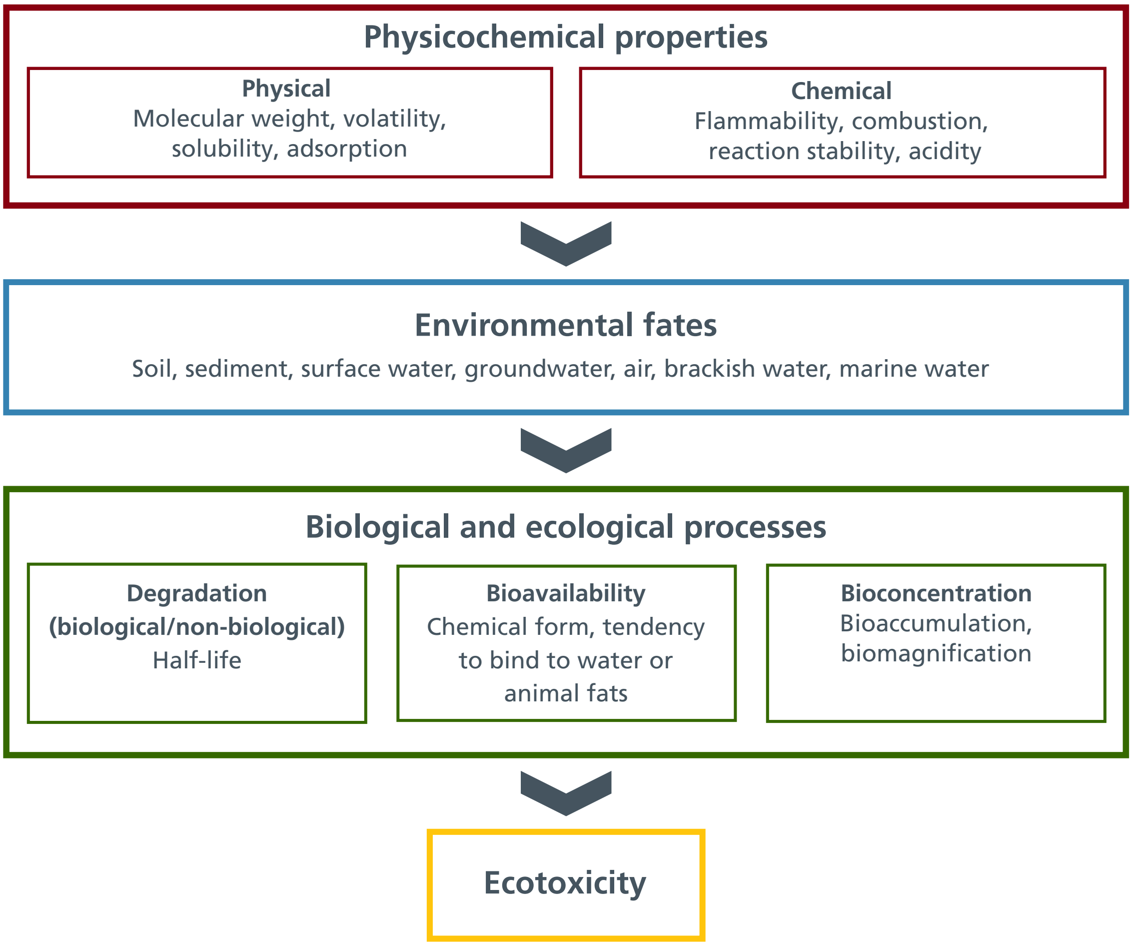
[5] Truhaut, 1977.

[6] ANZECC and ARMCANZ, 2000.

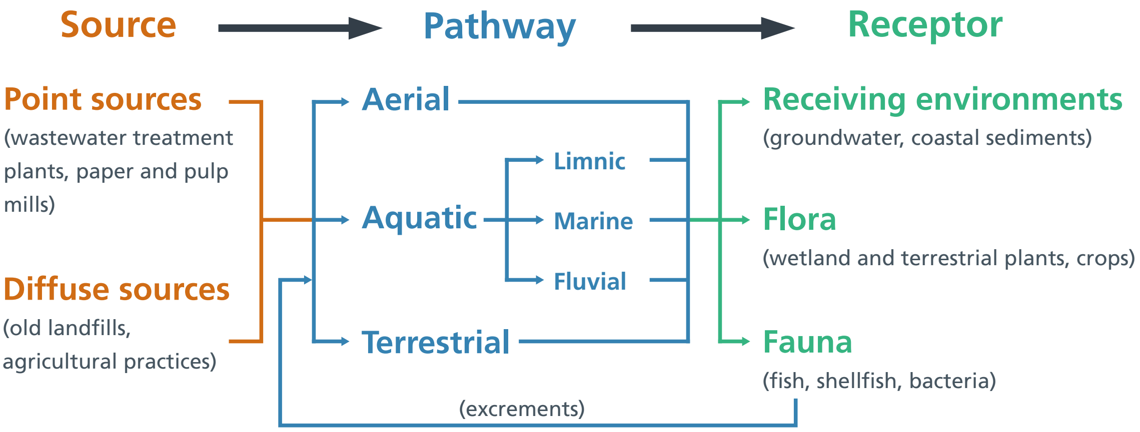
Key environmental factors affecting the rate of a chemical's degradation include exposure to light (photolysis), water (hydrolysis) or microbial activity (biodegradation). Even if a chemical is able to completely degrade, continuous release into the environment can lead to its constant presence in the environment. This is referred to as 'pseudo-persistence'.



Source: Adapted from the National Research Council, 2014

Figure 2.1: Diagram illustrating classes of physicochemical properties of a chemical and their influence on environmental fate, biological and ecological processes, and toxicity to living things.

How far a chemical can move from its source through to a receiving environment can be affected by interactions with other chemicals or non-biological factors such as pH, temperature, dissolved organic matter, or salinity.[7] The physicochemical properties of a chemical along with the characteristics of the system will dictate the specific routes a chemical will take (often called pathways). A chemical can be transported through different pathways, including soil, water or air, meaning that living things can be exposed to chemicals through different routes (Figure 2.2). Scientists use laboratory and field testing, as well as modelling, to monitor and predict the exposure routes of a chemical from its source to the various receiving environments and living things.[8]



Source: Adapted from Waldschläger et al., 2020

Figure 2.2: Source–pathway–receptor conceptual model (examples in brackets). The source describes the origin of a chemical. The pathway is the route that a chemical takes to reach the receptor. The receptor is the receiving environment and the entities that may be harmed by the chemical.

Two other aspects of chemicals that can be measured are their potential to accumulate in an organism over the span of its life, resulting in a higher concentration in older individuals (bioaccumulation), and their potential to magnify in concentration along the food web, resulting in a higher concentration in organisms higher up the food chain (biomagnification). The methylmercury disaster in Minamata Bay in the 1950s was one of the first cases where bioaccumulation and biomagnification of a chemical were evidenced in fish tissue.

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[7] For example, freshwater environments with low pH can influence the availability of copper to fish. This is because acidic water changes the form of copper to free and positively charged ions (Cu^{2+}), which are electronically attracted to the negatively charged receptors in fish gills. Depending on the amounts of copper ions available to fish, chronic or lethal effects can occur. For example, tropical fish exposed to 25 µg/L of copper suffer from intense cellular degeneration and necrosis in the gills (Mazon et al., 2002).

[8] Pavan and Worth, 2006.

Toxicity assessment – how do chemicals cause harm?

Once in an environment, a chemical can affect organisms like flora, fauna and microbes. Toxicity assessments help determine the potential harm a chemical may pose to different types of living things. Understanding a chemical's *mode of action* – that is, how it triggers or causes a toxic effect – is highly desirable when assessing how it may affect an organism exposed to it. Natural and synthetic chemicals can have more than one mode of action, and their effects will depend on how the chemical interacts with specific target sites in an organism.[9] Although toxicants such as biocides are designed with a specific mode of action that will target particular organisms, non-target organisms – sometimes from considerably different forms of life – can still be affected.

For example, some fungicides are designed to inhibit ergosterol, an essential component of fungal cells for maintaining cell membrane structure and function. Animals and plants lacking ergosterol in their cell membranes are not expected to be affected by these fungicides in the way they are designed to act. However, these fungicides have been found to have other modes of action on non-target organisms. In macro-algae, these fungicides affect photosynthetic pigments and enzyme activity, which alters their antioxidant defence system.[10]

Role of toxicity tests

A range of toxicity tests have been developed to assess how chemicals affect living things (Figure 2.3). These evaluate effects at different biological levels, including cellular and tissue (*in vitro* tests), whole organisms in the laboratory (*in vivo* tests) and communities in the field (*in situ* tests). Complementary tests can include computational predictors of toxicity (*in silico*) and chemical reactivity (*in chemico*) tests. Together, these assessments characterise the adverse effects of a chemical on a range of species in different environments.

Between the 1950s and 1980s, acute toxicity bioassays – tests measuring adverse effects on an organism after being exposed to a single chemical over a short period of time (e.g. 48-hour tests) – were the main type of tests used to assess the toxicity of a chemical in the environment. Acute tests are typically conducted on test species spanning a range of trophic levels (e.g. bacteria, microalgae, invertebrates such as the water flea, and fish such as the rainbow trout). Results from acute tests are expressed as LC_{50} values. LC_{50} refers to the 'median lethal concentration' of a chemical at which 50 per cent of the tested population is expected to die. Results from acute tests are extrapolated to give an indication of how other similar species might also respond.

Chronic tests are often used following acute tests to measure effects in organisms exposed to low concentrations of a chemical over longer timeframes. The range of concentrations used in these tests are not usually lethal over an acute exposure period, and the timeframes are intended to be indicative of a substantial portion of an organism's life span.[11] Chronic tests will often assess sublethal effects such as impaired mobility, altered behaviour, reproductive dysfunction and embryonic or birth defects. Sublethal results are expressed as an EC_{50} (the 'median concentration' at which 50 per cent of exposed organisms are expected to suffer a particular sublethal effect).[12] Without chronic tests, the long-term risk of some chemicals to organisms could be underestimated.

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[9] Yang et al., 2011.

[10] Alkimin et al., 2020.

[11] Warne et al., 2018.

[12] ANZG, 2018; ANZECC and ARMCANZ, 2000.

Species sensitivity distribution is a method that uses data from multiple *in vivo* (acute and chronic) toxicity tests, spanning a range of test organisms, to predict concentrations that affect (or protect) a proportion of species within a community. Given the variability in sensitivity to toxicants that can occur between different species at different trophic levels, the larger the range of organisms included in a species sensitivity distribution, the better.[13]

Typically, a hazard concentration will be calculated that protects the majority of test species. So, for example, a concentration that should protect 95 per cent of the test species is expressed as one that affects five per cent of the species, or HC5 Regulators can use these species sensitivity distributions to derive risk-based environmental quality guidelines. For example, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality specify a 95 per cent guideline value for copper in freshwater of 1.4 micrograms per litre.[14,15] This suggests concentrations of copper below this value should not affect 95 per cent of species in freshwater ecosystems in New Zealand.

Complementary tools

Testing chemicals on animals has and continues to raise concerns for animal welfare. It is also costly. Along with the increased efficiency of automated screening tools,[16] *in vitro* and *in silico* testing methods have become an attractive alternative. *In vitro* tests enable scientists to measure the toxicity of chemicals on isolated cells, avoiding testing on live animals and the ethical implications associated with doing so.[17] These techniques can also provide detailed information about the chemical’s mode of action, and can be used to assess very long-term effects (e.g. carcinogenic effects) of the chemical being tested. Despite the advantages of *in vitro* testing methods, these are often not a complete replacement for *in vivo* tests.

In silico methods (referring to the silicon in computer chips) can complement *in vivo* and *in vitro* toxicity testing, using computational models to collate, organise and analyse data to predict the toxicity of chemicals on biological activities.[18] These techniques can leverage existing data collected from *in vivo* tests to amplify the number of assessments being made and reduce the need for testing. However, these predictions still need to be validated, so assessing the potential harm of chemicals to the environment still ultimately relies on *in vivo* tests with live organisms.

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[13] Forbes and Calow, 2002.

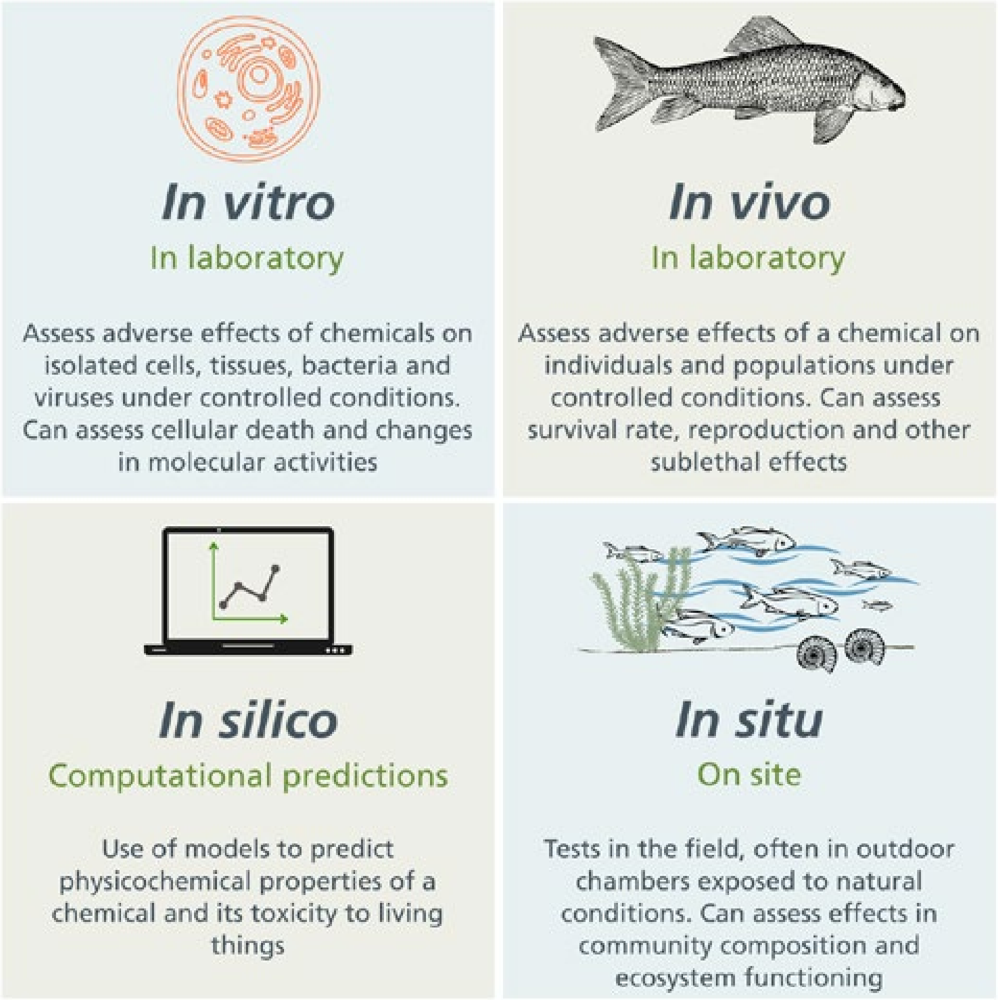
[14] See https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants.

[15] This concentration is recommended for application for slightly to moderately disturbed ecosystems. Concentrations are also provided for other levels of species’ protection.

[16] Known as high-throughput testing, these methods can rapidly screen a large amount of samples (> thousands) for biological activity at a molecular, cellular or organism level (Attene-Ramos et al., 2014).

[17] Two *in vitro* methods approved by the OECD and the International Organization for Standardization (ISO) for regulatory purposes are the fish embryo test (FET) and the fish gill cell line (RTgill-W1). Both tests have been approved as alternatives to *in vivo* fish acute toxicity testing.

[18] Raies and Bajic, 2016. Generally, modelling predictions consist of five steps: (1) gathering biological data on associations between chemicals and toxicity endpoints; (2) calculating molecular descriptors of the chemicals; (3) generating a prediction model; (4) evaluating the accuracy of the model; and (5) interpreting the model.



In vitro

In laboratory

Assess adverse effects of chemicals on isolated cells, tissues, bacteria and viruses under controlled conditions. Can assess cellular death and changes in molecular activities

In vivo

In laboratory

Assess adverse effects of a chemical on individuals and populations under controlled conditions. Can assess survival rate, reproduction and other sublethal effects

In silico

Computational predictions

Use of models to predict physicochemical properties of a chemical and its toxicity to living things

In situ

On site

Tests in the field, often in outdoor chambers exposed to natural conditions. Can assess effects in community composition and ecosystem functioning

Source: PCE

Figure 2.3: The range of methods available to assess the toxicity of chemicals to living things.

Clearly, *in vitro* testing provides ethical and cost effectiveness gains over *in vivo* testing, as well as valuable information about a chemical's mode of action. However, neither *in vitro* tests on cells nor *in vivo* tests on whole organisms can convey the impact of a toxicant on a larger scale (such as populations and communities) or on ecosystem functions (such as alteration to energy flow and species composition and interactions). To assess such community- and ecosystem-level effects, *in situ* experiments conducted on site are required. These studies often use outdoor experimental systems called *mesocosms*, which model the ecosystem being tested in a controlled environment.[19]

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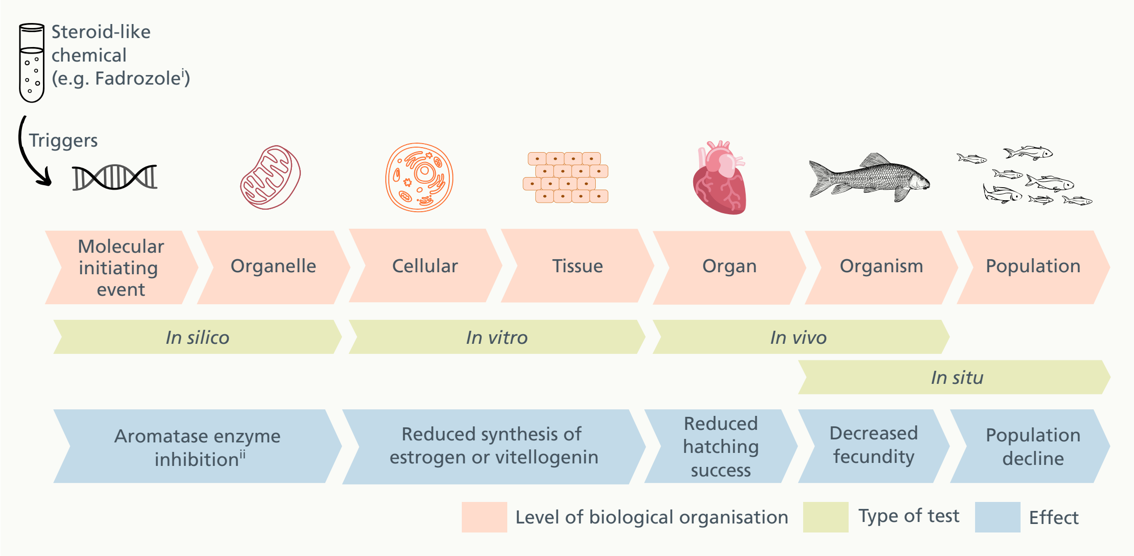
[19] See the 'Current scientific concerns and limitations' section later in this chapter for more about the advantages of mesocosm systems in assessing more environmentally realistic effects of chemical contaminants.

Adverse outcome pathways are frameworks that have been developed to relate and explain the flow-on effects chemical exposure can have on an organism. They follow the initial interaction between a chemical and an organism at a molecular level (known as the molecular initiating event, determined via *in silico* or *in vitro* tests), which can trigger key events in tissues or organs, resulting in adverse effects to organisms, populations, and communities (see Figure 2.4).



Source: Modified from Villeneuve, 2016

Figure 2.4: Example of an adverse outcome pathway showing how molecular events activated by a steroid-like chemical are linked to reproductive dysfunction in repeat-spawning fish species. The chemical activates molecular initiating events (e.g. inhibition of aromatase enzymes) that trigger key events at the cellular and tissue levels (such as the reduction of vitellogenin, the main contributor of egg yolk). This reduces egg production and fertility, and results in population decline.

Alongside advances in adverse outcome pathways, programmes such as Tox21 and the United States Environmental Protection Agency's ToxCast are being developed to support computational models that can identify molecular initiating events associated with untested chemicals.[20] Testing is evolving to identify problematic substances before they are even used, and to use all existing information on current chemicals to design less hazardous chemicals in the first place.

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[20] Gaw et al., 2019.

Assessing the environmental risk posed by chemicals

Environmental risk assessments aim to evaluate how likely a stressor is to cause adverse effects to exposed organisms and how large that stressor may be. When dealing with chemicals, an environmental risk assessment follows a framework that considers two main components: the routes of exposure of a chemical (e.g. using the source–pathway–receptor model presented in Figure 2.2), and the potential it has to cause harm to living organisms present in the receiving environment. Risk assessments are based on scientific evidence gathered from the tests presented above, which characterise the environmental fate and toxicity of chemicals. A summary example of the data used in environmental risk assessments is provided in Box 2.1.

Box 2.1: The physicochemical properties and toxicity of glyphosate and how they are likely to affect its environmental fate and impact on biota[21]

Glyphosate, a broad-spectrum herbicide, is a hydrophilic substance, which means it readily dissolves in water (Table 2.1). However, soil adsorption measurements (K_{oc} = 1,424) suggest glyphosate can also bind to soil or sediment particles, which restricts its dissipation in water. Sorption values, together with a relatively low bioconcentration factor and low persistence indicators, show glyphosate has low accumulation potential in organisms during its short half-life (e.g. DT_{50} 13.8–301 days in freshwater). However, field and laboratory studies show accumulation of glyphosate in wetland biofilms during a 24-hour exposure.

Toxicity of glyphosate is variable across organisms. Under short exposure tests, freshwater fish present high acute sensitivity to glyphosate compared to terrestrial organisms such as soil invertebrates. Glyphosate breaks down into the major metabolites aminomethylphosphonic acid (AMPA), sarcosine and carbon dioxide. Toxicity profiles for these metabolites is often missing and should be considered to assess the full impact of the compound. These data can give an idea of the risks associated with the use of glyphosate under specific conditions. However, exposure routes should be considered for risks at specific sites with different abiotic and biotic dynamics.

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[21] University of Hertfordshire Pesticide Properties DataBase, http://sitem.herts.ac.uk/aeru/ppdb/en/Reports/373.htm [accessed 4 November 2021]; Beecraft and Rooney, 2020; Carles et al., 2019; Mottier et al., 2013; Bringolf et al., 2007.

Table 2.1: Physicochemical properties and toxicity data of glyphosate used to examine its likely environmental fate and how it will affect biota.

Physicochemical properties	Measurement	Interpretation
Persistence	Half-life (DT50) in different environments: • Freshwater: 13.8–301 days • Soil: 2–197 days • Plants: 8–9 days	Half-life is the time taken for the total concentration to halve. The reported time periods indicate glyphosate has moderate to low persistence.
Affinity for mediums	Hydrophilic. Solubility 10,000–15,700 mg/L at 25 °C	Highly soluble in water.
Mode of action	Glyphosate disrupts the cellular pathway that synthesises aromatic amino acids	Inhibits production of enzymes fundamental to plant growth.
Sorption	Lipophilicity of glyphosate (log K_{ow}): -3.2 Mobility in soil (K_{oc}): 1,424	A low K_{ow} value of -3.2 means glyphosate preferentially partitions into water-based liquids. A K_{oc} value of 1,424 suggests glyphosate has high affinity to soil and is slightly mobile.
Bioconcentration and bioaccumulation	Bioconcentration factor (BCF)[i] = 0.5 L/kg	This measurement suggests glyphosate has a low to moderate uptake by organisms.
Metabolites	AMPA, sarcosine, CO_2	Glyphosate breaks down into toxic (AMPA) and non-toxic (e.g. sarcosine and CO2) compounds.
Toxicity **(median effect concentration (EC_{50}), lethal dose (LD_{50}) and lethal concentration (LC_{50}))[ii]**	**Freshwater fish species** Freshwater invertebrates LC_{50} = > 480 mg/L Fish LC_{50} = 3 8 mg/L Fish EC_{50} = 1.0 mg/L **Soil invertebrates** LC_{50} = > 5,600 mg/kg EC_{50} = > 28.8 mg/kg	**Bird species** LD_{50} = > 2,000 mg/kg EC_{50} = 96.3 mg/kg **Marine species** Oyster LC_{50} = 10 mg/L Oyster EC_{50} = 28–40 mg/L Crab LC_{50} = 934 mg/L Shrimp LC_{50} = 281 mg/L
Pathways	Soil, surface water, groundwater, wetlands, biofilms	Glyphosate can be transported to different environments via soil, surface water, groundwater, wetlands and biofilms, depending on environmental conditions.

Notes:

[i] BCF is an indicator of the probability a chemical has to accumulate in organisms. Values above 1 represent chemicals with an affinity for lipid content, suggesting they tend to accumulate in the body.

[ii] LC_{50} and LD_{50} values are values at which half the exposed population dies from the exposure. EC_{50} values are values at which half the population shows some specified effect. For fish, the EC_{50} and LC_{50} values are 48-hour exposures. For soil invertebrates, the LC_{50} value is for a 14-day exposure. For birds, exposure time for LC_{50} is not available, and the chronic (NOEC) value is for a 21-day exposure. For oysters, the LC_{50} value is for a 96-hour exposure, and the EC_{50} value range is for a 48-hour exposure.

But simply assembling the data is not enough. In order for the information to be examined holistically and the likely environmental impacts determined, it needs to be systematically compared using a unifying framework. Environmental risk assessment frameworks have been developed for two purposes: to support government decision-making processes for the approval of a chemical, and to assess the effects of contamination resulting from an existing activity (e.g. discharge of treated effluents), known as an environmental *impact* assessment. Most agencies from the OECD member countries follow the same general framework for risk assessments based on standard procedures developed by the United States Environmental Protection Agency.[22] They typically follow a step-by-step process to assess the potential risk of a chemical to the environment, which allows for the development of risk management plans to mitigate environmental impacts (Figure 2.5).

If a chemical has low toxicity, a known mode of action, low bioaccumulation, and it degrades quickly in the environment, then it is likely to generate a small hazard quotient and it becomes easy to assign it a low environmental risk. However, this calculation becomes trickier if some evidence is missing or if a chemical – and its breakdown products – exhibit a range of toxicities to different living things within multiple environments.

In such cases, computational models are useful as they can be used to generate new toxicity data, account for uncertainties due to lack of data, or suggest environmental exposure limits. Models can be used in both parts of an environmental risk assessment – in environmental exposure assessments, and in toxicity assessments. Models used in exposure assessments are used to predict transport pathways, degradation rates and concentrations of chemicals in different receiving environments. On the other hand, models used in toxicity assessments help to understand the physical, chemical and toxic properties of individual chemicals, mixtures and their breakdown products.[23]

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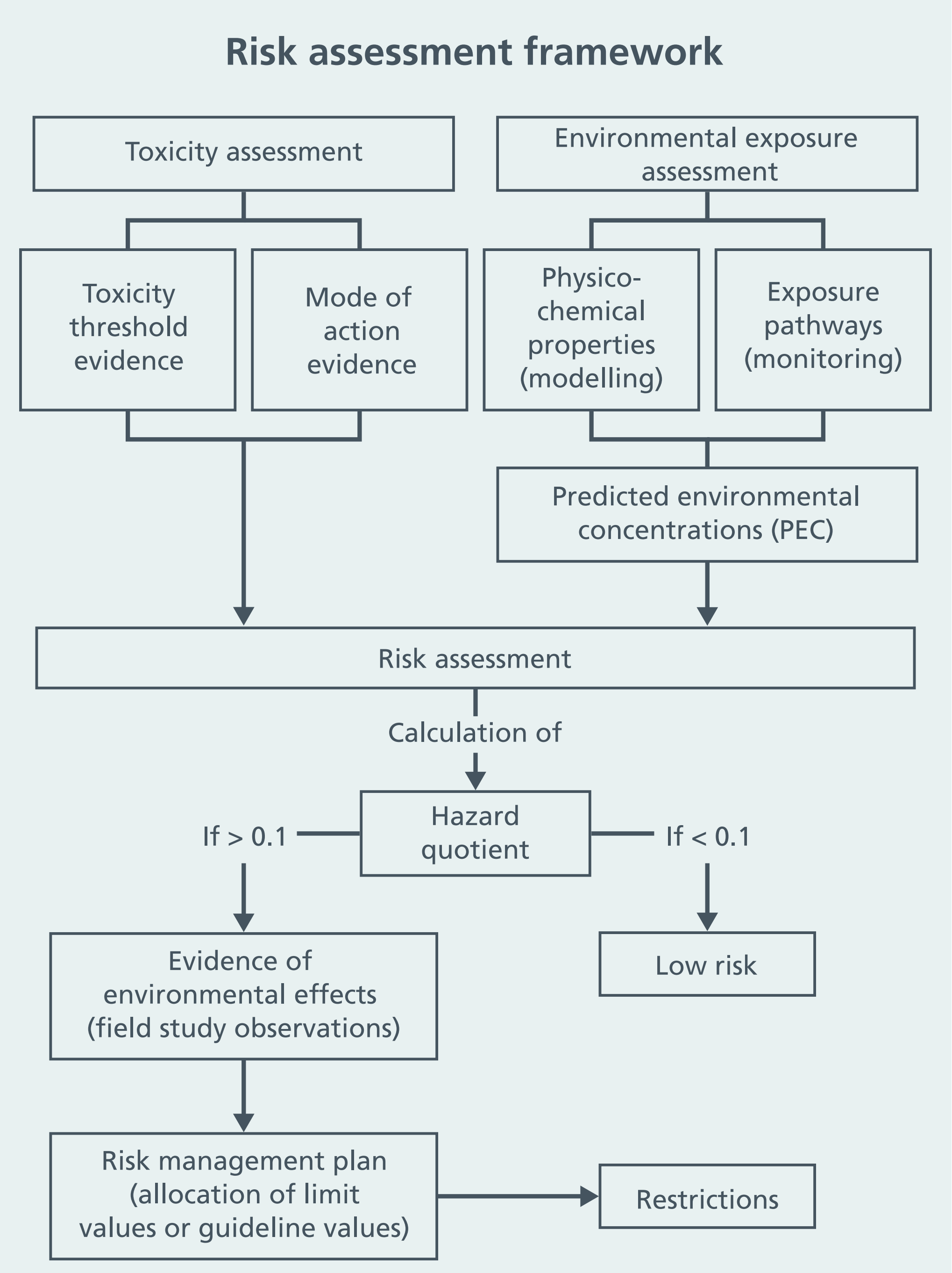
[22] Urban and Cook, 1986.

[23] Refer to Appendix 7.1 for further information on types of models used in environmental risk assessments across the world.



Source: PCE

Figure 2.5: A generic framework for environmental risk assessment of chemicals.[24] The toxicity assessment section is informed by the toxicity framework. Refer to Appendix 7.2 for further details.

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[24] Sánchez-Bayo and Tennekes, 2015.

How risk assessments inform regulations and guidelines for chemical concentrations

Applicable regulatory agencies in each jurisdiction – like the Environmental Protection Authority (EPA) in New Zealand – use information obtained from toxicity and exposure assessments, along with other considerations (e.g. cultural concerns, economic costs and benefits) to decide whether to approve the use of a chemical and under what conditions.[25]

Although the general processes and methodologies used for conducting environmental risk assessments (e.g. according to OECD or ISO standards for toxicity tests) may well be standardised across countries, the assessments that are ultimately produced will reflect particular understandings of risk and particular levels of risk aversion within individual organisations or societies. Because the balancing of risks occurs through different cultural filters in different cultural contexts, the outcomes of risk assessments may have some specificity and, as a result, it may not always be appropriate to generalise from one national context to another.

Once risks are identified when approving a new chemical for use, risk-based limit values may be allocated (though this varies across jurisdictions). These limits set the maximum concentration of an ecotoxic substance allowed in a particular environmental medium, or the maximum loading of a substance onto a surface. Chapter three provides more details about risk-based limit values and the other types of controls used to manage approved chemicals in the New Zealand context.

Controls imposed by regulatory agencies for the use of chemicals are legally binding. Other tools, such as guideline values (derived from ecotoxicity tests) are widely used, but do not always carry legal or regulatory weight.

Guideline values play an important role in managing the ecological impacts of chemical discharges to the environment. These are numerical values defining tolerable limits for specific contaminants for the protection of ecological receptors in air, freshwater, marine-water, sediments and soils. These values are mainly derived from multiple toxicity tests and species sensitivity distributions.

Guideline values available for use in New Zealand

The **Australian and New Zealand Guidelines for Fresh and Marine Water Quality** provide a framework for the management of water quality in New Zealand.[26] They include guidance for the setting of water and sediment quality objectives and were used as technical support for the National Policy Statement for Freshwater Management (NPS-FM). They provide default guideline values for a set list of priority toxicants in waterbodies across different levels of modification (e.g. pristine, modified or highly modified waterbodies).

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[25] A lower tier approach uses qualitative assessments (e.g. to identify magnitude and likelihood of the effect) on new substances with similar characteristics to an approved chemical. Higher tier approaches use quantitative assessments for new active ingredients or for the reassessment of an existing and approved substance.

[26] ANZG, 2018. Available at www.waterquality.gov.au/anz-guidelines.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality also provide advice on factors to consider when deriving site-specific trigger values for chemicals. This is important for regions with specific physicochemical characteristics where default guideline values may not be suitable, such as regions with naturally high concentrations of metals from volcanic rock or geothermally active areas. For example, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality have been adopted as standards by several regional councils, including Environment Canterbury and Environment Southland in either historical or existing regional water plans. These guidelines can be set as a regulatory limit or as a trigger value for further action.[27]

In the absence of official national guidance on the potential environmental impacts of contaminants on soil biota (microbes, invertebrates, plants), wildlife and livestock, Manaaki Whenua – Landcare Research developed the **New Zealand Ecological Soil Guideline Values (Eco-SGVs)** in 2016.[28] These provide provisional guidance for natural background concentrations of trace metals in New Zealand soils, and offer ecological soil guideline values for common soil contaminants (arsenic, boron, cadmium, chromium, copper, fluorine, lead, zinc, DDT, total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs)). Eco-SGVs are risk-based values derived using a species sensitivity distribution approach.

Like the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Eco-SGVs carry no legal or regulatory weight by themselves but can be used by regional councils to carry out initial assessments for the impact of land activities on soil biota and the setting of consent limits to support the management of contaminated land and monitoring of chemicals across regions on a consistent basis. In all cases where local data are lacking, it is recommended that the interpretation of results for site-specific scenarios is undertaken by a suitably qualified and experienced practitioner. For the regulatory implementation of Eco-SGVs, further direction is yet to be established to ensure alignment between national and regional policy objectives and plan rules.[29]

In the context of **contaminated land management**, the Ministry for the Environment has published a preferred hierarchy of New Zealand and overseas guideline values. Within this hierarchy, national risk-based guideline values have precedence over international ones. The contaminated land management guideline is accompanied by the Environmental Guideline Value (EGV) database, which provides reference documents for the derivation and application of any guideline value to be used during the assessment of a contaminated site. Caution is advised for the selection and application of guideline values, as documents could be superseded when revisions are made.[30]

Details on the use of risk-based guideline values for regulatory purposes in New Zealand are presented in chapter three.

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[27] Conwell, 2021, p.42.

[28] Cavanagh, 2019. Guidelines are yet to be implemented nationally.

[29] Kim, 2018.

[30] MfE, 2011.

Environmental monitoring

It is not enough to screen chemicals for the risks they may pose and impose controls on their use. To complete the circle, actual levels of environmental contamination and its subsequent effects on the environment need to be monitored. In this way, actual environmental effects can inform regulation and risk assessment – though this step can be done before or after a chemical has been approved for use.

Environmental monitoring of chemicals involves gathering a series of measurements for a specific chemical(s) within a defined area and period of time. The effectiveness of any chemical monitoring programme is dependent on the suitability of the methodology used for the purpose of the monitoring.[31] There exist many different monitoring programmes, which may be designed to obtain different types of information, including:

- identifying sources of a chemical discharged into the environment
- determining movement and transformation of chemicals along environmental exposure routes
- measuring contaminant concentrations in the environment and how they change over time
- identifying possible effects on organisms exposed to chemicals (e.g. biomonitoring)
- determining how well regulatory controls work, if they are fit for purpose, and revising as required.

Monitoring chemical contaminants in New Zealand

Some chemical contaminants known to be harmful are routinely monitored as part of state of the environment (SoE) reporting or through consent-based monitoring. Chemical contaminants we know less about are less well-monitored.

SoE monitoring of chemicals in New Zealand is intended to assess trends in receiving environments and inform regulators whether their controls are working or if natural changes are occurring (e.g. geothermal contamination). This monitoring programme focuses on a set group of chemicals (trace metals, hydrocarbons, nutrients and legacy pesticides) known to cause harm in different receiving environments such as coastal sediments, freshwater, groundwater, air and soils (Table 2.2). While monitoring of soils is focused on a wider range of stressors (such as microporosity, total nitrogen, Olsen phosphorus and total carbon), information on the presence and trends of trace elements in soils at a national scale was included in the SoE report *Our land 2021*.[32,33]

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[31] Refer to Appendix 7.2 (monitoring framework box), which illustrates a simplified decision tree used to assess soil or sediment contaminants.

[32] Stevenson and McNeill, 2020.

[33] MfE and Stats NZ, 2021.

Table 2.2: Chemical substances analysed under SoE monitoring and other routine monitoring programmes (excluding nutrients) under different receiving environments. Iron, manganese and boron are monitored in groundwater only, and they are indicators of groundwater quality, aquifer characterisation and surface water connectivity.[34]

Monitoring agency	Coastal sediments	Freshwater sediments	Groundwater	Soil
State of the environment (SoE) monitoring conducted by regional councils	• Trace metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel and zinc) • PAHs • Semi volatile/ volatile organic compounds (SVOCs/VOCs) • DDT	• Trace metals (arsenic, boron, cadmium, copper, lead, nickel and zinc)	• Trace metals (aluminium, arsenic, cadmium, cobalt, copper, chromium, mercury, nickel, lead and zinc) • Iron, manganese and boron	• Trace metals (arsenic, boron, cadmium, chromium, copper, lead and zinc) and fluorine
Institute of Environmental Science Research (ESR)	• None	• None	• Pesticides	• None
Institute of Geological and Nuclear Sciences (GNS)	• None	• None	• Organic contaminants not routinely monitored	• None

On the other hand, consent-based monitoring is intended to assess concentrations of particular chemicals used or disposed of in a receiving environment as a means to make sure individuals, companies or government are not breaching limits set down in resource consents. If the concentration of a target chemical is found to be over the limit, investigations and mitigation plans can be launched. Consent-based monitoring typically draws upon a similar suite of metals or other chemicals as those listed under SoE reporting, with copper, zinc and lead being the most frequently listed common metals.[35] Tables 6 and 7 in the Jacobs New Zealand Ltd consultancy report show details of the metals, metalloids and organic compounds tested per type of consent (wastewater, stormwater and landfill leachate).[36]

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[34] For detailed information refer to Tables 11–13 in Conwell (2021). Since 2013, GNS has conducted baseline soil surveys for 65 elements in Southland, Otago, Buller, Nelson and Marlborough. Rattenbury et al., 2018.

[35] There are cases where consent monitoring is very specific to an activity or process and covers parameters that would normally be tested for – e.g. hydrogen sulphide or mercury downstream of the Wairakei Geothermal Power Station, or chromium and/or chromium species associated with tannery effluent.

[36] Conwell, 2021.

There are few monitoring programmes for contaminants we know less about. The Institute of Environmental Science Research (ESR) runs a national groundwater survey of pesticides and emerging organic contaminants (i.e. carbon-based compounds, synthetically or naturally occurring) in groundwater. As part of this national monitoring programme, surveys have been conducted every four years since 1990 to assess the presence of targeted compounds and report whether they exceed ecological and human toxicity exposure limits. The 2019 survey reported detections of 227 organic contaminants in 85 out of 121 wells.[37] This survey is restricted only to groundwater and there are currently no equivalent national monitoring programmes for other receiving environments like surface waters and coastal receiving environments.

Additionally, the Institute of Geological and Nuclear Sciences (GNS Science) published a baseline assessment of emerging contaminants in New Zealand groundwater in 2019. This expanded the monitoring effort to 723 compounds, including 48 pesticides, 11 pharmaceuticals, ten industrial compounds, three preservatives/food additives and one personal care product.[38]

Other non-routine monitoring programmes have been developed to address different types of emerging organic contaminants. Examples include the Ministry of Business, Innovation and Employment's funded emerging organic contaminants programme;[39] Aotearoa Impacts and Mitigation of Microplastics (AIM^2), which is investigating the impact of microplastics in New Zealand;[40] and a one-off study to assess the presence of pesticides in surface waters.[41] Unfortunately, risk-based guideline values are yet to be derived for many non-routine chemicals, especially for chemicals in sediments.

In addition to this national strategy, some regional councils have already conducted one-off studies to monitor emerging organic contaminants.[42]

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[37] Close and Humphries, 2019.

[38] Moreau et al., 2019.

[39] See https://www.esr.cri.nz/home/about-esr/our-science-in-action/managing-the-risk-of-emerging-organic-contaminants/ [accessed 2 November 2021].

[40] See https://www.esr.cri.nz/our-research/research-projects/aotearoa-impacts-and-mitigation-of-microplastics-aim/ [accessed 20 June 2021].

[41] Hageman et al., 2019.

[42] Resource consents from three regions (Bay of Plenty, Hawke's Bay and Waikato) have analysed emerging organic contaminants in wastewater treatment plant effluents. Auckland Council has further included the assessment of emerging organic contaminants in its Global Stormwater Consent. Most of the data available on emerging organic contaminants have been considered in documents supporting a resource consenting application (or re-consenting application) but are not in the consent conditions themselves (Conwell, 2021).

Current scientific concerns and limitations

Environmental toxicology is in a state of constant evolution, in part to stay abreast of new products the chemical industry brings to market and to respond to novel sources of environmental contamination that accompany new practices and technologies. This section explores some key areas of development in the field, including:

- emerging contaminants
- breakdown products or metabolites
- chemical mixtures
- persistence and mobility
- secondary exposure routes
- modes of action
- suitability of standard test organisms
- interactions with multiple stressors
- managing uncertainty in modelling
- more environmentally realistic effects assessments
- epigenetic effects.

Emerging contaminants

Most monitoring is conducted for a selected group of chemicals that are known to cause harm. But there are hundreds of chemicals we know little about. Emerging contaminants are defined as chemicals that are not currently included in routine monitoring programmes but have the potential to enter (or are already present in) the environment and cause adverse effects.[43] They include pharmaceuticals, personal care products, petrochemicals, hormones, steroids, antibiotics, perfluorinated compounds, flame retardants, disinfection by-products and new generation pesticides, to which must be added the degradation products of all of these chemicals. A challenge with this definition is that what is considered an ‘emerging contaminant’ will vary regionally according to what chemicals are routinely monitored in different regions. Prioritisation of which emerging contaminants require attention is important, given the vast number of chemicals that lack routine monitoring.

Research on emerging contaminants is necessarily ongoing and is expanding as new analytical chemistry techniques improve our ability to detect chemicals in the environment. Unsurprisingly, data are still lacking on the occurrence, environmental fate and ecotoxicity of many of these chemicals. This is partly due to the sheer number of chemicals that come under the term ‘emerging contaminants’. In some cases, such as when chemicals have not previously been subject to an environmental risk assessment prior to their use, conceptual models that describe their environmental fate and behaviour are still to be developed.[44] Yet, to be considered for regulation, data on their ecotoxicity and occurrence in receiving environments are required.[45]

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[43] Close et al., 2021.

[44] Gaston et al., 2019.

[45] Gavrilescu et al., 2015.

There are also many chemicals that have been authorised for use but might have uncharacterised impacts. They might not necessarily be thought of as 'emerging contaminants' but might still lack routine monitoring in some regions or receiving environments. Examples include pesticides and trace elements that accompany fertilisers. These are authorised for use, but their long-term or cumulative environmental impacts might not yet be well-understood or monitored. Therefore, it is important to consider such contaminants in prioritisation frameworks for future research and assessment alongside emerging contaminants that we know even less about, as these authorised contaminants could still pose a significant and potentially unknown risk to the environment.

A programme to tackle emerging organic contaminants is starting to gain some attention in New Zealand. In June 2021, the Emerging Contaminants Advisory Panel released the *Aotearoa-New Zealand Strategy for Emerging Contaminants*. This strategy, which recognises the criticality of Māori partnerships, has three key goals:

- improve knowledge and understanding of emerging contaminants in an effective and timely manner
- identify research and development possibilities to improve knowledge of emerging contaminants
- provide direction, leadership and support to enable Aotearoa New Zealand to understand the effects of emerging contaminants on our people and the environment.[46]

Breakdown products or metabolites

Most chemicals degrade in the environment, and their transformation products add a layer of complexity to the investigation of chemical contamination. The metabolites of toxic chemicals are usually not as toxic as the parent compound, having lost the chemical structure that gave the original substance its specific mode of action. However, some metabolites are as toxic as their parent compound or even more so, and they can also be more persistent in the environment.[47] For example, four years after endosulfan was banned in New Zealand, its equally toxic metabolite endosulfan sulphate was found in 42 per cent of stream sediment samples obtained from surveyed farms in the South Island. Twenty-three per cent of those samples exceeded environmental thresholds.[48]

Chemical mixtures

Chemicals do not occur in isolation. They can be part of a formulation or can become mixed with other chemicals, as occurs in wastewater treatment plant influents. Predicting or assessing the environmental impact of an individual chemical is a challenge. Adding chemical mixtures to the equation increases the complexity many times over.[49] Chronic, low-level exposure to multiple chemicals in mixtures can cause toxicity at concentrations where exposure to an individual chemical might cause no effect. Mixture toxicity is of particular concern when multiple modes of action are present, as this can result in synergistic effects where the effect of a chemical mixture is greater than the sum of each individual chemical's effect.[50] Knowing what potential mixtures to pursue and developing predictive frameworks to estimate their combined effects without testing every possible combination, is a significant challenge.

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[46] See https://www.cawthron.org.nz/wp-content/uploads/2021/07/Aotearoa-NZ-Strategy-for-Emerging-Organic-Contaminants.pdf.

[47] Wan et al., 2005.

[48] Shahpoury et al., 2013.

[49] Lydy et al., 2004.

[50] Kortenkamp and Faust, 2018.

Since the 1980s, effects-directed analyses have been developed to identify the toxic effects of complex chemical mixtures in the environment. This approach reduces the complexity of mixtures to small fractions and evaluates the toxicity of these fractions to organisms using *in vivo* or *in vitro* tests. Analytical chemistry techniques are then used to determine which fractions are contributing most to the observed toxicity.[51]

Persistence and mobility

A current area of concern centres on the persistence and mobility of toxic chemicals. Traditionally, persistent, bioaccumulative and toxic chemicals have been prioritised by regulators, but scientists and regulators now also recognise the importance of chemical mobility, which can result in widespread chemical contamination of the environment.[52] The Stockholm Convention on Persistent Organic Pollutants has incorporated mobility into its criteria of chemicals that might present significant risk. For example, discovering PFAS in the environment has led to recent legislative updates in the European Union that prioritise chemicals of concern to include persistent, mobile and toxic chemicals, and very persistent, very mobile chemicals.[53] For some of the more well-known contaminants, including cadmium and fluorine, persistence in soil is also the specific feature that drives their gradual accumulation to potentially toxic levels.

Secondary exposure routes

In addition to mobility, some chemicals can be transported through the food web and cause exposure via secondary pathways. For example, some pesticides can accumulate in biofilms and be eaten by primary consumers, thereby becoming an additional route of exposure to aquatic organisms.[54] If monitoring programmes do not consider such exposure routes, the potential exposure of organisms to contaminants might be underestimated.

Modes of action

Understanding the mode of action of a chemical is an important aspect of environmental risk assessment and is foundational for the development of alternative risk assessment methods (e.g. adverse outcome pathways) to replace traditional *in vivo* toxicity testing. However, different international jurisdictions have developed different approaches to mode of action classification. A lack of standardisation may lead to conflicting results when using mode of action for risk assessments, especially in computational models, which limits the degree to which this tool can be used.[55]

Suitability of standard test organisms

Toxicity evaluations conducted as part of an environmental risk assessment begin with acute tests (exposing a range of organisms to a chemical over 24–74 hours). There are concerns about whether the species used in standard tests in this first step of risk assessment are representative of those species that are endemic to or naturalised in New Zealand. In some cases, species from the same taxonomic group in different continents have exhibited much higher sensitivity to toxicants than standard test species within the same group.

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[51] Burgess et al., 2013.

[52] Hale et al., 2020.

[53] Cortes et al., 2020.

[54] Beecraft and Rooney, 2020.

[55] Kienzler et al., 2017.

Additionally, standard test species are not always representative of the sensitivity of other organisms of the same trophic level to chemicals, as was the case with the water flea *Daphnia magna* being far more tolerant than other aquatic invertebrates to neonicotinoid insecticides.[56] For this reason, risk assessments aim to assess toxicity to a wider range of test organisms, although this is also balanced against trying to reduce the use of animal testing (particularly of vertebrates).[57] Therefore, increasing the range of test species typically occurs at lower trophic levels (invertebrates).

Interactions with multiple stressors

As well as interactions with chemical mixtures, other environmental or anthropogenic stressors can also interact with chemicals to alter their exposure and toxicity to organisms.[58] Indeed, climate change is predicted to increase the exposure of aquatic organisms to contaminants through increased heavy rainfall events, which result in pulses of high chemical concentrations in surface runoff.[59] Raised temperatures can also increase the toxicity of chemicals by increasing their uptake into organisms.[60] Impacts of land-use and climate-related factors can affect the mobility, behaviour, bioavailability and fate of chemicals in a range of receiving environments. In soils, for example, adding fertilisers that contain trace elements can alter the soil chemistry, changing how well the chemical can bind to soils and how available it is to organisms. Soil warming can alter microbial activity in the soil, which will subsequently influence degradation rates and leaching potential into groundwaters.

Similarly for chemical mixtures, identifying the most potent combinations of natural and chemical stressors is a challenge for multiple stressor research. Prioritising chemicals of concern and additional stressors to consider in risk assessment procedures is a complex but important field of investigation for researchers and regulators alike.

Managing uncertainty in modelling

A key challenge in using models for risk assessment is accounting for uncertainties. Uncertainty arises from several factors, including randomness in the environment that cannot be predicted statistically (e.g. stochasticity), errors in the execution of an assessment (e.g. measurement and data recording errors), limitations in the number of parameters the model can accurately consider (e.g. site-specific characteristics), and incomplete or imperfect data (e.g. inability to test all toxicological responses of all species exposed to a chemical).[61] Statistical methods are used to account for uncertainty, and uncertainty factors are usually applied.

More environmentally realistic effects assessments

Short-duration, tightly controlled laboratory tests are important to rapidly provide valuable toxicity data at relatively low cost. However, these tests may have little relevance for ecosystems where multiple factors are present and species interact in complex ecological networks. This is where supplementing laboratory tests with field or mesocosm studies is required to assess more environmentally realistic effects (see Appendix 7.2, toxicity assessment framework).[62]

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[56] Daam et al., 2013.

[57] Gaw et al., 2019.

[58] Other stressors that are known to interact with chemicals antagonistically (causing less-than-additive combined effects) or synergistically (greater-than-additive) include acidity (pH), hypoxia (oxygen depletion), desiccation, starvation and pathogens (Laskowski et al., 2010).

[59] Noyes et al., 2009; Noyes and Lema, 2015.

[60] Holmstrup et al., 2010; Macaulay et al., 2020.

[61] Jørgensen et al., 2005.

[62] Sánchez-Bayo and Tennekes, 2015.

Mesocosms simulate a model ecosystem on a small, controlled scale. In the environmental risk assessment of chemicals, they have several advantages, allowing controlled manipulation of toxic substances without risk of environmental contamination. They can also be an efficient approach to toxicity testing as they provide toxicity data on multiple species simultaneously under environmentally realistic conditions. Developing standardised procedures for mesocosm tests is important for regulators to use in toxicity assessments when laboratory tests have identified a chemical to be of high environmental risk (see Appendix 7.2, risk assessment framework).[63]

However, higher-tier studies are rarely performed in risk assessments due to their high cost and lower degree of control compared to laboratory experiments. An additional drawback of mesocosm studies and field trials is that sublethal responses of organisms are difficult, if not impossible, to assess. Therefore, chronic laboratory tests using sublethal doses are still important for complementing mesocosm experiments so that effects are assessed across multiple levels of biological organisation, from individuals and populations to community-level effects and impacts on ecosystem processes.

Epigenetic effects

Further to the sublethal effects that occur during an organism's lifespan is the effect chemical exposure might have on an individual's offspring. Heritable or generational effects resulting from changes to an organism's heritable genome are the focus of the field of epigenetics. Epigenetic toxicity can result in long-term effects on populations despite no effects being observable on an individual exposed to a chemical. These effects can occur through the alteration of DNA (mutation of an organism's genomic material), or changing the way cells read DNA sequences, triggering genes to turn on or off, which can affect protein production and cell development.[64]

Much of the interest in epigenetic effects of chemical exposure has focused on human health and predisposition to cancer, but studies involving other vertebrates (e.g. zebrafish) have steadily grown in recent years.[65] Today, there are also several standard test species of invertebrates that have well-characterised epigenetic biomarkers that enable the detection of chemical effects at the molecular level.[66] Such tools are not currently used in environmental risk assessments. However, they may become more prevalent as epigenetic biomarkers are established for a wider range of model organisms from different ecosystems, habitats and trophic levels. Although there are still several challenges to overcome in this field,[67] epigenetic markers present a highly promising tool for the development of sensitive and predictive biomarkers of environmental exposure in the field of ecotoxicology.[68]

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[63] Stewart et al., 2013.

[64] Burggren, 2015.

[65] Jeremias et al., 2020.

[66] Model invertebrates include the common water flea (*Daphnia magna*), roundworm (*Caenorhabditis elegans*) and the fruit fly (*Drosophila melanogaster*).

[67] Challenges include identifying epigenetic changes at environmentally relevant chemical concentrations; replicating tests in different developmental stages; applying next generation sequencing technology to define DNA methylation (gene expression) changes in the whole genome; and linking epigenetic modifications to gene expression patterns and phenotypes.

[68] Šrut, 2021.

Summary

Ecotoxicology is a relatively young scientific discipline that emerged to address the adverse effects of the indiscriminate use of chemicals and their resulting pollution of the environment.

Environmental risk assessments use the findings from ecotoxicology and environmental chemistry to support the approval and use of chemicals. Once approved, monitoring of chemicals in the environment is critical to understand the extent of pollution caused by chemical use.

Once chemical contamination is identified in the environment, new regulations and controls might need to be considered to reduce contamination and prevent adverse environmental effects. With continued investigation of current concerns and limitations in environmental toxicology, new developments and technologies can be used by regulators to further improve environmental risk assessments.

3

Ophioglossum coriaceum

The regulation of chemical use in New Zealand's environment

Introduction

In New Zealand, regulatory oversight of chemicals is undertaken at national, regional and local levels, and covers the full lifecycle of a chemical, from its import or manufacture through to its use or disposal. It is possible that environmental exposure can occur at any stage of this lifecycle. However, during transfer or while stored, chemicals are required to be contained within appropriate packaging. This chapter focuses instead on those parts of the regulatory system that deal with use and disposal.

After briefly covering the evolution of the current regime, this chapter introduces the regulators responsible for making decisions and monitoring compliance. It goes on to provide an overview of the risks they respectively manage. The chapter also explains the provisions designed to provide for engagement with Māori and the general public in decision-making processes, as well as the information and data requirements that are integral to decision making.

Evolution of the current regulatory regime for chemicals

How the legislative framework evolved

Pollution control legislation in New Zealand has been in existence since the 1950s, and included permit requirements for various environmental media, with a focus on point source discharges such as wastewater effluent into waterways.[1] These requirements were later consolidated and made more consistent under the Resource Management Act 1991 (RMA).

Prior to the current regime, chemical registration and licensing was required under several disparate laws. These included the Dangerous Goods Act 1974, the Toxic Substances Act 1979, and the Pesticides Act 1979. The Pesticides Act, for instance, included provisions to revoke or refuse registration in certain cases, including on health or environmental grounds.[2] However, a full risk assessment was not required.

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[1] This legislation included the Water and Soil Conservation Act 1967, Clean Air Act 1972, and Marine Pollution Act 1974 (MfE, 1988).

[2] Pesticides Act 1979, s 27(a)(i).

Local and global incidents in the 1980s raised red flags over the adequacy of the regime, and by the early 1990s, problems with the regulatory system managing chemicals became evident. One notable incident was a fire in 1984 at the Imperial Chemical Industries warehouse in Auckland, where a variety of agrichemicals were stored. The fire resulted in toxic smoke that made firefighters ill, and chemicals contaminating the water used to control the blaze, which killed fish and other aquatic organisms in Tāmaki Estuary.[3,4]

In 1988, the Interagency Coordinating Committee on Pollution and Hazardous Substances published a report highlighting the shortcomings of the existing chemical management system. This was described at the time as the "most comprehensive examination of pollution and hazardous substances management ever undertaken in New Zealand".[5] The report identified a lack of coordination and consistency when assessing potential impacts on human health and the environment leading to inconsistent and, at times, contradictory controls on the use of chemicals. The system was challenging for users – who sometimes required multiple authorisations – and for members of the public, who lacked avenues for public participation. Furthermore, most assessment processes did not incorporate environmental criteria.[6]

The interagency report fed into the Resource Management Law Reform process underway at the time, as did the results of a formal investigation into the Imperial Chemical Industries fire.[7]

While a new regime to manage hazardous substances and new organisms began as part of the resource management reform process and was included in the RMA in 1991, the provisions were split to form the basis of a separate Hazardous Substances and New Organisms Bill (HSNO Bill), introduced to Parliament in 1995. It received the scrutiny of a specially appointed parliamentary select committee.[8] Principles underpinning the HSNO regime included:

- the requirement for assessments of hazardous substances (and new organisms) to weigh up risks, costs and benefits
- the opportunity for public input into decision making
- controls (restrictions or obligations imposed on hazardous substances intended to prevent or manage adverse effects) tailored to each stage of a chemical's lifecycle and based on its hazardous properties. These were intended to be performance-based rather than prescriptive.[9]

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[3] Glass, 1985; New Zealand Fire Service, 1985; Elias et al., 1990.

[4] Tortell et al., 1985; Maxwell, 1987a, b.

[5] MfE, 1988, p.3.

[6] MfE, 1992, pp.9–10.

[7] Elias et al., 1990.

[8] Upton, 1999.

[9] MfE, 1992, pp.13–14; MfE, 1993.

None of the earlier legislation had considered the relationship with Māori or Te Tiriti o Waitangi, although Māori were lodging Waitangi Tribunal claims with direct reference to the impact that chemicals were having on their culturally significant sites.[10] The reforms of the 1980s began to make reference to Treaty principles, and this was reflected in the Hazardous Substances and New Organisms Act 1996.[11] Following the release of the findings of the Royal Commission on Genetic Modification in 2001, the HSNO Act was amended in 2003 to give formal recognition to the Māori advisory group Ngā Kaihautū Tikanga Taiao.[12] This is a group of independent Māori individuals with relevant skills and experience which still advises the Environmental Protection Authority (EPA) today to ensure that Māori perspectives are taken into account. The Royal Commission in 2000 also recommended that the Treaty clause be strengthened. This recommendation has not to date been adopted.[13]

The reform coincided with a reform of agricultural legislation initiated in the early 1990s. During this time, the Agricultural Compounds Bill was introduced and considered by the same select committee. Through this parliamentary process, HSNO legislation was targeted at domestic health and environmental risks, while separate agricultural compounds legislation was tailored towards risks to trade and primary produce, animal welfare and agricultural security.[14]

There is considerable overlap in the types of products covered by each law, and it was initially envisaged that all hazardous substances related legislation would be brought under one Act.[15] However, the final legislative outcome resulted in separate authorisations being required for hazardous substances and trade name agricultural compounds. Through this process, most human medicines became excluded from HSNO legislation.

Commercial considerations were also relevant to this tandem process. Particularly significant at the time was the signing of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) in 1995. This agreement provided commercial protections for human and veterinary medicines and specifically addressed new chemical entities in such products.[16] In domestic law, the effect of the TRIPS-derived legislation was to provide data protection for innovative products through the Agricultural Compounds and Veterinary Medicines Act 1997 (ACVM Act) and the Medicines Act 1981.[17]

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[10] See Waitangi Tribunal claims WAI 3, WAI 4, and WAI 6 for examples (https://waitangitribunal.govt.nz/publications-and-resources/waitangi-tribunal-reports/).

[11] The Treaty of Waitangi Act 1975 was the first statute to refer to the Treaty principles. Decisions in the court and by the Tribunal further clarified these principles.

[12] "To improve knowledge of Treaty of Waitangi and tikanga Māori elements and decision making by the Environmental Risk Management Authority, provision is made to formalise the role of the authority's Māori advisory committee, Nga Kaihautu Tikanga Taiao" (Hon. Marion Hobbs, 6 May 2003, Parliamentary Debates (Hansard), v.608, p.5333).

[13] Eichelbaum et al., 2001.

[14] Lockwood Smith, 5 November 1997, Parliamentary Debates (Hansard), v.564.

[15] MfE, 1992; Jill Smith, 5 November 1997, Parliamentary Debates (Hansard), v.564.

[16] WTO, 1995, article 39.3, p.336.

[17] For veterinary medicines, intellectual property protections were provided initially under the Animal Remedies Act 1967 (until repealed and replaced by protections under the ACVM Act). These protections were extended for an additional number of years (from 5 to 10 years for an innovative trade name compound) when the ACVM Amendment Bill was passed by Parliament and came into force on 8 November 2016. For human medicines, data protection is provided under section 23B of the Medicines Act 1981 (inserted, on 1 January 1995, by section 2 of the Medicines Amendment Act 1994).

Inception of the Hazardous Substances and New Organisms regime and the transfer process

The HSNO Act as a legislative instrument is administered by the Ministry for the Environment, which is responsible for its maintenance and update. The Act was initially implemented by the Environmental Risk Management Authority (ERMA), the predecessor of today's EPA. Under the HSNO Act, it became an offence to import or manufacture a hazardous chemical without an approval.[18]

Roughly 150,000 substances were notified to authorities prior to the HSNO regime. Hazardous substances provisions came into force on 1 July 2001, and ERMA commenced a process to make decisions to assign hazard classifications and appropriate controls.[19] It was required to complete the transfer within five years and a need to simplify the process quickly became evident.[20] Following 'teething issues', legislative amendments were made in the two years leading up to the deadline to permit the transfer of substances *en masse*.

An initial amendment enabled ERMA to transfer suites of higher-risk, discrete groups – for example, fumigants – into the regime via Gazette Notice rather than through regulation. Through this mechanism, each substance was assigned a classification and default controls (derived from regulations). These substances were then deemed to have been approved by ERMA and were exempt from the requirement to balance adverse and positive effects as required under section 29 of the HSNO Act.[21] Over 9,000 substances were approved via transfer notice, but that left many more still to process.[22]

A new approval mechanism – group standards – was proposed and incorporated into the HSNO Act in 2005. Group standards were intended to both expedite the transfer process and gain efficiencies in the subsequent approval process. Group standards can be issued (or amended) should the Authority be satisfied that they are a more efficient and effective way of managing the risks of a specific group of products. The Authority must also consider the best international practices and standards for the safe management of hazardous substances and products, as well as the appropriate controls for the group.[23] Chemical products are able to be approved under group standards if they fit the scope of a group standard, as defined by its classification and use pattern. While risk management of the group is considered at the stage of issuing a group standard, the balancing of adverse and positive effects of individual substances is not typically required.

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[18] "No hazardous substance shall be imported, or manufactured … otherwise than in accordance with an approval issued under this Act", HSNO Act 1996 s 25.

[19] Sefton, 1998, p.268.

[20] MfE, 2004a.

[21] Hazardous Substances and New Organisms (Transitional Provisions and Controls) Amendment Act 2004.

[22] As at April 2004, around two years before the expiry of transitional provisions on 1 July 2006, about 80,000 substances were still to be transferred to HSNO controls (MfE, 2004a).

[23] HSNO Act, s 96C.

These transfer mechanisms have left some enduring consequences in their wake.

Firstly, the bulk of substances present in New Zealand are managed under group standards. These are a more 'hands-off' form of regulation because they delegate responsibility to assign approval status to an importer or manufacturer. While records of this assignment must be kept, the EPA as the national regulator does not typically receive this information unless a compliance issue arises, so it provides little oversight.

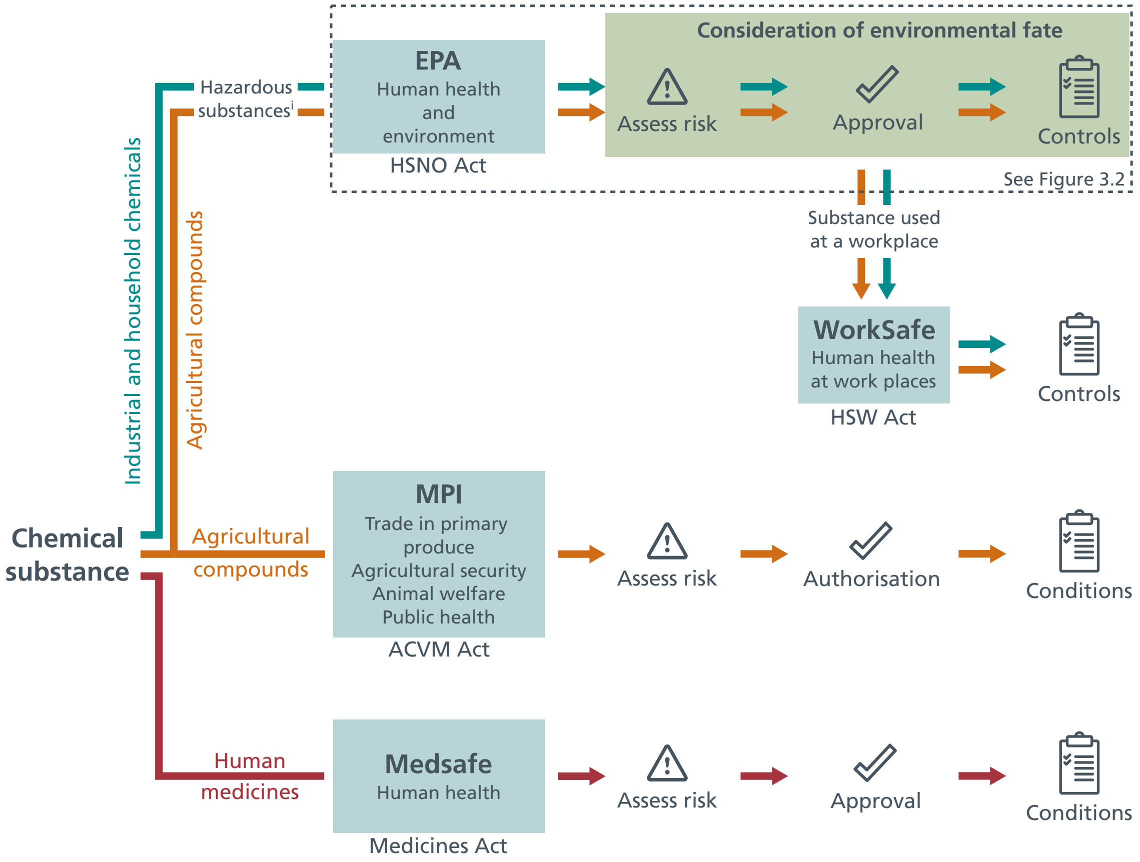
Secondly, at the time of transfer there was no formal risk assessment weighing up the risks, costs and benefits and effectiveness of individual substances because of the sheer size of the task. While group standards and transfer notices provided new controls, the evidence of risk, cost and benefit of individual substances cannot be evaluated until and unless they are reassessed. The EPA has been undertaking a programme of reassessments to address this situation. However, this programme is not without its challenges in terms of the resources required to manage it.

Health and safety reforms

The health and safety reforms that took place following the Pike River tragedy in 2010 resulted in further changes to the division of labour among regulators. Many of the hazardous substances regulations relevant to health and safety were brought under the Health and Safety at Work Act 2015 (HSWA), and the rules for hazardous substances (including their manufacture, use, handling and storage) relating to health and safety at work are now administered by WorkSafe New Zealand. Further changes are anticipated as the result of a forthcoming review of those regulations by the Ministry of Business, Innovation and Employment.

National-level regulators, approvals, assessments and controls

Four main national-level regulators play a role in chemical management in New Zealand. Each manages different risks derived from its respective statutory mandate. Figure 3.1 provides an overview. The EPA is the key gatekeeper responsible for the management of any environmental risks associated with chemicals that are hazardous substances. But the Ministry for Primary Industries (MPI), Medsafe and WorkSafe New Zealand also contribute to the national-level regulatory landscape.

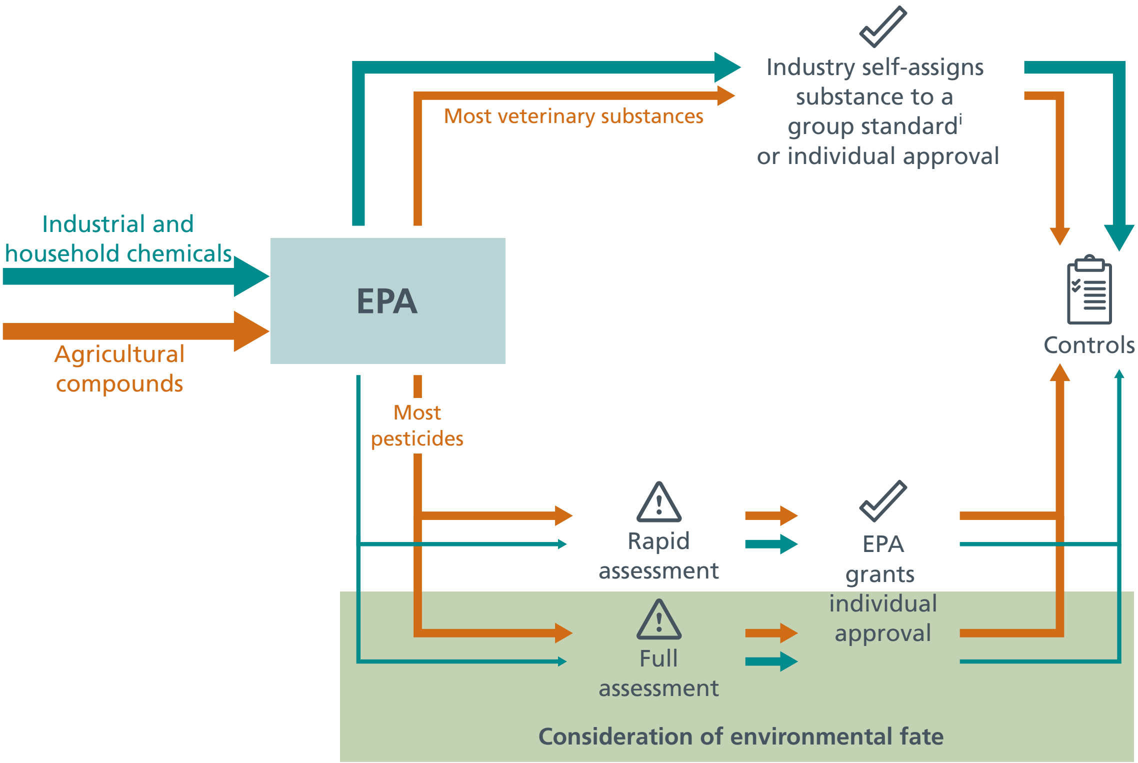


Source: PCE

Note:

[i] Excludes medicines in finished dose form, psychoactive substances, foods, manufactured articles aside from explosives

Figure 3.1: An overview of which national level regulator authorises, assesses risk and controls on the use of different groups of chemicals, showing where environmental fate is considered. The EPA is the main national level regulator responsible for managing environmental effects of chemicals. Some products (for example, medicines) are not assessed by the EPA so their environmental fate does not receive scrutiny. Others will require more than one authorisation (for example – an agricultural compound will often require MPI and EPA approval), with environmental fate being examined within the EPA process depending on the approval pathway (see figure 3.2).



Source: PCE

Note:

[i] 208 Group standards exist, each of which has had a risk, cost and benefit evaluation undertaken at their set-up phase.

Figure 3.2: Only some chemicals undergo a full risk assessment by the EPA where environmental fate may be considered in detail (shown in green box). In reality, most are approved via group standards, an approval pathway that relies on industry self-assigning a chemical to a relevant approval.

Role of the Environmental Protection Authority under the Hazardous Substances and New Organisms Act 1996

The EPA is the government agency responsible for regulating activities that affect New Zealand's environment. It is mandated under the Environmental Protection Authority Act 2011 (EPA Act) and is required to recognise and respect the Crown's responsibility to take appropriate account of Te Tiriti o Waitangi. The key legislative instrument governing the EPA's chemical management role is the HSNO Act. The purpose of the HSNO Act is to protect the environment and the health and safety of people and communities by preventing or managing the adverse effects of hazardous substances and new organisms. In performing their duties, those exercising functions under the legislation must take into account the principles of Te Tiriti o Waitangi, and a range of environmental, cultural, social and economic matters.[24]

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[24] HSNO Act 1996, ss 5–8.

A chemical falls under the scope of the Act if it meets the relevant definitions – including both the definition of a *substance* (which includes individual chemicals and mixtures), and the definition of a *hazardous substance*, given its intrinsic properties.[25] The HSNO Committee appointed by the EPA Board, or other parties with delegated authority, makes decisions on approvals for import or manufacture. It also makes decisions on reassessments, which are discussed further below. The decision maker can approve or decline the application by weighing up the risks, costs and benefits of its approval, taking into account any controls that may be imposed to restrict exposure, the effects of the substance throughout its lifecycle and the likely effects of the substance being unavailable.[26]

Approval to import or manufacture

To obtain approval, an importer or manufacturer may assign a substance to an existing approval where it matches an individual approval or a group standard (records must be kept of the self-assignment), or, if this does not apply, submit an application for a new approval.

An estimated 30,000 chemicals contained in over 150,000 substances are approved for use in New Zealand. Of the substances approved for use, approximately 3,500 have individual approvals, which comprise both single component chemicals and mixtures (each potentially covering multiple trade name products). The remainder, including most domestic and workplace chemicals, are covered by 208 group standards.[27] Numerous trade name products with varying hazard classifications can be covered by each group standard.[28] New group standards may be created by application or by the EPA on its own initiative.

Where a new individual approval is required, an applicant must submit specified information, including a risk assessment.[29] The EPA categorises applications according to the complexity and data required. Categories range from the reformulation of known active ingredients (chemicals that have already been approved for use in different mixtures or settings), to the assessment of substances containing a new active ingredient (a chemical that has not yet been approved for use in New Zealand). The latter typically requires a comprehensive information package, involving a full quantitative risk assessment, where the former is generally subject to a more cursory, qualitative assessment.[30]

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[25] HSNO Act 1996, s 2. Hazardous properties include explosiveness, flammability, a capacity to oxidise, corrosiveness, toxicity (including chronic toxicity), ecotoxicity (with or without bioaccumulation).

[26] HSNO Act 1996, s 29.

[27] Matthew Allen, EPA, pers. comm., 20 February 2020 and 19 November 2021.

[28] HSNO Group Standards. See https://www.epa.govt.nz/industry-areas/hazardous-substances/group-standards/types-of-group-standards/ [accessed 10 December 2021].

[29] EPA guidance requires that "each application must include an assessment of the hazards, risks, costs and benefits of using the substance in the New Zealand context. This assessment should include enough information so that we at the EPA can evaluate it, including a classification of the level of its hazard and a demonstrated understanding of its life cycle (where it would be released, where it would end up, how it would be disposed of)" (EPA, 2020g, p.3).

[30] However, in some cases information requirements for a new active ingredient may be reduced by the use of "read-across data" (EPA, 2015a).

Data requirements for a new active ingredient include a suite of original study data covering the identity of the substance, physical and chemical properties, environmental fate, toxicology and ecotoxicology. As New Zealand is an adherent to the OECD's Mutual Acceptance of Data agreement, studies must be based on internationally accepted test species and methods.[31] According to EPA data requirements, some studies are *required* and some are *conditionally required*.[32] Typically, if initial review indicates uncertainties or concern, further studies may be requested from the applicant.[33]

Risk is a function of hazard and exposure. The hazard classification system is set out in the Hazardous Substances (Hazard Classification) Notice 2020.[34] The EPA's *Risk Assessment Methodology for Hazardous Substances* details the level of human and environmental risk assessment required. It identifies where exposure may be assessed qualitatively or, for more complex assessments, using models.[35]

Controls

Controls are "obligations or restrictions imposed on any hazardous substance … for the purposes of controlling the adverse effects of that substance … on people or the environment".[36] The framework of controls for hazardous substances sits under both the HSNO Act and the HSWA.[37] Although the EPA classifies and assesses the risks of substances for both human health and the environment, WorkSafe New Zealand implements controls for human health and safety.[38] An application will be approved by the EPA only if decision makers are "satisfied that the benefits outweigh any residual risks and costs after the controls are applied, and that these residual risks are acceptable given the proposed uses".[39]

HSNO Act and HSWA controls address the risks of accidental exposure – for instance, aiming to prevent chemical leaks caused by faulty packaging, inadequate storage or equipment.[40] They also address some intentional releases – for example, requiring a specific rate and method of application of a toxicant to a forested area.

More details on the HSNO control toolbox for ecotoxic substances are available in Box 3.1.

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[31] See https://www.oecd.org/env/ehs/mutualacceptanceofdatamad.htm [accessed 10 December 2021].

[32] EPA, 2019.

[33] Matthew Allen, EPA, pers. comm., 11 October 2021.

[34] New Zealand has adopted the seventh revised edition of the Globally Harmonized System of Classification and Labelling of Chemicals.

[35] EPA, 2020g. For more detail on environmental risk assessment and models, see chapter two.

[36] HSNO Act 1996, s 2.

[37] MPI also sets conditions for agricultural compounds under the Agricultural Compounds and Veterinary Medicines Act 1997.

[38] Under the Health and Safety at Work (Hazardous Substances) Regulations 2017. The Ministry of Business, Innovation and Employment is responsible for the maintenance and update of these regulations.

[39] EPA, 2020g, p.39.

[40] Quality Planning, 2019.

Box 3.1: What tools are available to control ecotoxic substances at the national level?

The **Hazardous Substances (Hazardous Property Controls) Notice 2017** sets out controls relating to substances that are hazardous to the environment. The notice includes requirements relating to both workplaces and non-workplaces. Some examples of the sorts of provisions contained in the notice relevant to ecotoxic substances are:

- the ability to set buffer zone distances from sensitive areas[41]
- the ability to set a maximum application rate, frequency or interval within an application plot[42]
- keeping records when three kilograms or more of an agrichemical that is an aquatic ecotoxin is applied "in a place where the substance is likely to enter air or water and leave the application area",[43] and hold those records for at least three years[44]
- not exceeding environmental exposure limits (where these are set)[45] – see further below
- the requirement to avoid applying certain agrichemicals to water[46]
- protections for terrestrial vertebrates and invertebrate pollinators[47]
- qualifications required for people applying ecotoxic substances to the environment.[48]

Environmental exposure limits (EELs) are defined as a limit on the concentration of a substance (or any element or compound making up the substance) with ecotoxic properties in an environmental medium (soil, sediment or water). However, the EPA does not currently have a detailed operational policy in place covering the use of EELs and does not typically set them in practice.

The **Hazardous Substances (Disposal) Notice 2017** sets out options for disposal of different types of hazardous substances according to their classification. The notice includes detailed disposal requirements for ecotoxic substances.

Important provisions for environmental protection are set out in other EPA notices, including the **Hazardous Substances (Labelling) Notice**, the **Hazardous Substances (Packaging) Notice** and the **Hazardous Substances (Safety Data Sheets) Notice**. For example, the Labelling Notice requires a label statement for certain agrichemicals that are hazardous to invertebrate pollinators.[49]

In some instances, **more stringent and additional controls** are applied. For example, for the vertebrate poison 1080, specific permission is required from public health units and the Department of Conservation for each operation, and monitoring of water quality and impacts on plant and animal species must be carried out after aerial application, with results reported to the EPA.[50]

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[41] EPA, 2021n, cl 51.

[42] EPA, 2021n, cl 50.

[43] EPA, 2021n, cl 48(2).

[44] EPA, 2021n, cl 48(4).

[45] EPA, 2021n, cl 49, and HSNO Act, s 77B.

[46] EPA, 2021n, cl 52.

[47] EPA, 2021n, cls 53–58.

[48] EPA, 2021n, Subpart C.

[49] EPA, 2021p, cl 24.

[50] The EPA has the legal authority to grant permission to use vertebrate toxic agents under section 95A of the HSNO Act. For 1080, this power is delegated to the Department of Conservation and the Ministry of Health. See https://www.epa.govt.nz/everyday-environment/animals-and-insects/1080/ [accessed 28 January 2022].

Reassessments

Most approvals under the HSNO Act do not expire.[51] This means that controls imposed years ago still apply even where knowledge about the risks has advanced. Reassessments enable the EPA to change controls or even phase out a chemical. Reassessments may be initiated externally upon application at the cost of the applicant, though they are typically initiated by the EPA.[52] Before a reassessment can proceed, "grounds for reassessment" must be established that demonstrate at least one of the following:

- significant new information about the substance's effects has become available
- information showing a significant change in the substance's use or the quantity used has become available
- another substance with similar or improved beneficial effects and reduced adverse effects has become available
- a change in controls under HSWA.[53]

The EPA screens and prioritises chemicals for reassessment that "present the greatest risk, and that need further review and scrutiny".[54] Sixteen full reassessments, covering 210 approvals, have been completed since the HSNO Act came into effect in 2001.[55] The EPA Priority Chemical List has seen several iterations and currently contains around 40 chemicals. Past iterations of the list have focused on pesticides, but the most recent version addresses chemicals more broadly, including a number of industrial chemicals.[56]

Over the years, the EPA has articulated challenges to progressing its reassessments work programme, to the extent that it recently noted that the adequacy of hazardous substance controls is falling behind other OECD and major trading countries.[57]

The first key challenge identified by the EPA is that the playing field is tilted in favour of existing substances. Many older substances were effectively grandparented into the HSNO Act without comprehensive risk assessment and at no cost.[58] They were also approved without a time limit. This means, in practice, that many reformulations are approved on the basis of prior approvals with the same controls even though these may now be considered inadequate. This is because it is considered unfair to impose more stringent controls on a new approval when existing substances pose the same risks.

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[51] With some exceptions, such as containment approvals.

[52] EPA, 2020a.

[53] HSNO Act 1996, s 62.

[54] https://www.epa.govt.nz/industry-areas/hazardous-substances/chemical-reassessment-programme/about/ [accessed 10 December 2021].

[55] Matthew Allen, EPA, pers. comm., 19 November 2021.

[56] The priority list was developed with a screening tool called FRCAST developed to evaluate the chemicals' potential risk to human health and to the environment. This tool was peer reviewed by two international regulatory bodies – the National Industrial Chemicals Notification and Assessment Scheme in Australia and Environment Canada. See https://www.epa.govt.nz/industry-areas/hazardous-substances/chemical-reassessment-programme/priority-chemicals-list/.

[57] EPA, 2020a, p.6.

[58] EPA, 2014, p.20.

The EPA's ability to progress high priority reassessments within appropriate (short) timeframes has also been constrained by limited resources. The priority list is funded from the agency's core budget, as opposed to new applications, which are partially funded by applicants. Budget 2020 provided the EPA with a tiny $1 million budget for its reassessment programme (covering reassessments initiated by the EPA and from external applicants). At this level of resourcing, the EPA will be able to progress about two to three reassessments per year, assuming there are no other externally initiated reassessments. If the EPA were to progress reassessment of 2.5 chemicals selected from the Priority Chemical List per year, it would take 16 years to work through the list, which represents 0.1 per cent of chemicals contained in substances in New Zealand, numbering roughly 30,000. This hypothetical estimate does not account for the varying size and complexity of reassessments or the potential for other emerging issues to be prioritised over chemicals on the Priority Chemical List.

Modified reassessments (a reassessment of one aspect of an approval) are also provided for, and these include updates to hazard classifications. New tools, including adopting the International Uniform Chemical Information Database, will aid this process.[59] The Hazardous Substances and New Organisms (Hazardous Substances Assessments) Amendment Bill, currently at the select committee stage, is also anticipated to speed up both assessments and reassessments (particularly modified reassessments) by enabling the EPA to make more use of information from international regulators. The Bill would require the EPA to publish its reassessments workplan at least annually.[60]

Engagement with Māori

The EPA is subject to provisions in the HSNO Act and the EPA Act that define its obligations in respect of Te Tiriti o Waitangi and the relationship of Māori with the land and their culture.[61] To guide the EPA in the undertaking of its statutory and other obligations to Māori, the EPA developed a corporate statement – He Whetū Mārama – to "recognise the unique relationship of Māori to the environment in Aotearoa New Zealand, their place as tangata whenua, and the important role that Māori play in New Zealand's economic, environmental, social and cultural wellbeing".[62]

At a pragmatic level, the EPA engages with Māori on chemical applications in several ways. Ngā Kaihautū Tikanga Taiao is the statutory Māori Advisory Committee that provides policy, process and decision-making advice.[63] Kaupapa Kura Taiao is the EPA's Māori policy and operations unit, which supports engagement with Māori and applicants and also provides decision-making advice.[64] Engagement can take a variety of forms. For example, a series of hui have been undertaken for the reassessment of hydrogen cyanimide (also known as Hi-Cane) currently underway.[65] The EPA also produces Māori impact assessments to inform the decision on potential cultural impacts and any Treaty principle issues.

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[59] "The new database will enable New Zealand to record, store, maintain, and exchange data on chemicals in ways that are more aligned with other OECD countries" (EPA, 2020a, p.5).

[60] Hazardous Substances and New Organisms (Hazardous Substances Assessments) Amendment Bill, cl 4.

[61] Under the HSNO Act, the EPA and anyone exercising powers and functions is required to "take into account the principles of the Treaty of Waitangi (Te Tiriti o Waitangi)" (s 8). They should also recognise and provide for the maintenance and enhancement of current and future cultural wellbeing (s 5(b)) and take into account the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, wāhi tapu, valued flora and fauna and other taonga (s 6(d)). Under the EPA Act, they must "recognise and respect the Crown's responsibility to take appropriate account of the Treaty of Waitangi (Te Tiriti o Waitangi)" (s 4).

[62] EPA, 2016, p.2.

[63] When Ngā Kaihautū provide advice to decision makers, it will have a different weighting dependent on which Act the application relates to (EPA, 2016, p.13).

[64] Other Māori groups that provide the EPA with support include Te Herenga, a network of Māori environmental practitioners, and Ngā Parirau o te Mātauranga, a group of kaumātua from Te Herenga (EPA, 2020e, p.66).

[65] EPA, 2020d.

While applicants to the EPA are strongly encouraged to engage with tangata whenua as early as possible, there is no duty to engage, and therefore there are no requirements regarding the quality of that engagement.[66] If an applicant does engage with tangata whenua, a cultural impact assessment is sometimes produced as part of the application. At times, recommendations for controls will also be made. Māori are also able to submit on applications as part of the general submission process and can include te reo and mātauranga Māori.[67]

The Mātauranga Framework was developed by the EPA in an attempt to support decision makers to better test and probe mātauranga when deciding how to weight this evidence.[68] The Mātauranga Framework and programme is relatively new and its implementation has only just begun. It has been difficult for decision makers to test and probe mātauranga to determine whether applications do in fact have an impact on Māori because most HSNO committee members do not have the expertise to do so. Furthermore, there are sometimes different perspectives on cultural impacts from the various sources of information, including staff advice, Ngā Kaihautū Tikanga Taiao and iwi submissions, which substantiates the need for the Mātauranga Framework to assist decision makers.[69]

Public notification and engagement processes

Certain application categories – such as full reassessments under section 63 of the HSNO Act – are required to be publicly notified, whereas others may only be notified if the Authority "considers that there is likely to be significant public interest".[70] Decisions to notify are based on a range of considerations, including whether the substance is novel (most new active ingredient applications are publicly notified), contains a chemical on the Priority Chemical List or contains a component with a particular hazard,[71] is intended for use in sensitive sites such as public parks, or has potential to cause significant impact on Māori interests and culture, including Treaty considerations. Where notified, interested parties may submit on the application and may opt to speak to their submission at a public hearing. Public hearings are frequently held for high-profile reassessments but are relatively rare in the case of applications to import or manufacture a hazardous substance.

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[66] EPA, 2016, p.25.

[67] EPA, 2020e, p.30.

[68] EPA, 2020e.

[69] See the case study on neonicotinoids in chapter five.

[70] HSNO Act 1996, s 53(2).

[71] For example, CMR (carcinogenic, mutagenic or reproductive toxins), PBT (persistent, bioaccumulative, toxic), or very persistent and very bioaccumulative.

Role of the Ministry for Primary Industries under the Agricultural Compounds and Veterinary Medicines Act 1997

In contrast to the HSNO regime that manages human health and environmental risks associated with a broad range of *hazardous substances*, the ACVM Act deals with *trade name agricultural compounds*, and many substances will need an approval under both regimes.[72] The risks managed by MPI under the ACVM Act include risks to trade in primary produce, animal welfare, agricultural security and a limited subset of public health risks.[73] The Act also aims to ensure that the use of agricultural compounds does not result in breaches of domestic food residue standards,[74] and that consumer information is made available concerning agricultural compounds.

The ACVM Act allows for different types of authorisation, with the main two being the registration of trade name agricultural compounds and the exemption of groups of agricultural compounds from registration via regulations, provided that certain conditions are met.

In registering trade name agricultural compounds, MPI approves the label content related to the ACVM risk areas. While the ACVM Act does not manage risks to the environment, important linkages exist between EPA and MPI processes, including access to the data underlying some label statements that relate to use and safety in the environment.

The ACVM Act protects proprietary data, providing confidentiality for the active ingredients of agricultural compounds registered under a trade name. For example, the Act provides ten years of data protection for an innovative product (i.e. one containing a new active ingredient).[75] Information is not available to competitor companies or members of the public for the period of data protection but may be disclosed in specific circumstances.[76]

Product registrants tend to lodge their applications with MPI first to obtain data protection, but EPA approval must be confirmed before ACVM registration will be issued. This ensures that label statements issued by the EPA – such as a warning not to spray a pesticide that is harmful to bees on flowering plants – are present on the product label approved by MPI.

When registering trade name agricultural compounds, MPI considers efficacy, target animal safety, crop safety and residues in food commodities from treated animals and crops. For efficacy, MPI would consider, for example, studies that demonstrate a vaccine's effectiveness in treating a disease in cattle. However, this information is not part of the EPA's data requirements – even though the EPA is tasked with balancing both risk and benefit as specified under the HSNO Act.

Part of MPI's role includes setting maximum residue levels (under the Food Act 2014) for agricultural compounds. In relation to maximum residue levels, MPI sets a withholding period, which is "the minimum period that should elapse between the last application and the 'use' of the produce to which the agricultural compound was applied".[77]

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[72] **Trade name product** means "an agricultural compound identified and packaged under a trade name for a specified use or uses", and **use** "in relation to any agricultural compound, includes its use in such a way that animals, plants, or raw primary produce are exposed to it" (ACVM Act 1997, s 2).

[73] Public health risks managed by MPI under the ACVM Act are those falling outside the scope of other legislation (MPI, 2016, p.4).

[74] The ACVM Act regulates for risk management outcomes set under other related Acts. For example, maximum residue levels for food products are set under the Food Act 2014 (MPI, 2016).

[75] ACVM Act 1997, s 74B.

[76] ACVM Act 1997, s 74H.

[77] MPI, 2017, p.4.

The conditions that may be set under the ACVM Act are wide ranging, relating to "substances, products, systems, or people's behaviour".[78] Unlike EPA approval under the HSNO Act, which approves a substance for an indefinite period until a reassessment is triggered, an ACVM registration has an expiration period. If the registration conditions are not complied with, MPI can take action such as issuing fines.

When processing applications for registration of a trade name product, MPI must notify relevant departments and in some cases publicly notify the application with a summary of relevant information about the product.[79] All decisions are recorded on the ACVM register.[80]

Role of Medsafe under the Medicines Act 1981

Applications for consent for new medicines are submitted to Medsafe along with evidence to demonstrate that the medicine meets the claimed safety, efficacy and quality standards. Consideration in the Medsafe approval process is focused on human health risk and benefit, and does not address risk to the receiving environment, such as the presence of residual pharmaceutical compounds in wastewater.[81]

The HSNO Act covers the importation or manufacture of medicines in their pure form, but medicines in finished dose form are excluded from the HSNO Act. The power to approve medicines is delegated to the Ministry of Health. As a result, a wide variety of bioactive chemicals may reach the environment in waste media without any assessment of their environmental consequences.

Role of other central government regulators

Other regulators that play a role at this level include Waka Kotahi NZ Transport Agency in setting vehicle emission standards (Vehicle Exhaust Emissions Standard 2007) and the Commerce Commission in setting consumer safety standards, such as those that presently exist for children's nightwear and toys.

Regulating the release of chemicals into the environment at the regional and local level

Once a chemical is approved at the national level, a different set of regulators is involved in permitting specific releases into the environment. To understand the regulation of such releases, it is helpful to differentiate between the terms *hazardous substance* and *contaminant* in New Zealand law. A hazardous substance is defined as such under the HSNO Act on account of its intrinsic hazardous properties. A contaminant, by contrast, is defined under the RMA in terms of its ability to change the chemical, physical or biological condition of the receiving environmental media, and is not limited to chemical contaminants.[82]

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[78] ACVM Act 1997, s 4A(3).

[79] ACVM Act 1997, ss 13, 14.

[80] See https://eatsafe.nzfsa.govt.nz/web/public/acvm-register/.

[81] Andrea Eng, Medsafe, pers. comm., 17 November 2020.

[82] A contaminant includes "any substance (including gases, odorous compounds, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat— (a) when discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or (b) when discharged onto or into land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged" (RMA 1991, s 2).

Regional councils are primarily responsible for regulating discharges of *contaminants* into receiving environments under regional plans. Some discharges require resource consents and others are permitted, provided they meet certain conditions. The application of agrichemicals is a permitted activity in many regions provided certain standards and conditions are met.[83] Territorial authorities also play a role in land use zoning, activity consents and the administration of bylaws. In undertaking their functions, councils are discouraged from duplicating HSNO Act and HSWA lifecycle controls on *hazardous substances*, but additional RMA controls may be warranted where the use of the substance occurs adjacent to a sensitive environment or incompatible activity.[84]

Not all chemical contaminants are covered by national control frameworks, either because they do not require approval (not having been imported or manufactured) or do not trigger hazardous property thresholds under the HSNO Act. For such releases, the resource consenting process will be the primary form of control for environmentally harmful substances, and include stormwater, wastewater, landfill leachate, biosolids and some industrial wastes or their by-products (e.g. aluminium smelting waste).

Role of regional councils under the Resource Management Act 1991

Regional councils are responsible for managing contaminant discharges into the environment. Their role is mandated under the RMA and includes drawing up plans, rules and consents to manage environmental effects.[85] Decisions on resource consents are made by the governing body of the council or its delegate.[86]

Among the general matters regional consenting authorities must have regard to in respect of receiving environments,[87] the following is relevant.

With respect to *receiving waters* (in a generic sense) the RMA prevents a regional council from allowing a discharge to be a permitted activity or granting a discharge consent, if, after reasonable mixing, the discharge may result in:

- the production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials
- any conspicuous change in the colour or visual clarity
- any emission of objectionable odour
- the rendering of fresh water unsuitable for consumption by farm animals
- any significant adverse effects on aquatic life.[88]

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[83] For example, Rule 15-2 of Horizons Regional Council's One Plan sets out permitted activity conditions, including not contravening the manufacturer's instruction; no discharge within any rare, threatened or at-risk habitat; sufficient distance from a sensitive area; compliance with the New Zealand Standard NZS 8409:2004; and certification requirements (Horizons Regional Council, 2014, pp.5–7, 15).

[84] The Resource Legislation Amendment Act 2017 removed the explicit function of regional and territorial authorities under sections 30 and 31 to control the adverse effects of the storage, use, disposal and transportation of hazardous substances to ensure RMA controls do not duplicate controls in the HSNO Act and the HSWA (Quality Planning, 2019).

[85] In making their decisions, regional councils are required to achieve the aims of the RMA as well as take appropriate heed of the hierarchy of documents under the RMA planning framework. The Local Government Act 2002 is also relevant to regional councils' role.

[86] See Local Government Act 2002 (e.g. section 41 and Schedule 7).

[87] 'Receiving environment' is not defined under the RMA. However, a Quality Planning note states "the receiving environment is the environment upon which a proposed activity might have effects [including consideration of] the existing and reasonably foreseeable future environment". https://www.qualityplanning.org.nz/node/850 [accessed 10 December 2021].

[88] RMA 1991 ss 70, 107.

Note that these are minimum standards that the council can implement through its regional planning process. Before including a regional rule in its plan, a regional council must be satisfied that the inclusion of that rule is the most efficient and effective means of preventing and minimising adverse effects on the environment.[89]

With respect to the *coastal environment*, the New Zealand Coastal Policy Statement 2010 applies. Policy 23 states that (among other matters) particular regard must be given to:

- the sensitivity of the receiving environment
- the nature and concentration of contaminants to be discharged
- the capacity of the receiving environment to assimilate the contaminants
- avoiding significant adverse effects on ecosystems and habitats following reasonable mixing
- taking steps to avoiding adverse effects of stormwater discharge to water.[90]

With respect to *freshwater*, the National Policy Statement for Freshwater Management (NPS-FM) sets out objectives and policies that apply to all freshwater in New Zealand. However, while the NPS-FM includes contaminants such as sediment, nitrogen, phosphorus and *E. coli*, it does not currently include any of the chemical contaminants that are the focus of this investigation. Furthermore, the NPS-FM recognises Te Mana o te Wai, "the integrated and holistic well-being of a freshwater body". This philosophy, which places the environment first, human wellbeing second and extractive use third, resonates with Māori regarding chemical use and disposal.

The National Environmental Standards for Sources of Human Drinking Water require regional councils "to ensure that effects of activities on drinking water sources are considered in decisions on resource consents and regional plans." Under these standards, regional councils must decline discharge or water permits likely to result in community drinking water becoming unsafe for human consumption following existing treatment.[91]

Conditions and compliance monitoring

Through the resource consent process, regional councils consider relevant matters concerning the activity and location of a discharge and may set conditions to mitigate the adverse effects of chemical contaminants on the receiving environment.

An assessment of effects on the environment included with a resource consent application is required to be submitted in accordance with the scale and nature of the potential effects to the receiving environment. Through this process, decision makers consider the nature of the discharge, the treatment to which it will be subject and the type and quality of receiving environments, among other matters.[92]

Conditions may be set as part of a consent or permitted activity rule and include the requirement to monitor and report chemical contaminant levels. They might detail specific chemicals that must be monitored against **trigger values**.

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[89] See http://www.environmentguide.org.nz/issues/freshwater/freshwater-management-framework/restrictions/ [accessed 10 December 2021].

[90] See https://www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/new-zealand-coastal-policy-statement/new-zealand-coastal-policy-statement-2010/policy-23-discharge-of-contaminants/ [accessed 10 December 2021].

[91] See https://environment.govt.nz/acts-and-regulations/regulations/national-environmental-standard-for-sources-of-human-drinking-water/ [accessed 10 December 2021].

[92] Conwell, 2021, p.8.

A trigger value is defined as a "concentration threshold that once exceeded, [initiates] a predefined set of actions", which may involve further monitoring to check compliance, depending on the magnitude of the exceedance.[93] A trigger value may be specified for a discharge, the receiving environment or both. Monitoring against trigger values is a common – but not uniformly applied – condition imposed under wastewater, stormwater and landfill leachate consents.[94] There is variation among regional councils in terms of the purposes for which trigger values are set and in terms of how they are analysed.[95]

Monitoring requirements for discharges are usually specific and tailored to the activity and purpose of monitoring. As a result, differences can arise between seemingly similar consents depending on the context. For example:

- Monitoring may be required at the point of discharge only, or for one or more receiving environments (e.g. groundwater).
- Numerical limits can be set for one or more receiving environments, and in the case of surface water, would usually be set in relation to a zone of reasonable mixing tailored to the activity and location.
- Limits can be set as an absolute limit to protect a particular environmental value or can be set as trigger values.[96]

Some national-level guidance documents are available to support decisions on monitoring. While non-statutory, they promote a level of consistency around the requirements for key discharge types.[97] National guidance has been provided on landfills, biosolids and wastewater and for specific receiving environments – for example, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.[98]

Qualitative feedback from councils for the Jacobs New Zealand Ltd report commissioned for this investigation indicates that while more recent consents (from 2015 onwards) give greater consideration to chemical contaminants,[99] several barriers still remain for giving more extensive consideration to them in consenting processes. These include a lack of relevant limits in national guidance for many non-routine chemical contaminants; a lack of knowledge within councils of where (and whether) non-routine chemical contaminants are an issue and how to treat or mitigate effects; and high costs for laboratory analysis and dedicated, experienced council staff.[100]

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[93] Conwell, 2021, p.4.

[94] Conwell, 2021, pp.12, 23.

[95] For example, some consents might compare the concentration of a chemical in a waterway against Australian and New Zealand Guidelines for Fresh and Marine Water Quality guideline values for a specific level of protection (e.g. 90%). Others may analyse whether the concentration of a chemical exceeds the New Zealand drinking water standards guideline values (particularly for groundwater, where this is most directly relevant) (Conwell, 2021, p.42).

[96] Conwell, 2021, p.8.

[97] Conwell, 2021.

[98] WasteMINZ, 2018a and 2018b; NZWWA and MfE, 2003; NZWERF, 2002. Conwell (2021, p.7) notes regarding the Wastewater Monitoring Guidelines that these are "nearly 20 years old" and "whilst providing some guidance, best practices are out of date".

[99] Conwell, 2021.

[100] Conwell, 2021, p.38.

Public participation

When someone applies for a resource consent, the district or regional council must decide whether to publicly notify the application so that anyone can make a submission (public notification), to notify it to a limited group of parties (limited notification) or not to notify it at all (non-notification).[101]

In the case of public and limited notification, those notified may make a submission on the consent application. The subsequent process may involve further information requests, and meetings with the applicant and/or submitters to clarify a point or facilitate resolution.[102] A hearing must be held if the consent authority considers it is necessary or if the applicant or submitter has requested to be heard.[103]

Over the last decade, there has been a reduced emphasis on public notification under the RMA.[104] In regard to consents relating to effluents such as landfill leachate and wastewater, councils' decisions vary as to whether or not to notify. In some cases they are notified, and in other cases they are not.

Once a consent is granted, monitoring data gathered under resource consents are held by councils and are subject to Official Information Act 1982 requirements. However, these are not commonly held in a public database, nor are they recorded in a consistent form.

Māori engagement

The RMA requires those exercising functions and powers to:

- recognise and provide for the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, wāhi tapu and other taonga[105]
- have particular regard to kaitiakitanga[106]
- take into account the principles of the Treaty of Waitangi.[107]

In terms of process, the RMA requires local authorities to engage with tangata whenua through iwi authorities in the planning process.[108] Tangata whenua engagement with hazardous substance applications runs in the same way all other resource consent applications are run. There is no alternative process and these applications will go to relevant people that would also process other resource consent applications.

Engagement of Māori with each application varies considerably depending on the level of significance of the receiving environment, and resourcing considerations relevant to the iwi in the region.[109] Most resource consent applications are sent to the iwi, depending on the relationship between the iwi authority and the local authority. This provides the opportunity for iwi to submit on all applications. However, under-resourcing, time constraints and limited expertise hinder many iwi from making submissions in a timely manner. This is particularly so for hazardous substance applications, which are generally very technical in nature.

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[101] RMA 1991, s 95A.

[102] RMA 1991, ss 99, 99A.

[103] RMA 1991, s 100.

[104] Before 2009 the Act included a presumption of notification which was replaced in 2009 by a more discretionary process. In 2017, the discretion was removed.

[105] RMA 1991, s 6(e).

[106] RMA 1991, s 7(a).

[107] RMA 1991, s 8.

[108] See http://www.environmentguide.org.nz/rma/maori-and-the-rma/ [accessed 10 December 2021].

[109] Te Puni Kōkiri, 2006.

Treaty settlements may also require local authorities to engage with iwi or hapū if significant areas are affected. Iwi Management (or Environmental) Plans (IMPs) that are mandated by authorised iwi authorities describe resource management issues of importance. Under the RMA, these plans must be taken into account when preparing or changing regional policy statements and regional and district plans.[110] Some IMPs provide specific statements about hazardous substances, while many others provide broad statements regarding chemical contamination and pollution.[111]

Role of Taumata Arowai

A new national-level regulator, Taumata Arowai, was established as a Crown entity in March 2021 through the Taumata Arowai – the Water Services Regulator Act 2020. One objective of the new regulator is to "provide oversight of, and advice on, the regulation, management, and environmental performance of wastewater and stormwater networks".[112]

Under the Water Services Act 2021, Taumata Arowai is empowered to:

- set environmental performance measures as regulations that wastewater and stormwater operators have to report against annually and local authorities must use as minima for their own regulatory powers
- compile information about wastewater and stormwater networks in a national public database
- publish an annual report on the environmental performance of wastewater and stormwater networks and their compliance with applicable regulatory requirements (such as resource consents)
- identify, promote and report on best practices for the design, management, and operation of wastewater and stormwater networks.[113]

Taumata Arowai and local authorities are essentially co-regulators of the environmental performance of drinking water, wastewater networks and wastewater treatment plants with Taumata Arowai essentially imposing minimum standards that regional councils must reflect in resource consents they issue to operators. Exactly how the division of labour will work in practice remains to be seen.

The addition of another national-level regulator into the mix could further complicate the regulatory treatment of the environmental fate of chemicals. On the other hand, it represents an opportunity to introduce minimum standards for wastewater. For this to occur, Taumata Arowai will need to consider the wide suite of chemicals that are entering the networks it regulates and their environmental impact. This will mean duplicating some of the expertise currently held by the EPA and the regional councils.

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[110] RMA 1991, s 61(2A)(a), s 66 (2A)(a), and s 74(2A).

[111] For specific statements, see Te Rūnanga o Kaikōura (2007) and Ngāi Tahu ki Murihiku (2008). For broad statements see Hauraki Māori Trust (2004) and Ngāi Te Rangi et al. (2008).

[112] Taumata Arowai – the Water Services Regulator Act 2020, s 10(e).

[113] Water Services Act 2021. See https://www.legislation.govt.nz/act/public/2021/0036/latest/LMS374564.htmlta.

Compliance and enforcement

Following national-level approval under the HSNO Act and incorporating HSWA controls, enforcing compliance of controls on chemicals is primarily undertaken by WorkSafe New Zealand, local authorities and the EPA. For an overview of responsibilities, see Figure 3.3. The subsequent discussion focuses on enforcement of environmental controls and acknowledges some of the findings of the Hazardous Substance Compliance System Technical Working Group prepared for the EPA and the Ministry for the Environment.[114]

WorkSafe New Zealand plays a role in terms of the enforcement of both hazardous substance disposal rules and rules to protect the environment and human health in workplaces. While protection of human health and the environment are often complementary (e.g. the certification of large plant and equipment to prevent leaks or spills), the priorities and expertise of the agency are oriented towards health and safety rather than addressing risks posed by ecotoxic substances.

In addition to their role under the RMA, territorial authorities (district and city councils) are required to enforce the provisions of the HSNO Act on any premises situated in the district other than those assigned to other regulators, and other than to protect public health. However, in practice, many territorial authorities lack resources devoted to HSNO enforcement and are faced with many other competing priorities.[115] With some exceptions (e.g. 1080 drops), the extent to which national-level controls are implemented is generally unknown.

Regional councils and unitary authorities frequently monitor specific chemical contaminants in relation to their role in respect of discharge management under the RMA. Councils can issue infringement or abatement notices to people not complying with the RMA, national environmental standards or council plans. Regional councils *may* also enforce HSNO provisions where an officer may be in or on the premises for the purpose of enforcing RMA provisions. Their propensity to do so is likely to vary depending on capacity and capability.[116] In terms of their HSNO role, the Technical Working Group commented that "regional councils have no mandatory role in relation to HSNO. Yet, perhaps with the exception of some of the larger city councils, they are the local authorities best placed to perform such a role."[117]

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[114] Hazardous Substance Compliance System Technical Working Group, 2019.

[115] The Technical Working Group doubted "whether [most] councils have the incentives and resources to carry out the function effectively". They also observed that "councils tend to look to the RMA for enforcement remedies" and that rather than investing in councils' HSNO performance, a "step up in their RMA CME [compliance, monitoring and enforcement] capability and capacity would bring broader community and environmental benefits and would also contribute to meeting HSNO's purpose and its compliance system performance" (Hazardous Substance Compliance System Technical Working Group, 2019, pp.29–30).

[116] See HSNO Act, s 97, and Hazardous Substance Compliance System Technical Working Group, 2019, pp.15–16.

[117] Hazardous Substance Compliance System Technical Working Group, 2019, p.30.

Other agencies are also involved in hazardous substance enforcement activities, depending on where the substance is used. Responsibilities are shared in a complex arrangement between a number of agencies, with overall responsibility given to the EPA.[118] The Technical Working Group critiqued these diffuse arrangements and raised the following concerns:

> "The presence of multiple agencies with potential authority to act can create uncertainty and confusion about who has the authority to act in any situation. This can result in either a delay in action while enforcement agencies attempt to determine who has the proper authority to act; or in a complete failure to act, or enforce, where multiple agencies believe the enforcement responsibility lies with, or has been undertaken, by another agency."[119]

	Hazardous substance rules to PROTECT PEOPLE from WORKPLACE activities SET UNDER HSW ACT	Hazardous substance DISPOSAL rules and rules to protect the ENVIRONMENT in WORKPLACES* SET UNDER HSNO ACT*	Hazardous substance rules for IMPORTERS, MANUFACTURERS and SUPPLIERS** SET UNDER HSNO ACT*	Hazardous substance rules to PROTECT PEOPLE and the ENVIRONMENT in NON-WORKPLACES SET UNDER HSNO ACT*
Regulator	WORKSAFE	Environmental Protection Authority Te Mana Rauhī Taiao	Environmental Protection Authority Te Mana Rauhī Taiao	Environmental Protection Authority Te Mana Rauhī Taiao
Enforced by	WORKSAFE	WORKSAFE	Environmental Protection Authority Te Mana Rauhī Taiao	COUNCILS***

Source: EPA

Notes:

* There are other hazardous substance environmental and disposal rules set under the Resource Management Act 1991 and local council bylaws. These rules are enforced by local, district and regional councils.

** Such as labelling, packaging, safety data sheets and restrictions on ingredients in certain hazardous substances products.

*** City and district councils.

Figure 3.3: Compliance and enforcement roles and responsibilities under the HSNO Act and the HSWA.

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[118] Hazardous Substance Compliance System Technical Working Group, 2019, pp.15–16.

[119] Hazardous Substance Compliance System Technical Working Group, 2019, pp.23.

Key observations

Whether chemicals are permitted to reach, and potentially contaminate, the environment depends on their use pattern and risks. The current regulatory system brings into play different regulators at both national and regional levels.

In terms of assessing and managing environmental risk, the EPA is the key agency responsible at the national level. The EPA's toolbox of environmental controls ranges from more prescriptive ones, such as setting an application rate, label statements and a restriction to a specific use pattern, to performance-based requirements, such as specifying an EEL in a given environmental medium. However, in practice, EELs are rarely set.

Ideally, a national-level regulator would impose controls that reflect up-to-date evidence of the risks substances pose. However, given the sheer number of chemicals on the market, the basis on which many were brought into the current system and the limited resources available to the EPA to reassess them means that large numbers of substances are subject to controls based on evidence that is well out of date. Furthermore, the delegation to importers or manufacturers of authority to assign substances to existing approvals or group standards means there is even more limited visibility of what ends up being used and entering the environment.

Regulatory control under the RMA is imposed at the point of discharge into receiving environments, including groundwater, coastal water, surface water, soil and air. Regional councils make decisions on the discharge of contaminants to the environment. These may include, but are not limited to, chemicals authorised at the national level. Regional councils require compliance monitoring of some chemical contaminants present in discharges, and also undertake representative state of the environment (SoE) monitoring to assess regional conditions and trends. While guidance is available to regional councils on setting trigger values with respect to certain ecological receptors and discharge types, there are no consistent national limits and what gets monitored varies significantly from region to region.

Once approved at the national level, responsibility for compliance and enforcement of environmental regulatory requirements for chemicals sits with WorkSafe New Zealand, councils and the EPA. However, a recent report on the status of the hazardous substances compliance system identified constraints on the level of priority, capacity and capability that can be devoted to hazardous substances by enforcement agencies.

The combined effect of these limitations suggests that the comprehensiveness with which chemicals are managed for their environmental impacts and the agility of the system to respond to new information is questionable.

4


Pyrrosia eleagnifolia

Understanding sources and pathways of chemical contaminants

Managing the environmental fate of chemicals requires an understanding of how those chemicals enter the environment and how those sources and pathways can be managed. There are varying levels of scrutiny applied to different sources and pathways. Some of the assumptions made at the national level about chemical releases do not always neatly align with how chemicals are controlled at the regional level, and there are areas where regulatory gaps are apparent.

This chapter examines the management of the following specific sources and pathways:

- wastewater and biosolids
- landfill leachate
- stormwater
- agrichemical applications.

It also looks at the following 'outliers' – forms in which chemicals are found that may contaminate the environment but are not neatly captured under the current regulatory regime:

- manufactured articles
- naturally occurring contaminants
- complex mixtures and hazardous wastes.

Wastewater and biosolids

Wastewater treatment plants are a key point source of industrial and household contaminants that reach the environment through pathways that involve both discharges of liquid wastewater and the disposal of biosolids from treatment plants. While some advanced wastewater treatment processes can remove chemical contaminants to an extent, most are not generally designed for this purpose, so any removal is incidental.[1] Treated wastewater is generally discharged into freshwater or coastal environments. Use of biosolids and the irrigation of wastewater effluents to land can introduce a range of contaminants into soil.[2]

Through resource consent conditions, regional councils provide a degree of control over the quality of wastewater discharged into the environment. However, there are gaps in the regulation of what enters the wastewater system. The industrial use of some chemicals is regulated through trade-waste bylaws imposed by territorial authorities. But the composition of household wastewater entering the network is hard to control.

Chemical contaminants may interfere with treatment plant processes. For example, dissolved chromium in trade waste from industries working with the metal may be toxic to microbes used in the anaerobic treatment phase. Such microbes are essential for the breakdown of organic compounds and the digestion of biodegradable matter. Other chemical contaminants may also be present in biosolids at levels of ecological concern; for example, municipal biosolids usually contain per- and poly-fluoroalkyl substance (PFAS) compounds, as a consequence of the extensive community use of PFAS in household cleaning products, food packaging and non-stick cookware, among others.[3]

Territorial authorities control inputs to the wastewater network both to meet environmental discharge limits set by regional councils through resource consents under the Resource Management Act 1991 (RMA) and to manage the operational performance of wastewater treatment plants. Territorial authorities have the power to manage industrial and other trade waste under the Local Government Act 2002 (LGA) through trade-waste bylaws.[4] A model trade-waste bylaw is available for councils to use. Development of trade-waste bylaws involves consultation with the Ministry of Health and a public notification process. The LGA also provides for community and tangata whenua consultations when trade-waste bylaws are reviewed.

Regional councils manage wastewater discharges into the environment through the resource consenting process. Consents normally include conditions (including monitoring against trigger values) on wastewater discharges to land or water in respect of a range of contaminants. These include biological oxygen demand, nutrients and pathogens that have well understood public health and/or ecological concerns. Specific trade-waste contaminants (which may include chemicals) are lower order considerations in the resource consent process.[5]

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[1] Sewage contains excreted pharmaceuticals and their metabolites, illicit drugs, personal care products, food additives, household chemicals and industrial chemicals. In rural areas, discharge from septic tanks can contaminate ground and surface waters with organic contaminants (Stewart et al., 2016, p.4, citing Luo et al., 2014, Margot et al., 2015, Lara-Martín et al., 2014, and Phillips et al., 2015).

[2] Stewart et al., 2016, p.4, citing Weiss et al., 2008.

[3] Hall et al., 2021.

[4] Trade waste is defined as "any liquid, with or without matter in suspension or solution, that is or may be discharged from a trade premises to the Wastewater Authority's (WWA) sewerage system in the course of any trade or industrial process or operation" (BECA et al., 2020, p.60).

[5] BECA et al., 2020, p.62–66.

Regional councils have identified limitations to the monitoring and management of a wide range of chemical contaminants. These include shortcomings in their understanding of potential effects, appropriate treatment and mitigation techniques and cost considerations.[6] As a consequence, many contaminants may be passing through wastewater treatment plants unmonitored and unregulated. Work has been undertaken in anticipation of upgrading treatment plants to meet the requirements of the National Policy Statement for Freshwater Management (NPS-FM),[7] but the chemical contaminants of interest to this investigation are out of scope for that regulation.

Some chemical contaminants are **commonly monitored in wastewater**. These include metals (copper, lead, zinc and chromium, and to a lesser degree arsenic, nickel, cadmium and mercury), and organics (volatile and semi-volatile organic compounds ranging from paint-related through to petroleum-based sources).[8] However, others are not, including pharmaceuticals, personal care products and other industrial and household chemicals such as PFAS compounds. Councils typically do not require monitoring of these chemicals as part of resource consent conditions, although as resource consents are renewed, some councils are starting to look at covering a broader array of organic contaminants.[9]

Pharmaceutical manufacturers are required to keep records that are subject to auditing for the management and discharge of medicines waste.[10] However, relatively scant attention is paid to the fate and impact of pharmaceuticals reaching the environment through human wastewater. Sustained consumption at high levels can mean that some pharmaceuticals are ‘pseudo-persistent’ given their consistent presence in treated (and untreated) wastewater entering the environment. Common examples include broad-spectrum antibiotics and oestrogen.

Monitoring of the **effects of effluents on biota** is variable across consents and regions.[11] Whole effluent toxicity testing is sometimes conducted to assess the potential toxicity of effluents on standardised sets of indicator species (e.g. marine or freshwater algae, marine or freshwater amphipods, blue mussel, water flea, and common bully).[12] Other monitoring includes freshwater and marine ecological surveys of fish, buried organisms (such as shellfish and marine worms) and organisms living on the surface (such as algae and barnacles).

There is some shellfish contaminant monitoring (e.g. analysis of shellfish flesh to identify concentrations of trace elements such as zinc, copper and lead), which provides information on the health of mahinga kai. However, when considering the effects of effluents on biota from a te ao Māori perspective, even if the residue is below recommended thresholds for safe consumption, Māori may still be averse to the presence of any effluent in proximity to a mahinga kai site.[13]

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[6] Conwell, 2021.

[7] Boffa Miskell and GHD, 2018.

[8] Conwell, 2021.

[9] Conwell, 2021, p.iv.

[10] Medsafe, 2021.

[11] The design of a monitoring programme will depend on the objectives of monitoring, the scope (baseline assessment of environmental effects; consented activity and period of activity; reviews) and sampling design. See framework for the detailed design of a monitoring programme in the New Zealand municipal wastewater monitoring guidelines (Ray, 2002

[12] Conwell, 2021, p.68. Twenty-two per cent of wastewater consents included in the survey specified the requirement for whole effluent testing. See also Hall and Golding (1998).

[13] See, for example, Te Rūnanga o Kaikōura (2007).

Source: PCE

Figure 4.1: The Māngere Wastewater Treatment Plant is the largest in the country, treating a large proportion of Auckland's domestic and commercial wastewater before discharge into the Manukau Harbour. While the plant screens for a range of contaminants, including organics and heavy metals, wastewater treatment plant operators have limited control over some sources of chemical contaminants that pass through its treatment plant.

Biosolids present their own challenges. Biosolids are a product of the physical, chemical and biological treatment processes of wastewater treatment plants. While they can be beneficially reused in certain circumstances, they also pose risks as they tend to concentrate organic material, nutrients and contaminants, including chemicals and heavy metals. A relatively low proportion of biosolids are reused in New Zealand, with a significant proportion landfilled or managed in a similar way.[14] The rising cost of disposal to landfill means this is becoming an unsustainable option.

The high nutrient levels and trace minerals in biosolids are useful for plant growth – if the contaminants can be managed. *Guidelines for the Safe Application of Biosolids to Land in New Zealand* are available to assist regulators and dischargers to manage the discharge of biosolids.[15] The guidelines are intended for use in regional regulation as a reference when grading biosolids depending on their intended land use and include maximum acceptable contaminant levels for some heavy metals and a small number of organic compounds.[16]

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[14] BECA et al., 2020, pp.48–52.

[15] NZWWA and MfE, 2003.

[16] These include heavy metals and organic compounds such as organochlorines. Consult the biosolids guidelines (NZWWA and MfE, 2003) for the complete list of chemicals.

However, the guidelines, issued in 2003, are now out of date. Revised draft guidelines were published in 2017. Whereas the 2003 guidelines focused on sewage sludges, the scope of the 2017 revision is broader and recognises that "all wastes of animal origin, whether human or otherwise, contain similar levels of pathogens, trace elements and organic contaminants and therefore pose similar risks to productive soils and society".[17] The 2017 draft guidelines also include concentration limits for a broader range of organic compounds, including phthalates (plasticisers) and musks (synthetic aromatic substances used to perfume products such as clothes softeners and shampoo). One of the other areas revised was the limits for metals and organic compounds. The previous limits were not practical in most real scenarios due to their stringency, resulting in more treated sludge being sent to landfill. The draft suggests updated limits for those compounds, based on scientific data and international guidance.

There are still a number of outstanding issues to be resolved before the guidelines can be finalised. These include:

- inadequate partnership with Māori in the development of the guidelines – reuse of biosolids raises serious cultural concerns related to tapu and tikanga depending on the origin and intended use of the biosolids
- technical issues related to the monitoring of soils when biosolids are applied to different types of land (e.g. agricultural land, forestry, landfill cover) – monitoring should be tailored for each activity, and there are uncertainties about the testing and frequency of monitoring needed, and the costs of doing so
- how to manage the contaminant burden of biosolids where the current draft provisions are inadequate – for example, councils are understandably reluctant to authorise spreading PFAS on land in the absence of suitable guidelines.

What appears to be collaborative inertia has so far prevented the finalisation of the guidelines. The review has been led by Water New Zealand – the industry body for the three waters sector – in collaboration with WasteMINZ, the Centre for Integrated Biowaste Research and the New Zealand Land Treatment Collective. The Ministry for the Environment, the Ministry of Health and the Ministry for Primary Industries, as well as regional council representatives, are also involved. The concerns outlined above have mostly come from officials who will be the ones charged with overseeing and monitoring the environmental impact of biosolid application. None of the parties involved in finalising the guidelines seem to be giving it much priority and no date has been set for completion.

Landfill leachate

Landfills are the repository for a vast array of hazardous chemicals in different forms. They may remain *in situ* for an indeterminate period. The breakdown of waste within the landfill creates leachates, which are hazardous and form another source of chemical contaminants. Leachates may be treated on site or be transported via tanker to a wastewater treatment network for treatment and disposal (in which case they are treated as trade waste).

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[17] NZWWA and MfE, 2003; Water New Zealand, 2017, p.3.

A key regulatory control is around what waste can be disposed of, in which landfills. The Ministry for the Environment's *Hazardous Waste Guidelines: Landfill Waste Acceptance Criteria and Landfill Classification* are designed to be implemented through resource consenting processes to ensure that significant hazardous waste streams only go to a landfill that is suitable for long-term disposal of the wastes.[18] Landfills that offer a higher standard of environmental protection (Class A) have less stringent waste acceptance criteria than those that offer lower standards (Class B). Waste acceptance criteria also include total contaminant concentrations or leachability criteria for certain chemicals, depending on the landfill type.[19]

According to the *Hazardous Waste Guidelines*, non-municipal waste streams should be checked against the New Zealand Waste List.[20] Those wastes listed as hazardous may be suitable for disposal but "only after the landfill operator is confident the waste will not result in leachate from the wastes exceeding the leachate concentrations … for Class A landfills."[21] In practice, if contaminant levels exceed waste acceptance concentration thresholds, they should be treated at a hazardous waste facility before they are provided to the landfill for disposal. For example, soil with high heavy metal content might be treated to stabilise the contaminants to meet the waste acceptance criteria.[22]

In addition to the guidance available for resource consenting, the Hazardous Substances (Disposal) Notice 2017 sets out legal requirements for disposal of different types of hazardous substances – including containers that have been in contact with hazardous substances – according to their classification. It covers different options for disposal by hazard class, including treatment, discharge to the environment, or export from New Zealand. For substances hazardous to the environment, landfill management is included as an allowable form of treatment where it neutralises the hazard properties.[23]

However, there seems to be a lack of awareness of its existence among industry and users, and differing opinions about whether the Disposal Notice is applicable to Hazardous Substances and New Organisms Act 1996 (HSNO Act) approved substances or *all* substances (e.g. mixed wastes).[24] The Disposal Notice has been slated for review for some time but has not been commenced due to a lack of priority and resourcing. These issues raise serious doubts about the extent of compliance with the notice.

There are also some chemical contaminants, such as pharmaceutical wastes, that are challenging to assess and manage through the waste acceptance process and the Disposal Notice. Mixed pharmaceutical waste is collected by pharmacies and other collection points and ends up being disposed of in Class A landfills.[25] New Zealand currently has no high temperature waste incineration option, which is why some pharmaceuticals, such as cytotoxic drugs, are sent offshore for disposal. High temperature incineration was prohibited under the National Environmental Standard for Air Quality 2004.

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[18] MfE, 2004b.

[19] WasteMINZ, 2018a.

[20] See https://environment.govt.nz/guides/new-zealand-waste-list-l-code/ [accessed 10 December 2021].

[21] MfE, 2004b, p.4.

[22] Ross O'Loughlin, Waste Management, pers. comm., 15 December 2020.

[23] Clause 10(2)(a) states that treatment includes "depositing the substance in a landfill, incinerator (unless clause 11 applies), or a sewage facility if the landfill, incinerator, or sewage facility will treat the substance by changing the characteristics or composition of the substance so that the substance is no longer a hazardous substance" (EPA, 2021m, p.11).

[24] A legal opinion sought for this project found that the Disposal Notice is indeed applicable to all hazardous substances with the classifications covered by the scope of the notice.

[25] Technically, Class B landfills could also accept treated medicines if criteria for concentrations acceptance are stated.

While mixed pharmaceutical waste is subject to autoclaving (high temperature steam), this does not inactivate all hazardous properties. For example, several antibiotics (such as β-lactams, azlocillin, aztreonam, mezlocillin, and oxacillin) are heat stable. As a result, they may remain active and retain some of their potentially toxic and ecotoxic constituents after treatment.[26] The intravenous anaesthetic agent propofol accounts for a large proportion of waste disposed of by operating theatres and requires incineration to be destroyed.[27] There is a lack of clear guidelines available to medical professionals about appropriate disposal options given that incineration is not an option in New Zealand.[28]

Lack of information on waste quantities is also an issue. While pharmaceutical treatment facilities hold a barcode tracking system of waste from collection to disposal,[29] they are unable to identify the concentrations or quantities of each pharmaceutical per batch disposed of. In some overseas jurisdictions, such as the United Kingdom, the waste generator must make a declaration of waste. This enables treatment to be arranged that is appropriate for the type of waste.

The management of small quantities of hazardous wastes from sources such as households is also challenging. Household waste is most often disposed of through municipal collections outside of the formal landfill acceptance criteria process or in farm dumps that are often covered by permitted activity rules that at best have limited monitoring and compliance.

Disposal of veterinary medicine residuals raises another gap. For example, around 4 million teats with antibiotics are used annually to treat cows, raising the possibility of antimicrobial resistance developing in soils. Also, after application, residuals from injections remain in vials. It is not known where they end up being disposed of, but if they are disposed of in farm dumps they are unlikely to be subject to regulatory scrutiny.

Landfills (whether open or closed) require a discharge permit for any discharge of water or contaminants directly into land or water unless expressly allowed under regional planning provisions.[30] For monitoring the environmental effects of leachate, councils can use the *Technical Guidelines for Disposal to Land*.[31] Groundwater is the main receiving environment monitored. Frequently monitored contaminants for active landfills include lead, arsenic and zinc. Other chemicals such as copper, nickel, chromium and cadmium are monitored to a lesser degree. Trace metals, along with other parameters, including ammoniacal nitrogen and conductivity, are indicators of possible leaching.[32]

Some of the most commonly monitored organic compounds in landfill leachate include total petroleum hydrocarbons, followed by a screening test undertaken for multiple volatile and semi-volatile organic compounds. Phenols and some phased-out persistent organic pollutants, including pentachlorophenol, polychlorinated biphenyls and organochlorines are also sometimes monitored.[33]

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[26] Traub and Leonhard, 1995.

[27] Mankes, 2012.

[28] Paul Currant, Anaesthetist, Canterbury District Health Board, pers. comm., September 2021.

[29] In accordance with NZS 4304:2002 Management of Healthcare Waste.

[30] WasteMINZ, 2018a, p.32.

[31] WasteMINZ, 2018a.

[32] WasteMINZ, 2018b, pp.88–89. Caution is advised for the interpretation of results, as trace metals can emerge from other sources different to landfills.

[33] Conwell, 2021, p.40.

Stormwater

In contrast to landfill and wastewater, stormwater generally remains untreated before it is discharged into receiving environments (although some operators are required to provide a degree of treatment before their stormwater is discharged into the network).[34] While often considered a point source (when it is transported and released from a single pipe or ditch), stormwater runoff is also a diffuse source because it flows overland, collecting contaminants from a variety of areas (roads, treated pasture lands or gardens, storage sites) before reaching the receiving environment.

Overall, **monitoring of stormwater discharges** across the country focuses on heavy metals and organic compounds (including hydrocarbons and some volatile and semi-volatile organic compounds).[35,36] The monitoring of these discharges into receiving environments tends to be fairly standardised and aligned with chemicals assessed for state of the environment (SoE) programmes. New global stormwater consents (of which there are 58 currently active across New Zealand) are able to be structured and aligned with integrated catchment management plans, which are envisioned to improve our knowledge about their short- and long-term effects on receiving environments.[37]

Depending on the type of sampling method being deployed, stormwater discharge monitoring results can be misleading. A common practice is to collect single grab samples from each location at a specific (pre-programmed) time, which may not adequately indicate the regular concentration of contaminants entering the receiving environment. Single samples do not reflect the variability in chemical concentrations that result from the intermittent nature of stormwater flows. The timing of sampling can mean that first flushes after rainfall, which usually bring high concentrations of all types of contaminants held in the runoff, are missed. Contaminants can be missed entirely if rainfall occurs outside of working hours.[38]

In 2012 an Urban Runoff Quality Information System was created. This was a nationwide database combining stormwater and urban stream quality data. It was designed as a public open-access repository to provide a better understanding of the pattern of urban water quality pressures from different land uses, at type events (rain events or dry conditions). However, it has not been maintained and joins a long list of innovations in SoE monitoring that have suffered from not having dedicated support and funding.

The **monitoring of environments receiving stormwater** focuses mainly on coastal areas – in particular, soft sediments in which metals are available to filter feeders and foraging organisms. A 2014 study assessing the presence of contaminants in estuarine sediments and biota showed that the accumulation of metals is variable across species, with higher accumulation of zinc and cadmium reported for eel flesh compared to fish flesh. Although concentrations in kaimoana were low and presented a minor risk for consumption, researchers have called for ongoing monitoring to assess changes in contaminant accumulation over time.[39]

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[34] In some instances, specific industrial consents to discharge stormwater from industrial sites (e.g. Port of Tauranga) involve stormwater management programmes that may prevent the discharge of pollutants into the receiving environment. These could vary from the use of vacuum sweeper trucks to gross pollutant traps.

[35] Lead, copper and zinc – and to a lesser degree, nickel, chromium and cadmium – are typically monitored for. In addition, antimony, molybdenum, selenium, thallium, vanadium and silver are listed on occasional consent conditions. While not a trace element, cyanide is included in the suite of compounds assessed in stormwater (Conwell, 2021).

[36] Specifically, total petroleum hydrocarbons (TPHs), polycyclic aromatic hydrocarbons (PAHs), organochlorine compounds, (OCs), and multi-screen tests for semi-volatile/volatile organic compounds (SVOC/VOCs) (Conwell, 2021).

[37] A global consent is an overarching consent over a specific region or district that allows a specific activity to take place. It reduces the number of individual consents, reduces the time and cost associated with compliance, and provides a mechanism for monitoring and managing the activity in a consistent way across catchments. Conwell, 2021, p.4, 13, 41.

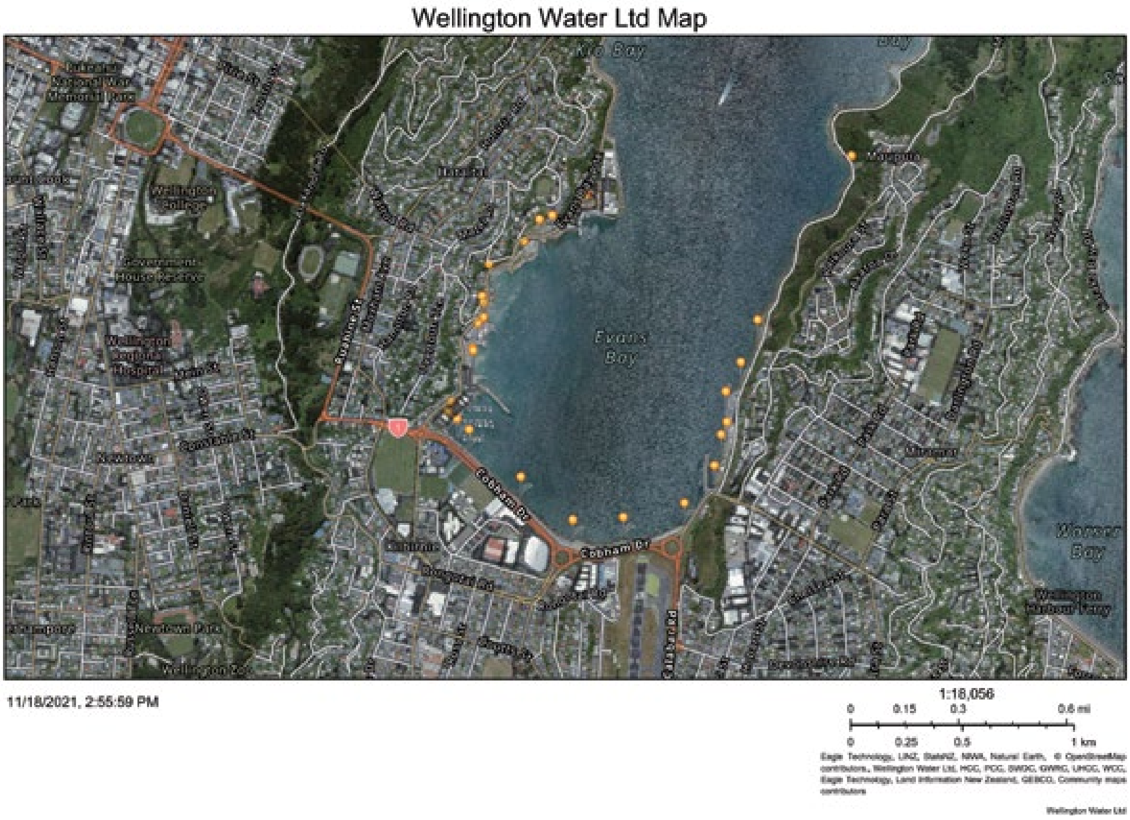
[38] Gadd and Milne, 2019, p.7. Automatic samplers are being developed but do not appear to be in routine use.

[39] Cavanagh and Ward, 2014.

Other chemicals aside from heavy metals and hydrocarbons are not usually included in stormwater resource consents. PFAS have been suggested, for example, as emerging contaminants to be included in biomonitoring programmes.[40]

A key challenge in monitoring both the quality of the stormwater and its environmental impact is *where* to monitor. The dual diffuse and point source nature of stormwater means it enters the environment at multiple points. The Kaiwharawhara Stream in Wellington, for example, drains a catchment of just 19 square kilometres. Yet it receives stormwater discharges at over 300 points despite its two main tributaries totalling just under 15 kilometres in length.[41] Similarly, stormwater, even in relatively small areas, discharges to multiple points in the coastal environment (see Figure 4.2).

Regulation of stormwater contaminant sources through the introduction of reduction targets has been used overseas but is currently limited in application in New Zealand (see box 4.1).



Source: Wellington Water ArcGIS

Figure 4.2: Multiple stormwater outlets in Wellington Harbour. Yellow markers indicate the exact locations stormwater discharges occur.

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[40] University of Auckland, 2019.

[41] See https://gis.wcc.govt.nz/LocalMaps/Gallery/ [accessed 10 December 2021].

Box 4.1: Reduction targets for heavy metals

The contribution of metals such as zinc and copper from sources such as degrading brake pads and tyres in the runoff from urban roads has been widely documented internationally. These have provided the evidence base for regulations that limit the use of these compounds in products. For example, a Californian brake pad law passed in 2014 limited the maximum allowable concentration of copper by weight to five per cent. This led to the introduction of the California Brake Friction Material Requirements in 2017.[42]

In New Zealand, SoE monitoring identifies the location of zinc exceedances in urban settings. Seventy-three per cent of sites in Auckland, 60 per cent in Wellington and 33 per cent in Christchurch exceed trigger values,[43] suggesting a possible impact on five per cent of species in freshwater ecosystems. However, understanding of the sources of heavy metals and their loads in urban areas is less well advanced. SoE monitoring programmes only provide a general view of the loads of metals such as copper or zinc reaching receiving environments at a specific point in time. They are insufficiently comprehensive to identify the contribution to loads by source with any confidence (e.g. from tyres, roofs).

An initiative to impose restrictions on the maximum amount of zinc in galvanised or zinc-coated roofing materials was considered for inclusion in the proposed Auckland Unitary Plan in 2013.[44] Despite numerous studies demonstrating these roofing types as sources of zinc, there was insufficient information to conclusively demonstrate that these are the major source of zinc in any urban area. This, together with the inability to enforce repainting of roofs that have lost their coating, has so far prevented regulators from setting maximum allowable concentrations of zinc per roofing product.

Agrichemical applications

Monitoring and managing the environmental effects of agrichemicals used in agriculture, horticulture and forestry is particularly complex because of the range of chemicals used, their toxicity and their use in close proximity to receiving environments. Chemicals used include pesticides (both applied directly to plants and land or as part of treated seed) and a range of veterinary medicine treatments. Controls are imposed through national-level processes under the Environmental Protection Authority (EPA) and Ministry for Primary Industries’ remit covering the different risk profiles of agrichemicals. However, national controls and conditions do not typically require monitoring (except in a small number of cases, such as the use of 1080). Further, the level of monitoring and control of agrichemical use at a regional level is limited due to the diffuse nature of the discharges and their release being a permitted activity under many regional plans.

As noted in chapter three, an environmental risk assessment is performed by the EPA for some substances during initial approval or during a reassessment. For agrichemicals, this process may entail quantitative modelling to estimate exposure. The risk assessments often result in tailored controls (e.g. a maximum application rate) based on the assumptions relied upon, in addition to the standard suite of controls that follow from a given hazard classification and use pattern.

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[42] https://dtsc.ca.gov/regs/hazardous-materials-motor-vehicle-brake-friction-materials/ [accessed 3 August 2021].

[43] MfE and Stats NZ, 2020.

[44] Auckland Council, 2013.

By contrast, a lower level of national scrutiny is applied to many other substances. While veterinary medicines are assessed for efficacy and animal health risks under the Agricultural Compounds and Veterinary Medicines Act 1997, the environmental risks have generally not been specifically assessed by the EPA because in most cases they are covered by group standard approvals or were approved by transfer at the initiation of the HSNO Act.[45] The controls that apply to these group standards are often based on hazard and use patterns that have been set with little scrutiny of the environmental fate of the contaminants within individual substances.

As a result, even where environmental risk from agrichemicals has been assessed, it has been done only at a high level based on multiple assumptions, not real-world on farm usage.

The suite of chemicals used, how they are used and in what quantities varies depending on land use, different management practices and different geographies. Some chemical users keep good records of what chemicals they use, where, in what quantities and when. Others do not. Even when records are kept, these tend to be for internal farm management purposes rather than regulatory purposes, although record keeping is sometimes required for certain chemicals (such as Hi-Cane for kiwifruit) either under the HSNO controls set by the EPA, by an industry body or the local regional council.

In a regulatory sense, we are managing the environmental effects of diffuse rural chemical use in a near vacuum. Only limited monitoring and testing of farm soils for chemical accumulation occurs. In certain scenarios, the acceptable annual loading of approved substances has been high enough to noticeably increase the natural levels of metal content in soils, and in adjacent ecosystems.[46] A lack of consideration for the long-term accumulation of such compounds may result in toxicity threshold exceedances.

Some of the risks arising from the regulatory gaps that relate to agrichemicals can usefully be illustrated by two examples: treated seed and animal wastes.

Imported treated seed

Seed treated with agrichemicals – including fungicides, pesticides and other chemicals – is imported into New Zealand. It is not currently regulated by the EPA because of an internal disagreement within the EPA about whether the seed is a manufactured article (and therefore interpreted as outside the rules relating to hazardous substances) or not. However, there are good reasons why imported seed treated with chemicals should not be considered a manufactured article. The chemical on the seed is designed to be taken up by the plant with the result that it must enter the environment rather than remain contained within the seed. Rather than treat the seed and coating as separate items, the coated seed should be regarded as a hazardous substance and any imported seed treated with chemicals should be regulated under the HSNO Act as a hazardous substance. This regulatory grey-area, caused by internal inconsistency, needs to be addressed by the EPA.

The issues around treated seed are elaborated further in chapter five.

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[45] Veterinary medicines that are 'finished dose' (e.g. a flea tablet in a blister pack) or 'closed-system application' (such as an oral drench applied with a drench-gun) are typically covered by group standards and do not require assessment as relatively little environmental exposure is anticipated.

[46] Robinson et al., 2006; Vermeulen and Kim, 2016.

Animal wastes

Group standards for veterinary medicines do not control contaminants that remain in animal wastes. Many veterinary medicines are able to be self-allocated by industry to group standards and have therefore not been subject to EPA risk assessment, with the result that few tailored controls relating to specific environmental risks of individual substances apply. The pathway of potential environmental exposure through manure is not considered under these group standards, which cover finished-dose or non-dispersive applications.

In view of the lack of regulatory guidance for the management of manure on productive land, some industries have taken a proactive approach to its handling and recycling (e.g. the Poultry Industry Association of New Zealand and DairyNZ). However, there does not seem to be adequate consideration within industry guidelines of the variable timeframes over which veterinary products degrade in manure and different types of soil. For example, the degradation of antibiotics in animal waste will depend on their exposure to ultraviolet light, temperatures and microorganisms and can range from less than two days to more than 180 days.[47]

Applying animal manure to productive land is also being addressed in the revision of the *Guidelines for the Safe Application of Biosolids to Land in New Zealand* mentioned earlier. The current 2003 guidelines do not include manure within the definition of biosolids, so provide no guidance on acceptable levels of organic and inorganic compounds in the manure. This is one of the areas still under discussion in finalising the 2017 draft revisions.

Source: Megan Martin

Figure 4.3: Domestic bioassay testing the impact of horse manure containing residues of herbicide on broad bean plants. Left: control plants (grown in herbicide-free potting mix); right: treated plants (plants exposed to herbicide).

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[47] Degradation variability is wide across antibiotics. For example, persistence of macrolides in liquid manure can range from two days to 130 days; persistence of sulphonamides range from eight days in broiler faeces to 90 days in laying hen faeces; and persistence of tiamulin in liquid manure can last for more than 180 days (Boxall et al., 2008).

The outliers

There are some forms in which chemicals may be present or released into the environment that are not easily categorised and do not fall neatly within the current regulatory regime. The two key pieces of legislation operate under different paradigms: the HSNO Act is substance-based and sets management controls at a national level across the lifecycle, whereas the RMA is effects-based and considers specific releases into receiving environments. As a consequence, there may be a lack of clarity for certain substances that do not neatly fit under the definition of a hazardous substance under the HSNO Act (or are exempt for other reasons) or are not yet recognised as contaminants that are able to be managed through regional-level processes under the RMA.

Manufactured articles

A manufactured article is defined by the EPA as "something for which its intended use is primarily to do with its physical shape, rather than its chemical composition". The EPA has taken the position that manufactured articles, aside from explosives and articles containing persistent organic pollutants, are not considered to be hazardous substances where they do not fit the definition in the Act.[48] This means chemicals arriving in New Zealand within many products lack any consideration of their impacts on the environment. An example is chemical additives in plastics. Chemical additives can make up a sizeable proportion of a polymer product and include stabilisers, antistatic agents, flame retardants and plasticisers. These articles are typically safe in their used form, but environmental risks arise when they break down into the environment. There is uncertainty around the environmental impact of some of these agents, as well as the rate and consequences of their leaching from plastics.[49] Toxic additives can also be present within fibre-based products such as cardboard packaging.

While there is provision for group standards to be issued for manufactured articles – as well as waste products and manufacturing by-products – few have been created.[50] An example of a group standard that does include manufactured articles is that covering graphic materials, which includes finger paints, children's crayons and children's water colour paints. It is unclear why group standards have not been created for other categories of manufactured articles, but it is likely to be a consequence of the mismatch between the size of the task set for the EPA and the resources available to it.

Naturally occurring contaminants

Naturally occurring contaminants may enter the environment in increased quantities as a result of human economic activity and land use. Examples include metals present in mine processing waste, or natural oestrogenic hormones from dairy cows. Some controls exist in the form of group standards (e.g. the Fertilisers (Subsidiary Hazard) Group Standard 2017), and also in the form of local controls over discharge quality (e.g. regional plan rules or resource consents for a discharge to water). How well the environmental fate of these contaminants is managed will depend on the capability and resourcing of individual councils.

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[48] EPA, 2011.

[49] Grant Northcott, Northcott Research Consultants Ltd, pers. comm., 23 October 2019.

[50] HSNO Act, s 96B(2)(d).

Complex mixtures and hazardous wastes

Mixed stored waste, such as a drum of used chemicals, also falls outside the scope of any one individual substance approval. While sites storing significant quantities of such wastes are subject to Health and Safety at Work Act 2015 and RMA rules, enforcement for non-compliances has proved challenging in practice. For example, at a property in Ruakākā, Northland, a stockpile of over 1 million litres of solvent was found to be stored in a haphazard condition, far exceeding the initial land use consent for 50,000 litres. It took several years to initiate an effective clean-up despite concerns being voiced by regulators at all levels.

Similar issues can arise for the by-products of manufacturing processes that do not require EPA approval as they are neither imported nor specifically manufactured. For example, dross created during the manufacturing of aluminium is a hazardous by-product of a non-hazardous material manufacturing process.

Managing the environmental fate of these potentially very hazardous substances relies almost entirely on the capacity and technical capabilities of regional councils and is probably beyond most of them individually. Given the environmental risks, greater national-level guidance and technical assistance to regional councils is needed.

In summary

There is a wide variety of sources and pathways by which chemicals may enter receiving environments. For some, like landfill leachate and wastewater, the main regulatory challenge is not knowing where it enters the environment (which is relatively easy to define), but rather controlling what substances have entered the system, assuming that they are even known. Other sources and pathways, such as stormwater and agrichemical use, are diffuse, making it hard to know both what is being discharged to the environment and where. And then there are other potential ‘outlier’ sources – such as manufactured articles, naturally occurring contaminants and complex mixtures – that are under-regulated and would benefit from greater national-level guidance.

The different pieces of guidance and legislation in place add up to a complex picture of regulation from importation through to release into receiving environments. It is a mosaic of approval, guidance, consenting and monitoring that does not always capture the environmental fate of some contaminants and in other cases misses them entirely.

Nephrolepis flexuosa

5

Chemical case studies

Introduction

The preceding chapters have introduced the scientific tools used to understand the environmental fate and impacts of chemicals in New Zealand, and the regulatory system that governs them. This chapter follows four chemical substances through the lifecycle of their use and disposal to illustrate the way the regulatory system intervenes – or does not – to limit their impact on the environment. The four chosen substances are:

- the **neonicotinoid** class of insecticides
- **tetracycline** antibiotics
- the herbicide **terbuthylazine**
- the metal **zinc**.

Each of the four chemicals poses some potential hazard to the environment.[1] In other respects, they are heterogenous, representing different use patterns (agricultural, industrial, household), different likely receiving environments (surface water, land, groundwater and coastal) and different degrees of knowledge about the impacts of the chemical.

The case studies highlight the different approaches to the management and level of monitoring for each chemical. The selected chemicals are not representative of all chemicals approved and used in New Zealand, and their selection is *not* an indication of any priority for regulatory review or control. The intention of providing case studies is, rather, to provide the reader with illustrative examples of the different ways the environmental fate of chemicals is managed by New Zealand's regulatory system.

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[1] A workshop was held to assist with the selection. The workshop included experts in the fields of ecotoxicology and environmental chemistry and ecologists with specific knowledge of the different compounds or elements, receiving environments and regulators. Key criteria considered included persistence (and/or pseudo-persistence), potential for significant negative impact on receiving environments (e.g. through bioaccumulation or biomagnification) and significant (and/or increasing) volume of use.

The neonicotinoid case study includes insights into the extent that the regulatory system accommodates concerns held by Māori about the impact of chemical contamination on or in habitats containing taonga species. Impacts range from the degradation of the mauri of individuals and ecosystems to effects on mahinga kai or rongoā (traditional medicine) that may be consumed by people. This case study includes a specific example of concerns raised by Māori during the approval process for a neonicotinoid-containing product, or in applications for specific uses of a product. It should be noted that this application was lodged in 2014 and the EPA has since taken steps to improve the use of mātauranga Māori in the decision-making process.[2]

Each case study provides an overview of the chemical and its use patterns, evidence for environmental contamination associated with its use, and the regulations that apply to it in New Zealand. Each includes a semi-quantitative mass flow analysis of the volumes of the chemicals across their lifecycles in New Zealand. These analyses show estimated volumes from import and manufacture, through to their key uses, and their potential outputs into receiving environments. They also provide an indication of gaps in knowledge. The data presented were informed by regulatory and industry sources. Table 5.1 provides a summary of the chemicals and key aspects considered.

Supplemental information for each case study is available in the appendices.

Table 5.1: Summary of selected chemicals and key aspects considered in the case studies.

	Neonicotinoids	Tetracyclines	Terbuthylazine	Zinc
Imported form	• Active substance • Formulations • Coated seeds	• Product (antibiotic)	• Active substance • Formulations	• Active substance or raw material • Formulations • Articles
Use pattern	• Agriculture • Household • Veterinary treatment • Timber treatment	• Agriculture • Household	• Forestry • Agriculture • Utility vegetation control	• Industry • Household • Agriculture
Source of pollution	• Diffuse	• Point source • Diffuse	• Diffuse	• Point source • Diffuse
Receiving environment	• Soil • Groundwater • Freshwater	• Soil • Coastal	• Soil • Groundwater • Freshwater	• Soil • Groundwater • Freshwater • Coastal
Monitoring in the environment	• Limited (one-off soil and stream surveys)	• None	• Some routine monitoring in groundwater and surface water • Limited in soils	• Routine monitoring in groundwater and surface waters, coastal sediments, soils

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[2] See chapter three.

Neonicotinoids

Overview of the chemical and its use

Neonicotinoids are a class of systemic insecticides with a chemical structure similar to nicotine. They were first developed in the late 1980s. The main marketed neonicotinoids (in order of development) are nithiazine, imidacloprid, thiacloprid, thiamethoxam, nitenpyram, acetamiprid, clothianidin and dinotefuran.

These insecticides are neurotoxic. They act by binding to nicotinic receptors that transmit nerve activity in the invertebrate nervous system. Unlike natural neurotransmitters, which are quickly broken down by natural enzymes, neonicotinoids are not easily broken down. When these chemicals bind to the nicotinic receptors, they cause continual stimulation of the invertebrate nervous system, which eventually leads to paralysis and death.

Neonicotinoids have selective toxicity for insects over vertebrates.[3] They are highly effective against sucking and chewing insect pests but have a very low affinity for vertebrate nicotinic receptors because the binding sites in vertebrates have a slightly different structure; therefore, neonicotinoids have low vertebrate toxicity.[4]

Neonicotinoids have become the most widely used insecticides in the world. They are commonly used as seed treatments, a convenient method of application whereby seed is coated with the insecticide prior to sowing in soil. The chemical is then taken up by the germinating plant and is distributed throughout the developing plant, known as systemic action.

In horticultural products they can also be used as foliar sprays, soil drenches and granules.

In addition to the use patterns mentioned above, imidacloprid – the most widely used neonicotinoid globally – is the active ingredient in household insecticides, wood preservative products for controlling termites, and several flea treatment products for agricultural and domestic parasite control. It was first registered for use in New Zealand in 1992, with thiamethoxam and thiacloprid later being registered in 2000, clothianidin in 2003 and acetamiprid in 2006 (though there are currently no products containing acetamiprid sold for use in New Zealand).[5]

Semi-quantitative mass flow analysis

There is no systematic reporting for neonicotinoids imported, manufactured, sold or used in New Zealand at a regional or national level. To arrive at an estimate, sales volumes of neonicotinoid-containing products in 2019 and estimates of their use in key sectors in New Zealand were sought from key industry members. From the data supplied, the following estimate of neonicotinoid use in New Zealand was made (Figure 5.1). Any attempt to understand possible environmental contamination from the use of neonicotinoids would benefit from this information on volumes applied. Known contamination of receiving environments shown in Figure 5.1 comes from one-off monitoring studies. A summary of neonicotinoid usage in seed treatments is provided in Table 5.2.

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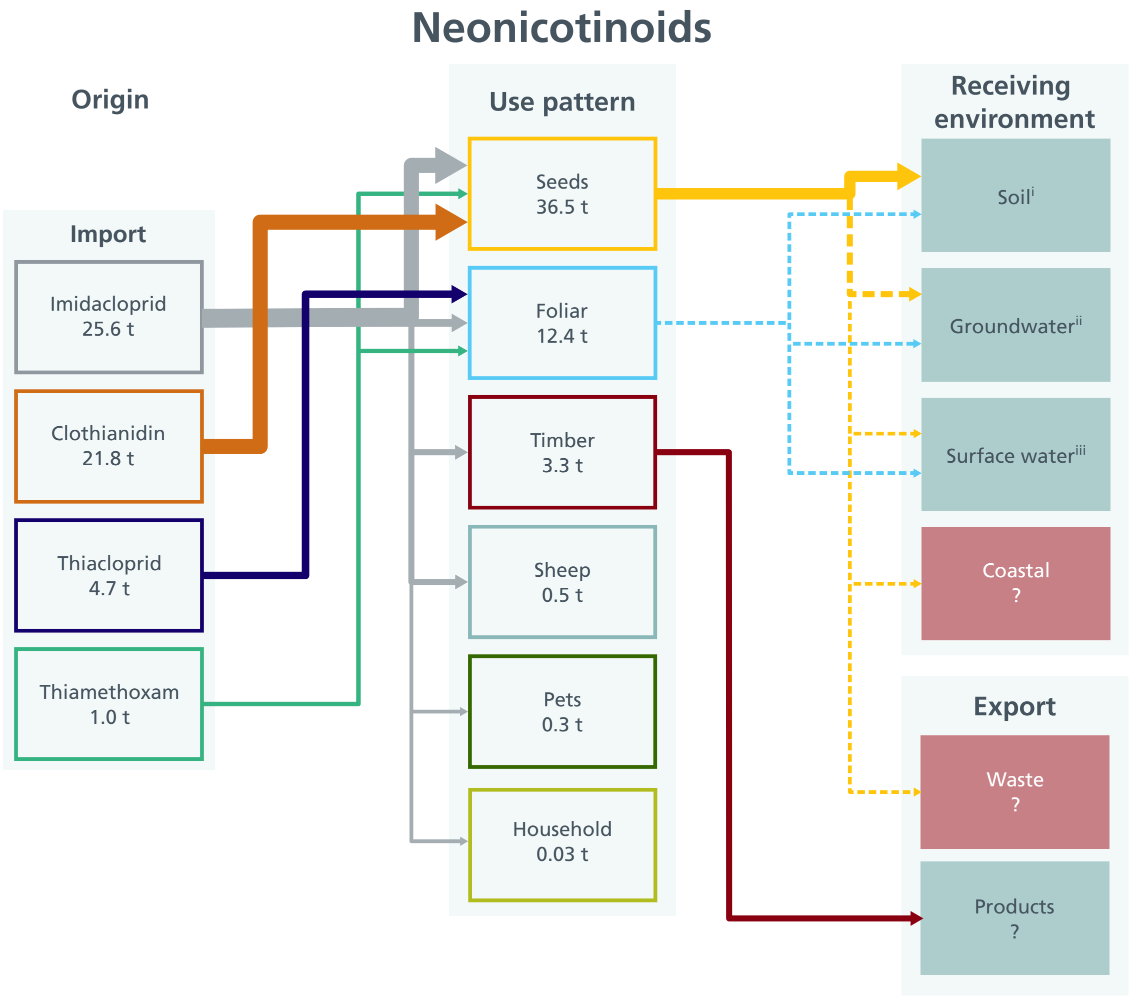
[3] Matsuda et al., 2001.

[4] Tomizawa and Casida, 2005.

[5] Acetamiprid has been approved for use on ornamental plants and fly sprays.



Source: PCE

Notes:
Pink boxes denote unknown quantities. Arrow width is indicative of the mass flow to next point. Dotted arrows denote uncertainty in the mass flow along this pathway.

i Imidacloprid and clothianidin detected in > 95% of soil samples from New Zealand maize fields. Imidacloprid concentrations exceeded 1 µg/kg.[6]

ii Imidacloprid, clothianidin and thiamethoxam were detected in groundwater samples at 9, 12 and 4 sites, respectively, in the Waikato region (47 state of the environment (SoE) monitoring sites and 9 additional targeted sites were sampled). Concentrations detected ranged from 0.0062 to 0.32 µg/L for imidacloprid, 0.0002 to 0.15 µg/L for clothianidin and 0.0057 to 1.8 µg/L for thiamethoxam.[7]

iii The first nationwide survey of pesticides in New Zealand streams found imidacloprid, clothianidin and thiamethoxam in 22%, 8% and 3% of samples, respectively.[8]

Figure 5.1: Semi-quantitative mass flow diagram for neonicotinoids imported and sold for use in New Zealand in 2019. See Table 5.2 for a breakdown of seed treatments by crop type.

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[6] Pook and Gritcan, 2019.

[7] Moreau et al., 2019.

[8] Hageman et al., 2019.

Table 5.2: Percentage of seed treated with neonicotinoids in New Zealand.

Crop type	% of seed treated	Neonicotinoids used
Pasture	45	Clothianidin
Forage brassicas	90	Imidacloprid Thiamethoxam
Fodder beet	75	Imidacloprid Clothianidin Thiamethoxam
Maize	95	Clothianidin
Cereals	90	Clothianidin

Environmental fate and exposure to non-target organisms

When applied as a seed coating, it is estimated that between 2 and 20 per cent of the active ingredient is taken up by the germinating plant.[9] The remainder is left in the soil where it can persist or degrade, depending on soil conditions, or be transported into the wider environment. The systemic activity of neonicotinoids, enabling their use as seed treatments, is made possible by their high solubility. The same property, however, results in mobility through the environment, including contamination of groundwater and leaching or runoff into surface waters during rainfall (Figure 5.2).[10]

Half-lives (DT_{50}) in soil vary considerably depending on soil type. For the three neonicotinoids used as seed treatments, DT_{50} values range from 28 to 1,250 days for imidacloprid, 148 to 6,931 days for clothianidin and 7 to 353 days for thiamethoxam.[11] Several field studies have found neonicotinoids present in agricultural soils more than a year following application by sowing of treated seeds.[12] These include detections of imidacloprid and clothianidin in maize fields in the North Island, with reported soil concentrations of imidacloprid exceeding 1 part per billion (the levels for which the Environmental Protection Authority (EPA) has set an environmental exposure limit (EEL) for some substances containing imidacloprid).[13]

With repeated annual application, neonicotinoid residues can accumulate in soil where they can still be detected several years after the last known application. Evidence from field studies suggests that degradation ensures that there is not indefinite accumulation in soils, but that neonicotinoid concentrations plateau after two to six years of repeated application. Nevertheless, these studies also show that the annual sowing of treated seed causes chronic contamination of soils with neonicotinoids in low concentrations (in the parts per billion range), which will act as a constant source of exposure for soil-dwelling organisms and for their transport into the wider environment.[14]

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[9] Sur and Stork, 2003; Alford and Krupke, 2017.

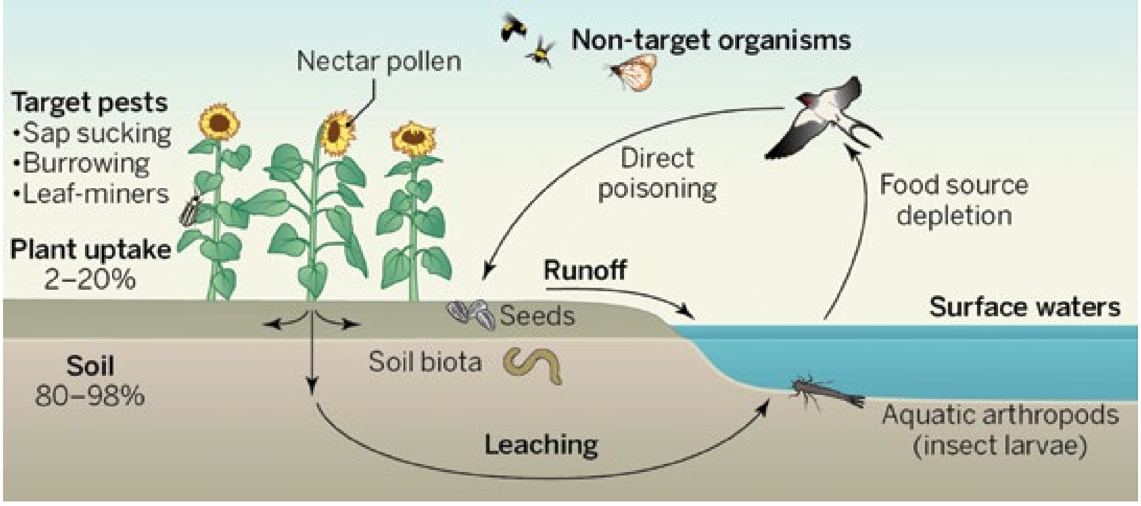
[10] Morrissey et al., 2015.

[11] Goulson, 2013. Note that clothianidin is also a primary metabolite of thiamethoxam.

[12] Wood and Goulson, 2017.

[13] Pook and Gritcan, 2019.

[14] Wood and Goulson, 2017.



Source: Sánchez-Bayo, 2014

Figure 5.2: Environmental fate and exposure of neonicotinoids to target and non-target organisms when applied as a seed coating.

Although direct exposure of non-target organisms to neonicotinoid spray drift is avoided when applied as seed treatments, contaminated dust clouds generated during the sowing of treated seed and contaminated plant tissues can become important routes of exposure to non-target insects, especially bees and other pollinators.[15] Overseas studies show that toxic concentrations can be present in pollen, nectar and sap of both treated crops and non-target plants.[16,17] An analysis of honey from across the world found neonicotinoids present in 75 per cent of samples, including in New Zealand.[18]

Due to their high solubility, the major source of surface water contamination by neonicotinoids is from runoff after periods of high rainfall, which can cause pulses of higher concentrations to enter waterways.[19] Low concentrations of neonicotinoids continuously leach through soils into groundwater and can enter into surrounding surface waters via subsurface flows.[20] Neonicotinoids can also enter surface waters through snow melt, spray drift from foliar application, contaminated dust clouds during seed planting, and transport of decaying neonicotinoid-treated plant material into waterbodies.[21]

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[15] Girolami et al., 2012; Tapparo et al., 2012. See Appendix 7.3 for further details about methods employed to reduce dust drift.

[16] Girolami et al., 2009; Tapparo et al., 2011; Krupke et al., 2012; Stoner and Eitzer, 2012.

[17] Botías et al., 2015; David et al., 2016. See Appendix 7.3 for further details about non-target plant contamination.

[18] Mitchell et al., 2017.

[19] Chiovarou and Siewicki, 2008; Hladik et al., 2014; Struger et al., 2017; Hladik et al., 2018a.

[20] Lamers et al., 2011; Huseth and Groves, 2014.

[21] Kreutzweiser et al., 2008; Nuyttens et al., 2013; Main et al., 2014; Bonmatin et al., 2015.

Although neonicotinoids generally degrade quickly by exposure to light in water (aqueous photolysis),[22] they degrade much more slowly by hydrolysis (in water in the absence of light).[23] It is clear from global monitoring data that the high leaching potential, solubility and usage patterns of neonicotinoids result in contamination of surface waters at potentially toxic concentrations to non-target aquatic organisms (see 'Key environmental concerns' section below).

Ecotoxicity and environmental threshold values

Neonicotinoids are very toxic to non-target insects, though toxicity varies depending on the active ingredient. For example, thiacloprid and acetamiprid are considerably less toxic to honeybees (*Apis mellifera*) than imidacloprid, clothianidin and thiamethoxam (Table 5.3).

In stark contrast to their toxicity to non-target insects (both terrestrial and aquatic), neonicotinoids have much lower toxicity to other terrestrial invertebrates such as worms and slugs.[24] Algae, fish and the common test crustacean *Daphnia magna* are also tolerant to neonicotinoids (Table 5.3). However, the low toxicity of neonicotinoids to *D. magna* is not representative of the sensitivity of other aquatic invertebrates to neonicotinoids, the most sensitive (mayflies and midges) having average toxicity values several orders of magnitude lower than *D. magna*.[25]

Table 5.3: Acute and chronic toxicity of neonicotinoids to standard test species, as expressed by the effective concentration (EC_{50}) or lethal dose (LD_{50}) that adversely affects 50 per cent of test organisms (parts per billion as µg/L or µg/kg; or µg/bee).[26]

Neonicotinoid compound	Algae (µg/L)[i]	Water flea (µg/L)[ii]	Earthworm (µg/kg)[iii]	Honeybee (µg/bee)[iv]	Fish (µg/L)[v]
Thiacloprid	60,600	> 85,100	105,000	17.32	> 90,100
Acetamiprid	> 98,300	49,800	9,000	14.53	> 100,000
Thiamethoxam	> 100,000	> 100,000	> 1,000,000	0.005	> 125,000
Imidacloprid	> 10,000	85,000	10,700	0.0037	> 83,000
Clothianidin	55,000	> 40,000	13,210	0.004	> 104,200

Notes:

[i] *Selenastrum capricornutum*, *Scenedesmus subspicatus* or *Pseudokirchneriella subcapitata* 72-hour EC_{50} (growth).

[ii] *Daphnia magna* 48-hour EC_{50}.

[iii] *Eisenia fetida* 14-day LC_{50}.

[iv] *Apis* spp. oral acute LD_{50} worst case from 24-, 48- and 72-hour values.

[v] *Oncorhynchus mykiss* (rainbow trout) 96-hour LC_{50}.

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[22] Aqueous photolysis DT_{50} values of 0.1, 0.2 and 2.7 days for clothianidin, imidacloprid and thiamethoxam, respectively.

[23] The hydrolysis DT_{50} of imidacloprid is between 33 and 44 days.

[24] See Appendix 7.3 for further details about ecotoxicity to honeybees and terrestrial invertebrates.

[25] Morrissey et al. (2015) reviewed 178 acute toxicity studies with neonicotinoids, conducted with 49 arthropod species, and calculated a mean LC_{50} for mayflies of 3.9 parts per billion, whereas the mean LC_{50} for *Daphnia magna* was ≥ 44,000 parts per billion.

[26] University of Hertfordshire, 2021.

In New Zealand, four substances containing imidacloprid are subject to an EEL for soil/sediment of one part per billion (microgram per kilogram dry weight) and for water of 0.038 parts per billion (microgram per litre). A comparison with other international aquatic exposure limits for imidacloprid is provided in Table 5.4.[27] None of the substances for which these limits have been set are agricultural insecticides (two flea treatments for pets, one bed bug treatment and one wood preservative product).

One substance containing thiamethoxam has an EEL for freshwater of 0.35 parts per billion (micrograms per litre) and 69 parts per billion (micrograms per litre) for marine environments. This is a foliar spray used in horticulture and in-furrow planting in potatoes. There are no EELs set by the EPA for substances containing the other neonicotinoids registered for use in New Zealand.

Table 5.4: Comparison of aquatic exposure limits for imidacloprid.

Source	(Acute/chronic)	Exposure limit (µg/L)
United States Environmental Protection Agency aquatic life benchmark (invertebrates)	Acute	0.385
	Chronic	0.01
Canadian Council of Ministers of the Environment Water Quality Guidelines	Chronic	0.23
European Union Water Framework Directive	Acute	0.2
	Chronic	0.0083
Environmental Protection Authority environmental exposure limit (water)	Chronic	0.038

There are no maximum acceptable values set for drinking water in New Zealand for any neonicotinoids, nor in World Health Organization drinking water guideline values for that matter.[28,29] Imidacloprid is on a list of chemicals awaiting the derivation of default values for inclusion in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Key environmental concerns

The major environmental concern of neonicotinoid use is their negative effects on non-target insects, especially pollinators.[30] Following a risk assessment of three neonicotinoids (clothianidin, imidacloprid, thiamethoxam) to bees published by the European Food Safety Authority in 2013,[31] the European Commission severely restricted the use of these active substances on crops attractive to bees (oilseed rape and sunflower) with the exception of use in greenhouses.[32] Following the European Food Safety Authority's review of neonicotinoids and subsequent restrictions on outdoor use, the EPA opened two calls for information for the three neonicotinoids in August 2018, and for thiacloprid and acetamiprid in April 2020.

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[27] Hladik et al., 2018b.

[28] Ministry of Health, 2018.

[29] WHO, 2017.

[30] See Appendix 7.3 for further details about ecotoxicity to honeybees and terrestrial insects.

[31] EFSA, 2013a, b, c.

[32] European Union, 2013. See https://ec.europa.eu/commission/presscorner/detail/en/IP_13_708 [accessed 8 December 2021].

Information requested included manufacture and import volumes, use and application, environmental exposure mitigation measures, and scientific and technical information on the ecotoxicity or occurrence of neonicotinoids in the environment.[33] The EPA then determined that there were grounds to reassess neonicotinoids in New Zealand, and this reassessment is planned to run at the same time as the Australian Pesticides and Veterinary Medicines Authority review of neonicotinoids.

Contamination of surface waters with neonicotinoids has become a global problem.[34] A review of surface water surveys covering 11 countries found imidacloprid at average concentrations of 0.73 parts per billion (micrograms per litre).[35] The average concentrations of all neonicotinoids in water exceeded the European aquatic exposure limit 27 per cent of the time, and the Canadian and United States aquatic limits 66 and 79 per cent of the time, respectively.

The only regular monitoring of pesticides in the New Zealand environment is a four-yearly survey of groundwater, last carried out by regional councils and coordinated by the Institute of Environmental Science and Research (ESR) in 2018.[36] However, these surveys have yet to test for neonicotinoids. A one-off survey of emerging contaminants in groundwater in the Waikato region detected imidacloprid, clothianidin and thiamethoxam in samples from 9, 12 and 4 sites, respectively.[37] The first nationwide survey of pesticides in New Zealand's streams found imidacloprid, clothianidin and thiamethoxam in 22, 8 and 3 per cent of the samples, respectively.[38] The highest concentrations measured in both of these one-off surveys were below the EPA's EELs.

In a survey of soil from maize fields in the North Island, imidacloprid was detected in 43 out of 45 samples and clothianidin in every sample.[39] At eight of the nine sites sampled, imidacloprid exceeded the EPA's EEL of one microgram per kilogram. This study showed that neonicotinoids used in maize seed treatments in New Zealand can leave residues in the soil for at least two years following application. Further monitoring of soil, groundwater and surface water in areas of neonicotinoid use in New Zealand is required to improve our understanding of the potential environmental contamination of these insecticides, and the risk of hazardous exposure to non-target organisms.

Regulation

The EPA regulates products containing the neonicotinoid active ingredients under the Hazardous Substances and New Organisms Act 1996 (HSNO Act). Imidacloprid, clothianidin, thiamethoxam have approved seed treatment formulations. Apart from clothianidin, the other four registered active ingredients also have suspension concentrate formulations approved for use as foliar sprays. Imidacloprid and thiacloprid are approved substances for use as timber treatments or wood preservatives, in household insecticides (termiticides, ant and fly baits) and veterinary treatments for fleas and lice. Acetamiprid is approved for use on ornamental plants and in fly sprays, but there are currently no products containing this active ingredient sold for use in New Zealand.

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[33] EPA, 2021j. See https://www.epa.govt.nz/public-consultations/in-progress/call-for-information-on-clothianidin-imidacloprid-and-thiamethoxam/ [accessed 8 December 2021].

[34] Morrissey et al., 2015.

[35] Sánchez-Bayo et al., 2016. This average concentration is the geometric mean from 33 surveys.

[36] Close and Humphries, 2019.

[37] Moreau et al., 2019.

[38] Hageman et al., 2019. This survey sampled 36 streams across New Zealand in the Waikato, Canterbury, Otago and Southland regions and occurred during a long drought when in-stream pesticide concentrations are at their lowest.

[39] Pook and Gritcan, 2019.

Imidacloprid, thiamethoxam and acetamiprid were approved under the HSNO Act on 1 July 2006 via the Hazardous Substances (Chemicals) Transfer Notice 2006. Thiacloprid was approved on 25 November 2009. While clothianidin does not have an individual approval, it is listed on the New Zealand Inventory of Chemicals and there are approvals for clothianidin-containing substances.

Tables in Appendix 7.3 summarise the HSNO default controls applied to products containing imidacloprid (Table 7.3.1), and clothianidin, thiamethoxam and thiacloprid (Table 7.3.2) for their main uses.

Once approved by the EPA, agricultural products containing neonicotinoids are registered by the Ministry for Primary Industries (MPI), which records the trade names under which they are registered under the Agricultural Compounds and Veterinary Medicines Act 1997 (ACVM Act).

In contrast to other uses, imported seed pre-treated with neonicotinoids is not currently regulated under the HSNO Act.[40] This discrepancy seems to arise because imported neonicotinoid-coated seed has been considered to be a manufactured article by the EPA, which falls outside of the scope of the HSNO Act according to the EPA's interpretation of the law.

However, it can be argued that a seed coated in a hazardous substance should be considered in terms of its hazardous properties – that is, the seed and the neonicotinoid coating cannot be considered separate items. It can also be argued that seeds coated in a hazardous substance are not a 'manufactured article' as that term is defined in the definition of 'substances' in the HSNO Act. Accordingly, imported neonicotinoid-coated seed *should* be regulated under the HSNO Act because planting it involves the release of a hazardous substance into the environment. There is also no clear exemption for coated seeds from regulation by the ACVM Act, so they should also be registered by MPI.

Neither national regulatory agency requires the monitoring of neonicotinoid residues or their metabolites in the New Zealand environment. Therefore, existing data on neonicotinoid contamination of the environment are from one-off surveys by New Zealand research groups.

Māori involvement in the application to import the neonicotinoid pesticide Solvigo (containing thiamethoxan), lodged with the EPA in 2014 under the HSNO Act, occurred at numerous levels. During the pre-application process an EPA staff report assessed the application and Kaupapa Kura Taiao advised that there was no need to consult Māori based on their internal criteria. When the application was publicly notified, Te Rūnanga o Ngāi Tahu submitted a recommendation to the EPA to decline an application for the use of Solvigo because the ecotoxicity information provided was not specific to New Zealand species,[41] or too few species had been tested to cover the range of species potentially impacted by the pesticide's use (e.g. macrophytes, aquatic macro-crustacea or molluscs).[42]

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[40] Imported treated seed is estimated to be only a small proportion of neonic-treated seed compared to domestically coated seed (approx. < 10%). Maize and fodder beet seed are the key crops imported pre-treated with neonicotinoids.

[41] See Appendix 7.3 for information from the scientific literature on neonicotinoid toxicity to New Zealand native species.

[42] Other concerns included not being able to receive information that was deemed confidential, and that expert advice should be sought to determine whether there were cultural impacts (Sutherland, 2014a).

Ngā Kaihautū Tikanga Taiao, EPA's independent statutory Māori advisory committee group, also produced a report during the public notification period in which it also highlighted concerns about whether the toxicity data was sufficiently protective for endemic species, especially invertebrate species. Further, it raised concerns that the applicant had determined that "under normal conditions the substance will have no detrimental effects on cultural, spiritual and ethical issues", even though there was no evidence of (a) engagement with Māori as part of the application process or (b) relevant applicant expertise to substantiate this claim.[43] In considering all of the information, the EPA's Māori Policy and Operations decision-making committee determined that the use of Solvigo was unlikely to pose an inconsistency with the principles of the Treaty of Waitangi or impact the relationship that Māori have with the environment.

Although this case demonstrates how the HSNO application process can facilitate multiple views and perspectives to be placed before the decision makers, they must ultimately be satisfied that, in approving an application, there are sufficient controls in place to mitigate or minimise significant risks. This decision, however, might not reflect the views or concerns presented in submissions by Ngāi Tahu.

Tetracyclines

Overview of the chemical and its use

Tetracyclines are a family of broad-spectrum antibiotics designed to inhibit the synthesis of proteins in bacterial cells. This results in the impairment of cellular growth and bacterial death.[44] While tetracyclines are designed to act on a wide range of gram-positive and gram-negative bacteria,[45] concerns about their possible adverse effects on non-target organisms and their role in the development of antimicrobial resistance are on the rise.[46]

Tetracyclines are some of the most frequently used antibiotics (e.g. doxycycline or oxytetracycline) due to their action against a wide range of bacteria and low cost. They are used to treat human and animal infections in the skin, chest, urinary tract, genitals and lymph nodes. They are used in combination with other medications to treat stomach ulcers and as a prophylaxis for malaria. In New Zealand, tetracyclines are mainly used in multiple production species (such as cattle, sheep and pigs), with smaller amounts used in companion animals and aviary birds.

Tetracyclines are widely used worldwide, and while the total amount used by humans per year is difficult to estimate, a 2015 estimate of the global consumption of antibiotics in livestock alone was 63,000 tonnes, with predictions of an increase to 107,000 tonnes by 2030.[47]

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[43] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP201999/cad7b23bba/APP201999-APP201999-Solvigo-NKTT-Report.pdf [accessed 14 September 2021].

[44] Chopra and Roberts, 2001.

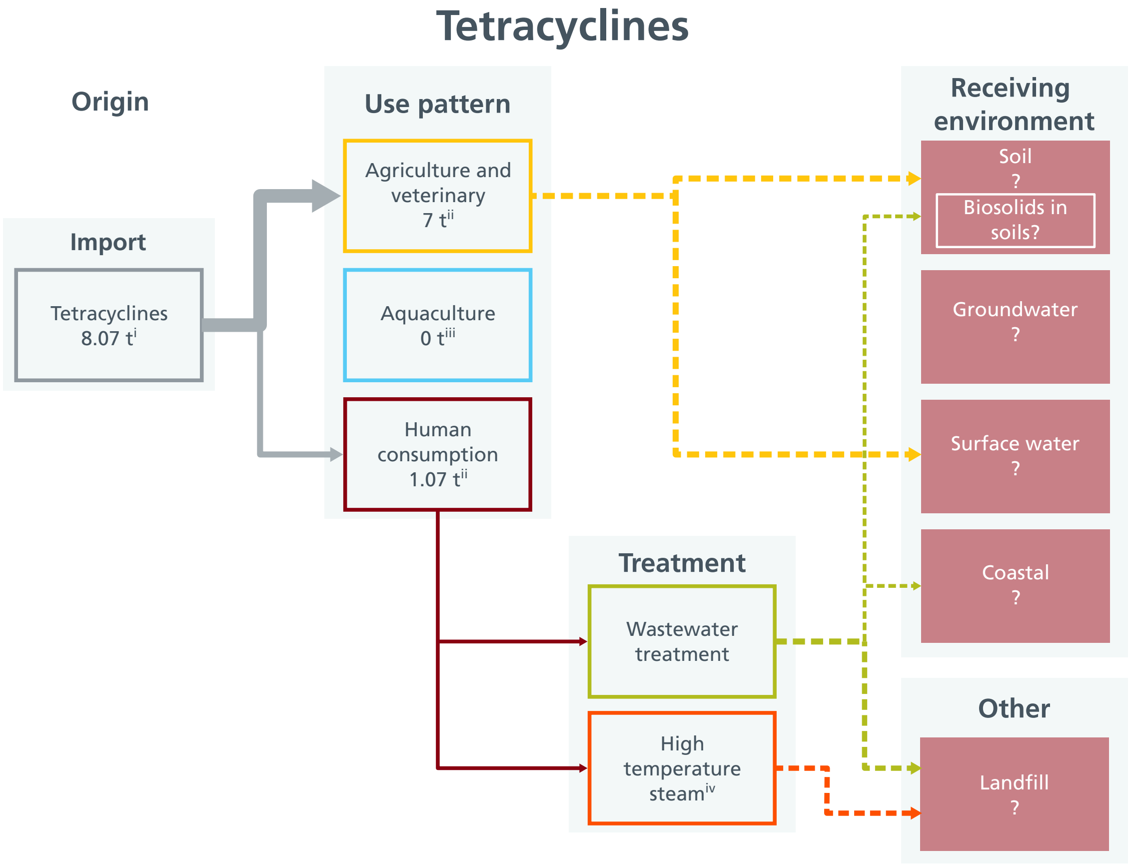
[45] Gram positive bacteria are characterised for having a thick cellular layer called peptidoglycan and an outer lipid membrane. Conversely, gram negative bacteria have a thin layer and lack an outer lipid membrane.

[46] Chow et al., 2021. See Appendix 7.4 for details about development of antimicrobial resistance.

[47] van Boeckel et al., 2015.

Semi-quantitative mass flow analysis

There is no systematic reporting for tetracycline antibiotics imported in New Zealand at a regional or national level. However, the use of tetracyclines for human and livestock treatment is recorded by the Ministry of Health and MPI, although the data are not comprehensive. There is no information available on the quantity of tetracyclines reaching receiving environments from either point or diffuse sources for the year 2019 (Figure 5.3).



Source: PCE

Notes:

Pink boxes denote unknown quantities. Arrow width is indicative of the mass flow to next point. Dotted arrows denote uncertainty in the mass flow along this pathway.

[i] Not a comprehensive volume due to limited import information available.

[ii] Active ingredient.

[iii] Tetracyclines are commonly used in aquaculture farms overseas but were not reported as used in New Zealand's aquaculture industry in 2019.

[iv] High temperature steam (140 °C) is the current approach to inactivate medical waste in New Zealand. The process may not be effective for some pharmaceuticals but can be adequate for tetracyclines (> 98% of the initial concentration of the residues of tetracyclines get destroyed).

Figure 5.3: Semi-quantitative mass flow diagram for tetracycline compounds imported and sold for use in New Zealand in 2019.

Environmental fate and exposure to non-target organisms

Tetracyclines can readily dissolve in water and are often not fully metabolised by the body. On average, more than 75 per cent of tetracyclines consumed by humans and livestock are released into the environment in an active form (either as the parent compound or as a metabolite) via faeces and urine, through the spread of manure and biosolids, or via treatment plant effluents.[48]

Tetracyclines have an affinity for sticking or fixing to soil, sludge, manure and sediments. They are highly adsorbed by acidic and clay soils, and under these conditions are less likely to leach to surface and groundwater or be taken up by organisms. The stronger the bonds between soils and tetracyclines, the lower the uptake by organisms and the slower the degradation. This suggests that strong bonds may increase the half-life (DT_{50}) of tetracyclines (86.6 days), which is longer than that of other antibiotics.[49]

Once in the environment, tetracyclines break down under the action of ultraviolet and microbial activity. However, degradation of tetracyclines in soils is also further influenced by the presence of specific metal ions, type of soil and pH.[50]

The tetracycline family has three generations of tetracyclines,[51] each with different metabolisation rates. First generation tetracyclines have minimal metabolisation, with only five per cent of the parent compound being converted to the metabolite 4-epitetracycline. Conversely, second generation tetracyclines, such as minocycline, can break down into up to six metabolites, with the main one being 9-hydroxyminocycline.[52] Less than 20 per cent of third generation tetracyclines are metabolised, breaking down into metabolites, such as glucuronide and N-acetyl-9-aminominocycline.

Worldwide, tetracyclines are the second most frequently used class of antibiotics detected in the environment.[53] It has been shown that, in general, repeated use of manure from livestock as fertiliser has resulted in the release of tetracycline residues into agricultural soils. Concentrations of tetracyclines in manure from livestock on farms around the world were in the range of 30 to 1,210,000 micrograms per kilogram,[54] and concentrations of tetracyclines in agricultural soils following manure application as fertiliser were between 3 and 970 micrograms per kilogram.[55] The strong adsorption and the slow degradation of tetracycline results in its persistence in topsoil, leading to potentially higher environmental risks to microorganisms.[56]

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[48] Boxall et al., 2008; Scaria et al., 2021. See Appendix 7.4 for details about alternative pathways for the movement of tetracyclines into the environment.

[49] Pan and Chu, 2016.

[50] Degradation of tetracyclines can be inhibited when they bind to magnesium, hydrated iron and manganese oxides. Conversely, degradation is enhanced by bonds between tetracyclines and calcium. In water, degradation is enhanced by bonds with ferric (Fe^{3+}) ions. See Appendix 7.4 for further details about factors affecting degradation of tetracyclines in receiving environments.

[51] First generation tetracyclines, obtained from natural biosynthesis, include chlortetracycline, oxytetracycline, tetracycline, and demethylchlortetracycline. Second generation tetracyclines, obtained from semi-synthesis of tetracyclines, include doxycycline, minocycline, lymecycline and demeclocycline. Third generation tetracyclines, obtained from total synthesis, include tigecycline. In New Zealand, the most widely used tetracyclines are from the first and second generation.

[52] Agwuh and MacGowan, 2006.

[53] Nunes et al., 2015.

[54] Monitoring of other tetracyclines such as oxytetracycline have been reported at concentrations between 30 and 183,000 µg/kg. Conde-Cid et al., 2018.

[55] Conde-Cid et al., 2020.

[56] Pan and Chu, 2016.

Research on tetracyclines (specifically oxytetracycline, from the first-generation group) in surface waters suggests there is a low risk of contamination to those environments from diffuse sources. However, tetracyclines in wastewater effluents carries a medium environmental risk to sensitive microalgae and cyanobacteria species when discharged into surface waters. Although tetracyclines and their metabolites are found in relatively low concentrations in most overseas surveyed environments, they have been frequently detected (in above 80 per cent of samples) on account of continuous use and ongoing release. Even concentrations below analytical tools' detection limits have proved to be high enough to trigger antimicrobial resistance in the environment in some regions of Europe, Asia and North America.[57]

Ecotoxicity and environmental threshold values

Tetracyclines can have negative effects on non-target species such as algae and invertebrates. Antibiotics from the tetracycline family have variable toxicities, with tetracyclines generally being more toxic to water flea and some algae species (Table 5.5), followed by oxytetracycline and doxycycline.[58]

When compared to other antibiotics, tetracyclines present the highest toxicity to bacteria beneficial to soil processes, freshwater fleas and aquatic algae.[59] While the toxicity of tetracycline compounds may be higher than that of other antibiotics, their availability and mobility to different systems is limited.

Table 5.5: Acute and chronic toxicity of tetracyclines to standard test species, as expressed by the effective concentration (EC_{50}), lethal concentration (LC_{50}) or lethal dose (LD_{50}) that adversely affects 50 per cent of test organisms (µg/L or µg/Kg).[60]

Tetracycline compound	Bacteria (µg/L)[i]	Algae (µg/L)[ii]	Water flea (µg/L)[iii]	Fish (µg/L)[iv]	Earthworm (µg/Kg)[v]
Tetracycline	> 100	7,730	2,870	145	> 1,352,000
Oxytetracycline	81	5,400	4,440	127,600	–
Doxycycline	–	> 15,200	1,100,000	3,800,000	–

Notes:

[i] *Shewanella* sp. 6-hour EC_{50} (inhibitory effect); *Vibrio fischeri* oxytetracycline 72-hour EC_{50} (growth inhibition).

[ii] *Chlorella vulgaris* 96-hour EC_{50} tetracycline (growth inhibition rate); green algae 46-hour EC_{50} oxytetracycline; *Chlorella vulgaris* 48-hour LC_{50} doxycycline (mortality rate).

[iii] *Daphnia magna* 48-hour LC_{50} (mortality rate).

[iv] *Danio rerio* embryo 120-hours EC_{50} tetracycline (post-fertilisation malformation rate); 72-hour EC_{50} oxytetracycline; EC_{50} doxycycline (delayed hatching, inflammatory response, altered gut bacteria).

[v] *Eisenia fetida* 28-hour EC_{50} (reproduction inhibition).

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[57] Chow et al., 2021.

[58] Scaria et al., 2021.

[59] Xu et al., 2021; Fernandez et al., 2004; van der Grinten et al., 2010. See Appendix 7.4 for further details about accumulation and toxicity of tetracycline compounds in terrestrial and aquatic biota.

[60] Long et al., 2020; Ye et al., 2017; Yang et al., 2020; Scaria et al., 2021; Escobar-Huerfano et al., 2019; Oliveira et al., 2013.

The toxicity of tetracycline metabolites has yet to be fully assessed. Available information shows that at concentrations above five milligrams per litre (i.e. 5,000 µg/L), metabolites (4-epitetracycline and anhydrotetracycline) can damage cellular structure and cause oxidative stress to green algae.[61] At higher concentrations (20,000 µg/L), these metabolites can inhibit beneficial bacterial growth, and are more toxic to *Shewanella* bacteria than the parent compound.[62,63]

While recent research has focused on the impact of tetracyclines on different organisms, there is a need to focus on the environmental risks associated with low exposure concentrations of these antibiotics, including the toxicity of their metabolites on terrestrial and aquatic organisms.[64]

To date, there are no accepted international guidelines, environmental limits or antibiotic reference standards for antibiotic pollution. This affects the way they are monitored and addressed in receiving environments. However, in 2020 the European Union, under the Water Framework Directive, added two antibiotics (amoxicillin and ciprofloxacin) to its surface water watchlist to collect monitoring information that may inform the risk of these antibiotics to the environment.[65]

Key environmental concerns

The lack of monitoring of tetracyclines and tetracycline-resistant genes in the environment hinders our ability to assess their transport pathways, their interactions with other chemicals, and the potential risk for antimicrobial resistance development. This is of concern given that tetracycline-resistant genes (e.g. *Tet*(M) gene) have been identified at sites exposed to low levels of tetracycline in soils, surface and groundwater, and wastewater treatment plants overseas.[66]

These findings are of concern for New Zealand, given the wide use of tetracycline antibiotics (above eight tonnes per year, most of it applied to multiple production animals)[67] and the lack of regulation to monitor and treat these contaminants at wastewater treatment plants, or their presence in manure as fertiliser in farmlands. Further, guidance is lacking for the disposal of antibiotic-containing vials, which may contain residuals of the antibiotics. Currently, unused and empty containers are generally sent to landfill.[68]

An international survey of antibiotic levels in the environment has recently led to calls for regulators to recognise antimicrobials as pollutants and regulate them like other hazardous substances.[69] The absence of monitoring programmes for antibiotics in different environments limits our ability to determine the risks they may pose to receiving environments.

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[61] Xu et al., 2019.

[62] *Shewanella* is a genus of bacteria involved in the recycling of organic and inorganic matter in soils. Its ability to detoxify and thrive in water containing hazardous compounds has been used to develop wastewater treatments.

[63] Long et al., 2020.

[64] Toxicity data have been obtained for green algae, bacteria, and zebrafish embryos.

[65] Cortes et al., 2020.

[66] Chee-Sanford et al., 2001. See Appendix 7.4 for further details about antimicrobial resistance and antibiotic synergies with other emerging contaminants.

[67] This number includes veterinary and human use of antimicrobials dispensed in the community. It excludes information of antimicrobials dispensed in private or public hospitals. Refer to semi-quantitative mass flow diagram (Figure 5.3).

[68] Chief Veterinary Officer, New Zealand Veterinary Association, pers. comm., 16 February 2021.

[69] Chow et al., 2021.

Given the widespread use of tetracyclines, and the variability of degradation across types and receiving environments, it is important to consider the potential accumulation of tetracyclines with low degradation rates, and the capacity of their metabolites to revert to the parent compound.[70]

Regulation

The approval of tetracyclines for human consumption is regulated by Medsafe, in accordance with international standards for quality, safety and efficacy. Tetracycline chemicals imported to manufacture medicines need a HSNO substance approval, which falls in the Pharmaceutical Active Ingredients Group Standard 2020.[71]

For pharmaceutical manufacturing plants, a new code is being implemented that requires good manufacturing practice auditors to verify that companies implement specific measures for waste handling and contaminated rinse-water. As per the code, manufacturers now need to retain documentation in relation to waste stream analysis for each antimicrobial agent produced, the quantity and nature of the waste generated, monthly reports on its collection, treatment and disposal, and information on waste treatment methods.

Because tetracyclines have a relatively short half-life, there is no monitoring typically required of their presence or concentration in the environment. However, their sustained consumption at high levels can mean that some pharmaceuticals are ‘pseudo-persistent’ given their consistent presence in the receiving environment.

Tetracyclines as veterinary medicines are registered and approved by MPI under the ACVM Act and by the EPA under the HSNO Act. Thirty-one tetracycline products are currently registered for animal treatment, and their use has been monitored by MPI since 2004. In 2017 MPI and MoH presented a joint National Action Plan at the World Health Assembly to manage antibiotic resistance in New Zealand (see Box 5.1).[72]

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[70] Massé et al., 2014.

[71] Workplaces involving the management of hazardous substances covered by the Pharmaceutical Active Ingredients Group Standard have obligations under the Health and Safety at Work Act 2015 (EPA, 2020f).

[72] Ministry of Health and MPI, 2017.

Box 5.1: New Zealand’s current surveillance and the national antibiotic strategy

Some data on human and animal antibiotic consumption are collected via the Ministry of Health’s Pharmaceutical Collection for humans and through MPI’s survey of use for animals.[73] This valuable dataset helps authorities identify volumes dispensed, general use patterns and the effectiveness of treatment.

Information collected through surveillance is fundamental for progressing the 2017 New Zealand Antimicrobial Resistance Action Plan, a strategy focused on addressing antimicrobial resistance using a multisectoral approach. The plan has 18 action points under five main objectives: awareness and understanding; surveillance and research; infection prevention and control; antimicrobial stewardship; and governance, collaboration and investment.[74]

The Prime Minister’s Chief Science Advisor is now working on an infectious disease project, with a focus on antimicrobial resistance. This project emerged from the 2018 briefing *Antimicrobial resistance: An imminent threat to Aotearoa, New Zealand*,[75] which raised seven urgent actions needed for New Zealand action. The following actions are relevant to this investigation:

- building on existing baseline data, a detailed assessment of current use of antibiotics, appropriateness of use, and the extent of antimicrobial resistance in humans and animals
- laboratory-based surveillance in both humans and animals to identify emerging and persisting patterns of antimicrobial resistance
- comprehensive use of recording systems for prescribing and dispensing statistics, and data on environmental isolates.

Data captured under current surveillance led by MPI and the Ministry of Health further aid authorities to classify the criticality of antibiotics based on their use extent, following the World Health Organization classification system.[76] This approach ensures prudent use of antibiotics in humans, animals and horticulture practices. To date, penicillin, macrolide, aminoglycosides, polymyxin, fluoroquinolone, and third and fourth generation cephalosporin families have been classified in New Zealand.[77]

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[73] The Pharmaceutical Collection holds information on antimicrobials dispensed in the community by prescription but excludes information on antimicrobials dispensed in private or public hospitals, or via dispense order (e.g. family planning clinic), which has poor National Health Index reporting.

[74] Ministry of Health and MPI, 2017.

[75] https://www.pmcsa.ac.nz/topics/antimicrobial-resistance-and-infectious-disease/antimicrobial-rsistance/ [accessed 21 July 2021].

[76] WHO, 2019.

[77] NZFSA, 2020. The WHO classification for antimicrobials identifies three groups – critically important, highly important, or important antimicrobials – based on two criteria:

Criterion 1 – The antimicrobial class is the sole, or one of limited available therapies, to treat serious bacterial infections in people.

Criterion 2 – The antimicrobial class is used to treat infections in people caused by either:

(a) bacteria that may be transmitted to humans from nonhuman sources, or

(b) bacteria that may acquire resistance genes from nonhuman sources.

Critically important antimicrobials meet criteria 1 and 2; **highly important antimicrobials** meet either criterion 1 or criterion 2; and **important antimicrobials** meet neither criterion.

Most tetracycline substances were transferred into the HSNO regime in 2006 without quantitative risk assessments being performed (see chapter three for details on the hazardous substance transfer process). Approval of at least two tetracycline-containing substances has been granted since then without quantitative risk assessments being performed. This suggests no models were run to assess predictive environmental concentrations of tetracyclines in the environment.

In 2021, the EPA reallocated some tetracycline substances to multiple group standard approvals.[78] Individual approvals were retained for tetracycline substances not covered by the veterinary medicines group standards.[79]

Group standards consider the application of antibiotics in closed systems, but there are no controls for levels of tetracycline in animal manure – some of which are reapplied to land.

The controls for some tetracycline substances are provided in Appendix 7.4 (Table 7.4.2).

Regional council requirements

Regional councils have plans and rules for the discharge of contaminants into and onto receiving environments. While limits for some chemicals (e.g. nitrogen) are included in regional statutory documents, there are no specifications for the management and use of tetracycline-containing manure, or for the elimination of tetracyclines in wastewater treatment plants.

No monitoring is conducted for the presence of tetracyclines in receiving environments or through effluents or biosolids leaving wastewater treatment plants. While no requirements are set by any agency for the monitoring of antibiotics, some industries (e.g. the Poultry Industry Association of New Zealand) track the use of tetracyclines on a voluntary basis and provide guidance for the spread of wood shavings. Aside from data captured by industry, there is no mechanism in place to assess the contribution and accumulation of tetracycline in receiving environments, or the effects they may have on exposed biota.

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[78] The group standards are Veterinary Medicines (Limited Pack Size, Finished Dose), Veterinary Medicines (Non-dispersive Closed System Application), and Active Ingredients for Use in the Manufacture of Agricultural Compounds.

[79] EPA, 2021l.

Terbuthylazine

Overview of the chemical and its use

Terbuthylazine is a selective herbicide widely used for vegetation management in forestry, agriculture, horticulture and in utility vegetation control. Terbuthylazine belongs to the chloro-s-triazine chemical family, which also includes atrazine, simazine, propazine and cyanazine.[80]

Terbuthylazine is applied as a foliar spray and directly to soil for spot vegetation control. It is taken up by the roots of broad-leaved and grassy-weed seedlings and acts by binding to proteins involved in photosynthesis to inhibit it. It also blocks carbon fixation. The process forms toxic free radicals that destroy membranes and organelles, causing cellular damage.

Terbuthylazine has relatively low solubility (5–12 milligrams per litre) and therefore does not penetrate to lower soil levels (below ten centimetres). This means it has little effect on deep-rooted crops. The selective effect of terbuthylazine is due to the ability of some plants to metabolise the herbicide soon after it is taken up. For example, maize is resistant to chloro-s-triazine herbicides due to its effectiveness at detoxifying triazine molecules before they can cause damage.

Globally, terbuthylazine is used to kill weeds in maize, sorghum, potatoes, peas, sugar cane, vines, fruit trees, citrus, coffee, oil palm, cocoa, olives, rubber and forestry.[81] The predominant market for terbuthylazine in New Zealand is forestry, where it is one of the most commonly used herbicides to control weeds in new plantations, making up approximately 80 per cent of New Zealand's annual terbuthylazine use (Figure 5.4). Vegetation control in agricultural and industrial utility areas (e.g. around fences, driveways, sheds, shelter belts) makes up the next largest use pattern (approximately ten per cent) with forage crops (lucerne) accounting for approximately five per cent of use and the remaining five per cent including arable crops (peas and maize), orchard crops and grapes.

Semi-quantitative mass flow analysis

There is no systematic reporting for terbuthylazine-containing products imported, manufactured, sold or used in New Zealand at a regional or national level. To arrive at an estimate, sales volumes of terbuthylazine-containing products in 2019 and estimates of their use in key sectors in New Zealand were sought from key industry members. From the data supplied, the following estimate of terbuthylazine use in New Zealand (and associated possible contamination of the environment resulting from its use) was made (Figure 5.4).

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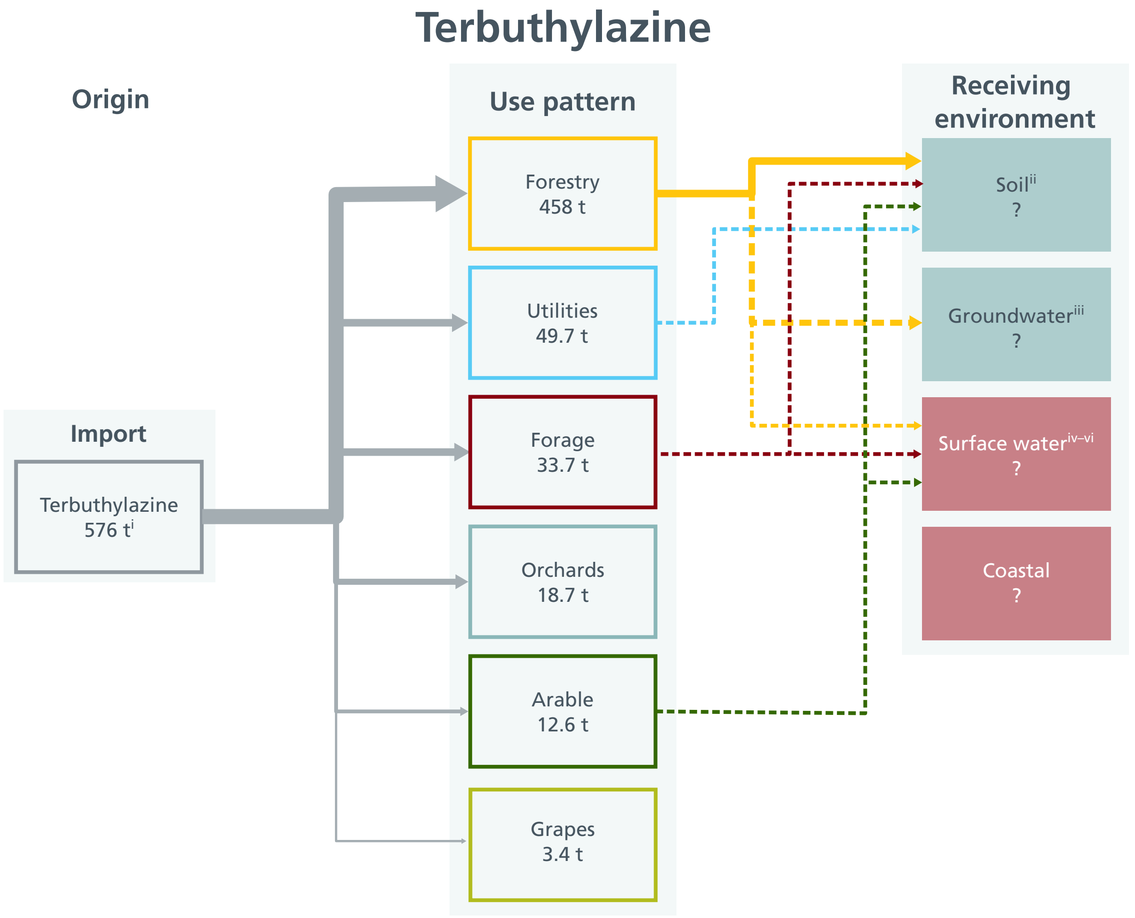
[80] Breckenridge et al., 2010.

[81] WHO, 2003.



Source: PCE

Notes:

Pink solid boxes denote unknown quantities. Arrow width is indicative of the mass flow to next point. Dotted arrows denote uncertainty in the mass flow along this pathway.

i Not a comprehensive volume due to lack of import information available.

ii Contamination of forest soils (pumice = 25% of forestry soil type and recent soil = 13%) with low carbon concentrations showed short half-lives of 10 and 0.06 days, respectively. Ten per cent of terbuthylazine remained after 15 days.[82]

iii Terbuthylazine was detected in 36 groundwater wells (16% of wells sampled) at concentrations ranging from 0.005 to 0.35 µg/L in the most recent four-yearly nationwide survey of pesticides in New Zealand groundwater (2018). The metabolite desethyl-terbuthylazine was detected in 15 wells.[83]

iv Movement of terbuthylazine has been documented from steepland recent forest soils into surface waters (in the Pekepeke catchment, which flows into the Rangitāiki River, Kāingaroa Forest, Bay of Plenty).[84]

v Terbuthylazine was detected in 100% of passive samplers from Canterbury stream sites (concentrations unknown).[85]

vi Waikato Regional Council's 2018 survey of the Waikato River detected terbuthylazine at the detection limit of 0.02 µg/L on three occasions (quarterly water samples taken from six sampling sites). Desethyl-terbuthylazine was tested for but not detected at a detection limit of 0.04 µg/L.[86]

Figure 5.4: Semi-quantitative mass flow diagram for terbuthylazine imported and sold for use in New Zealand in 2019.

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[82] Baillie, 2016; Garrett et al., 2016; Baillie et al., 2017.

[83] Close and Humphries, 2019.

[84] Baillie et al., 2015.

[85] Hageman et al., 2019.

[86] Waikato Regional Council staff, pers. comm., 28 October 2021. Report on survey due for publication in December 2021.

Environmental fate and exposure to non-target organisms

The persistence of terbuthylazine in soil is strongly affected by biological (microbial) activity. The higher the level of biological activity, the more terbuthylazine breaks down, with a half-life in biologically active soils of 30 to 60 days. Terbuthylazine is expected to have only slight mobility in soils due to its high potential to adsorb to soil molecules, which increases with increasing organic matter content.[87]

Because of its relatively low solubility, the main routes of transport to waterways are via spray drift during foliar application or via adsorption to sediment and organic matter that run into waterways during rainfall following application.[88] The half-life of terbuthylazine is similar in aquatic and soil aerobic conditions (between 33 and 73 days).[89] Terbuthylazine has the potential to bioaccumulate, as indicated by its octanol-water partition coefficient (log K_{ow}) of 3.2,[90] which is greater than the United States Environmental Protection Agency standard reporting threshold (log $K_{ow} > 3$) for persistent, bioaccumulative and toxic chemicals.[91] (Chemicals with a log K_{ow} greater than five are considered to bioaccumulate under the Stockholm Convention.)[92]

The major metabolites of terbuthylazine are desethyl-terbuthylazine, hydroxy-terbuthylazine and desethyl-hydroxy-terbuthylazine. Metabolites containing the hydroxy compound are relatively persistent in soil and water compared to the parent compound and the other metabolites.[93] See Box 5.2 for an example of how terbuthylazine groundwater concentrations are predicted by models, and the advantages of models that can directly incorporate metabolites.

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[87] Watt et al., 2010.

[88] Kronvang et al., 2003.

[89] Baillie, 2016.

[90] Forestry Stewardship Council, 2007.

[91] US EPA, 1999.

[92] UNEP, 2018.

[93] EFSA et al., 2017.

Box 5.2: A comparison of groundwater models for terbuthylazine concentrations

The current model used by the EPA to calculate predicted environmental concentrations of pesticides in groundwater (PEC_{gw}), Sci-Grow 2.3, can only include four parameters: application rate, number of applications, mobility in soil (normalised for organic carbon content; K_{oc}) and soil metabolism (DT_{50}).[94] There is no ability to incorporate metabolites into this model.

By contrast, the European Union uses a model developed by the Forum for the Coordination of pesticide fate models and their use, called the Pesticide Leaching Model (PELMO) to model PECgw. This model has many more parameters, including application depth in soil, timing of application and more specific aspects related to the pesticide degradation and mobility in soil. PELMO can include the full suite of metabolites, including multiple breakdown pathways (primary, secondary, etc), and can be run for site-specific scenarios across Europe that take into consideration different soil types and climatic parameters such as precipitation rates and temperature at these locations. The output also provides a range of predicted concentrations across 20 years of predicted climatic patterns, and the 80th percentile of these concentrations is used in risk assessment.

Our herbicide case study chemical terbuthylazine provides a useful illustration of what different outputs for PEC_{gw} from the Sci-Grow and PELMO models can contribute to quantitative risk assessment. Running a Sci-Grow model simulation for terbuthylazine used in the product Tag G2 provides a single PEC_{gw} of 15.6 µg/L. By contrast, the output from running a similar scenario through PELMO, incorporating the breakdown pathways of three common metabolites together with additional application parameters and different climatic scenarios in selected European regions, provides the output presented in Table 5.6 below.

Table 5.6: The breakdown pathways of three common metabolites together with additional application parameters and different climatic scenarios in selected European regions.

Regional scenario	**PEC_{gw} at 1 m soil depth (µg/L)**			
	Terbuthylazine	**2-Hydroxy-terbuthylazine (GS23158)**	**Desethyl-terbuthylazine (GS26379)**	**Desethyl-hydroxy-terbuthylazine (GS28620)**
Châteaudun	< 0.001	28.228	0.780	8.392
Hamburg	0.001	39.291	2.577	15.685
Jokioinen	< 0.001	38.198	1.737	13.716
Kremsmünster	< 0.001	36.637	2.480	13.886
Okehampton	0.001	39.813	4.029	16.252
Piacenza	0.007	35.992	4.695	15.945
Porto	< 0.001	23.854	1.826	9.360
Sevilla	< 0.001	13.716	0.078	2.758
Thiva	< 0.001	20.163	0.250	5.104

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[94] Note that Sci-Grown is no longer used by its developer (the United States Environmental Protection Agency (US EPA)) to predict groundwater concentrations. The US EPA currently uses an adapted version of the Pesticide Root Zone Model for groundwater.

While these concentrations are purely indicative (the example scenario is hypothetical and does not correspond to actual application rates and usage patterns in Europe), the example output illustrates the different complexity of the models and the insight that can be obtained by incorporating metabolites, compared to the single concentration for terbuthylazine obtained from Sci-Grow. It is clear that, despite the indicative nature of the output concentrations, the hydroxy compound present in two of the metabolites significantly increases the predicted groundwater concentrations.

Terbuthylazine has regularly been detected in surveys of groundwater in New Zealand, including its primary metabolite, desethyl-terbuthylazine.[95] However, these surveys currently do not test for metabolites containing the hydroxy compound. In Europe, concern around the potential for contamination of water with terbuthylazine and its metabolites led to a voluntary withdrawal of non-agricultural use by industry (such as for industrial vegetation control). This assessment was able to be made based on the results of PEC_{gw} modelling and experimental studies.

Ecotoxicity and environmental threshold values

Given its primary mode of action of photosynthesis inhibition, terbuthylazine is highly toxic not only to broad-leaved and grassy weeds, but to non-target aquatic plants and algae as well. Some terrestrial plants such as maize and sorghum are able to metabolise terbuthylazine (as well as other triazines) and are thus physiologically tolerant to terbuthylazine.[96] Other woody plants rely on deeper root systems to avoid the effects of terbuthylazine, which does not penetrate the soil by more than five to ten centimetres. This makes it an effective knock-down herbicide for shallow-rooted weedy plants in newly planted forests. Terbuthylazine has moderate toxicity to aquatic invertebrates (based on the standard taxa tested) and vertebrates (Table 5.7; fish).

The herbicidal activity of the major metabolite desethyl-terbuthylazine is comparable to the toxicity of the parent compound. Other metabolites (including the many minor metabolites not described here in detail) that may occur in groundwater at average concentrations above 0.1 micrograms per litre (based on European groundwater models) are not considered to be of toxicological relevance.[97]

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[95] Close and Humphries, 2019.

[96] Rahman, 1970.

[97] EFSA et al., 2017; note that this is for toxicity to humans.

Table 5.7: Acute and chronic toxicity of terbuthylazine to standard test species, as expressed by the effective concentration (EC_{50}), lethal concentration (LC_{50}) or lethal dose (LD_{50}) that adversely affects 50 per cent of test organisms (parts per billion as µg/L or µg/kg; or µg/bee).[98]

Terbuthylazine toxicity measurement	Algae (µg/L)[i]	Water flea (µg/L)[ii]	Earthworm (µg/kg)[iii]	Honeybee (µg/bee)[iv]	Fish (µg/L)[v]
EC_{50}/LC_{50}	12	21,200	> 141,700	22.6	2,200

Notes:

[i] *Pseudokirchneriella subcapitata* 72-hour EC_{50} (growth).

[ii] *Daphnia magna* 48-hour EC_{50}.

[iii] *Eisenia fetida* 14-day LC_{50}.

[iv] *Apis* spp. oral acute LD_{50} worst case from 24-, 48- and 72-hour values (µg/bee).

[v] *Oncorhynchus mykiss* (rainbow trout) 96-hour LC_{50}.

No approved substances containing terbuthylazine have an EEL for terbuthylazine set by the EPA for any environmental media. The maximum acceptable value for drinking water in New Zealand for terbuthylazine is eight micrograms per litre, which is comparable to the World Health Organization drinking-water guideline value of seven micrograms per litre).[99,100]

Terbuthylazine is on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality waiting list to have default guideline values derived for it.

Key environmental concerns

Terbuthylazine and its metabolites have regularly shown up in ground and surface waters around the world.[101] The most recent nationwide survey of pesticides in groundwater in New Zealand found terbuthylazine in 16 per cent of wells (36 detections) and detected the major metabolite desethyl-terbuthylazine in 15 wells.[102] The relatively persistent terbuthylazine metabolites (containing the hydroxy compound) have not been tested for. It is, however, likely that these metabolites are also present and possibly in even higher concentrations (see Box 5.2). The first nationwide survey of pesticides in New Zealand streams detected terbuthylazine in all passive samplers from Canterbury stream sites, however the concentrations were unable to be determined from these samplers.[103] In the Waikato Regional Council's most recent five-yearly survey of the Waikato River (2018), terbuthylazine was detected on three occasions (at the detection limit of 0.02 µg/L).[104]

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[98] University of Hertfordshire, 2021.

[99] Ministry of Health, 2018.

[100] WHO, 2017.

[101] Kronvang et al., 2003; EFSA et al., 2017.

[102] Close and Humphries, 2019.

[103] Hageman et al., 2019. Passive samplers measure chemicals over a long period of time, and the methods for determining chemical concentrations are still being developed for some types of passive samplers.

[104] Waikato Regional Council staff member, pers. comm., 28 October 2021. Report planned for publication in December 2021. Water samples were taken from six sampling sites on four occasions during 2018. Desethyl-terbuthylazine was tested for but not detected (with a detection limit of 0.04 µg/L).

Terbuthylazine was on the Forest Stewardship Council's (FSC) list of hazardous pesticides prohibited from use in FSC-certified forests from 2007 to 2015. This was based on its high bioaccumulation potential.[105] However, a change in FSC hazardous criteria means terbuthylazine was removed from the prohibited chemicals list.

Studies assessing the persistence and mobility of terbuthylazine in two key forest soil types in New Zealand – pumice (25 per cent of forest soils) and recent (13 per cent) – found that the highest risk of movement off-site was during the first two weeks following spray application, after which, risks were low.[106] The half-lives measured in these soils were also considerably shorter than half-lives reported in the literature, indicating that low organic carbon content reduces the persistence of terbuthylazine in these soil types.[107]

The reduced persistence of terbuthylazine in low organic carbon soil types common in New Zealand forest plantations was the key mitigating factor that led to its subsequent removal from the FSC list of highly hazardous pesticides. However, the high rates of application of terbuthylazine in forests (up to 9.9 kilograms per hectare) mean there is concern about environmental contamination from its widespread use in New Zealand forestry. These high application rates are likely a key cause of terbuthylazine and its major metabolite, desethyl-terbuthylazine, being a commonly detected contaminant in groundwater, albeit at low concentrations.[108]

The presence and relative persistence of terbuthylazine and its metabolites in water (ground and surface) mean there is the potential for chronic toxicity (exposure to low concentrations over several weeks to months) to non-target organisms in these environments. However, the lack of chronic toxicity studies means these possible environmental impacts remain unknown. Limited regular monitoring in surface waters (with the exception of Waikato Regional Council's routine but infrequent state of the environment (SoE) monitoring of pesticides in the Waikato River) also limits our knowledge of the extent of terbuthylazine contamination of these environments.

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[105] Forestry Stewardship Council, 2007.

[106] Garrett et al., 2016.

[107] Garrett et al., 2015.

[108] Note that the hydroxy-metabolites may be present in higher concentrations according to groundwater models, but these metabolites are not yet tested for in New Zealand groundwater surveys.

Regulation

The EPA regulates products containing the active substance terbuthylazine under the HSNO Act. Terbuthylazine was first approved for use in 1984. Quantitative risk assessment of a product containing terbuthylazine was undertaken in 2006 during the application for approval of TAG G2 for total vegetation control for non-croplands and selected orchard crops.[109]

Terbuthylazine has the following hazard classifications:

- acute oral
- dermal and inhalation toxicity (category 4)
- hazardous to the aquatic environment (acute category 1)
- hazardous to the aquatic environment (chronic category 2)
- hazardous to soil organisms
- hazardous to terrestrial vertebrates.[110]

Table 7.5.1 in Appendix 7.5 summarises the HSNO default controls applied to products containing terbuthylazine in the form of a suspension concentrate. Once approved by the EPA, agricultural products containing terbuthylazine are registered by MPI , which records the trade names they are registered under. There are 20 products containing terbuthylazine on the MPI's ACVM register.

Neither of the national regulatory agencies requires the monitoring of terbuthylazine residues or its metabolites in the New Zealand environment. Therefore, the only data on terbuthylazine contamination of the environment are from four-yearly national surveys of pesticides in groundwater prepared for regional councils,[111] five-yearly monitoring of the Waikato River (by Waikato Regional Council), a handful of one-off stream surveys,[112] and studies investigating the fate of terbuthylazine in forest soils and nearby waterways after spraying.[113]

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[109] A herbicide containing 350 grams per litre terbuthylazine, 60 grams per litre amitrole, 15 grams per litre oxyfluorfen and 100 grams per litre glyphosate in the form of a suspension concentrate.

[110] EPA, 2021k. https://www.epa.govt.nz/database-search/chemical-classification-and-information-database-ccid/ [accessed 9 December 2021].

[111] Close and Humphries, 2019.

[112] Hageman et al., 2019.

[113] Garrett et al., 2015, 2016; Baillie, 2016; Baillie et al., 2017.

Zinc

Overview of the chemical and its use

Zinc is a chemical element – with the symbol Zn – naturally found in the Earth's crust, including soils. Zinc is an essential trace element for growth and metabolism processes in living organisms. Despite its natural origin and beneficial properties, zinc can become toxic to organisms at elevated doses. At high concentrations, zinc can also outcompete other essential elements (e.g. calcium and copper) for binding sites on soils and within biological tissue. This can result in plants and animals obtaining an altered intake of other nutrients (such as copper, iron and manganese), affecting plant growth, photosynthesis and respiratory rate, and degrading the intrinsic antioxidant defence system of cells, causing damage to DNA, protein and carbohydrates (via enhanced generation of reactive oxygen).[114]

Worldwide, zinc is mainly used in galvanising and processing in steel industries. Zinc is also used to a lesser degree in the production of antifouling paints, fungicides, human and veterinary medications and health supplements, as well as cosmetics, wood preservatives, paint pigments, pesticides, fertilisers, household products, alloys and as an agent in rubber vulcanisation.

Semi-quantitative mass flow analysis

The reporting of the import, manufacturing, sales and exports of zinc compounds in New Zealand is not systematic (Figure 5.5). Analysis conducted for this review highlighted the absence of mechanisms for regularly collecting and updating industrial emissions and release data at a national level. The data presented in the figure were made available directly from major stakeholders. However, information about the amount of zinc reaching receiving environments is patchy at best and often lacking.

Likewise, there is limited knowledge of zinc loadings from diffuse sources (e.g. roofing and flashings, wearing of vehicle parts, use of agricultural chemicals, or washed off sunscreen). A variety of models have been developed to estimate annual loads of zinc in urban areas over the last 20 years (e.g. Contaminant Loads Model (CLM), Catchment Contaminants Loads Model (C-CALM) and Catchment Land Use for Environmental Sustainability (CLUES)). However, the steady-state, statistical nature of these models limits their ability to resolve event-based variations in zinc yields or adequately account for concentrations of copper and zinc metals in streams. Auckland Council is developing a process-based model – the Freshwater Management Tool (FWMT). The model produces continuous information of zinc yields for various weather conditions across multiple land uses. Decision makers can use it to optimise management interventions and to develop least-cost action plans to achieve instream concentration or load targets.[115]

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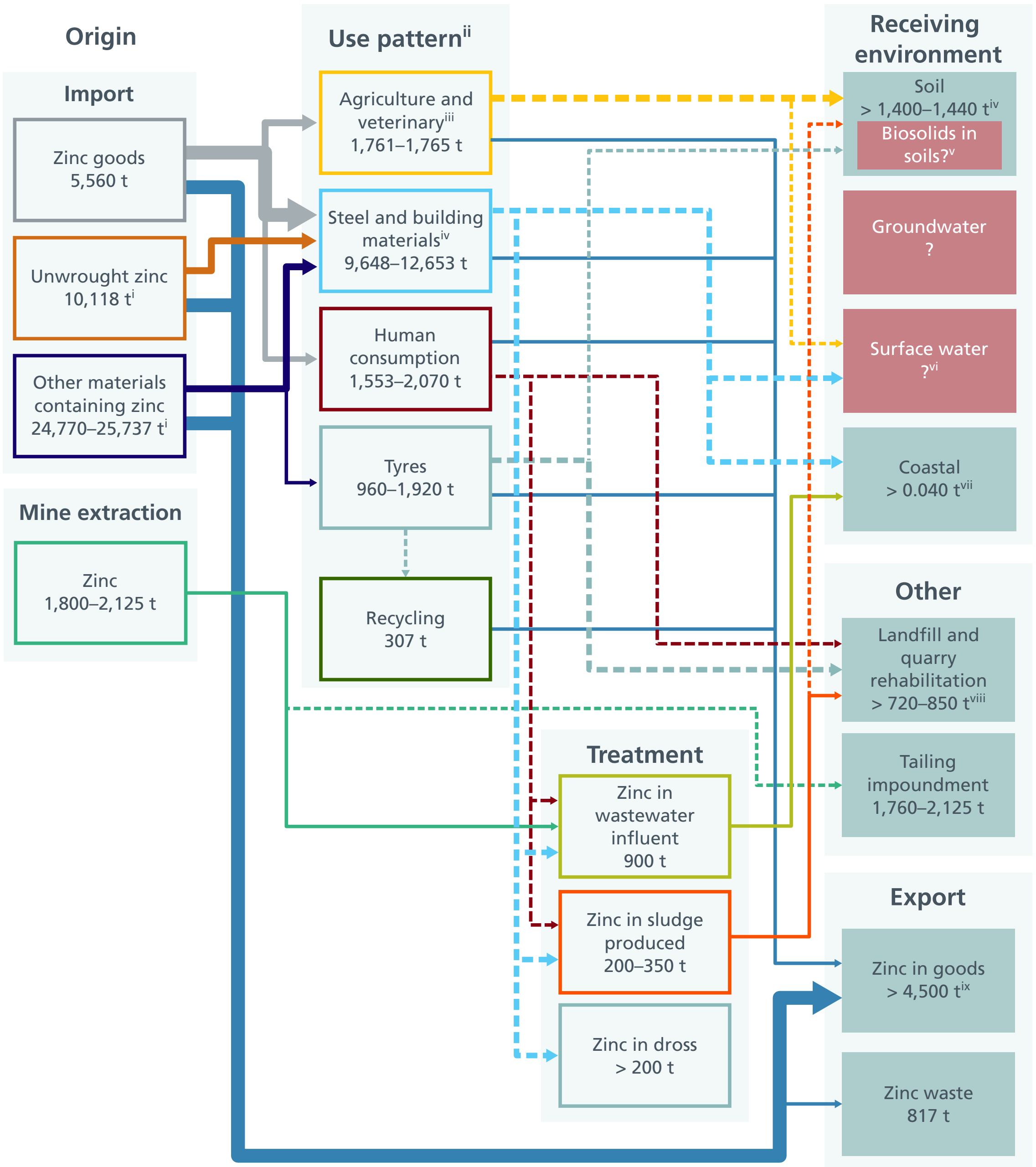
[114] Wallig and Keenan, 2013; Shahid et al., 2014.

[115] Auckland Council, 2021. Future iterations of the FWMT will consider the following points:

- Loads of total zinc on streams and coastal areas are available for urban and rural sources but confidence in loads from rural sources is limited.
- Outputs for loads of total zinc averaged from 15-minute outputs to annual period over the baseline period (2003–2017).
- External peer review has recommended targeted monitoring and modelling a range of toxicity modifying factors for Stage 2 of the FWMT.

Zinc



Source: PCE

Notes:

Pink boxes denote unknown quantities. Arrow width is indicative of the mass flow to next point. Dotted arrows denote uncertainty in the mass flow along this pathway.

[i] Unwrought zinc and other materials containing zinc are not comprehensively considered in the mass flow, given they are unlikely to reach the environment and the essential character of the good is not zinc.

[ii] The use phase combines the use of zinc compounds for the manufacturing of a product and the use of zinc-containing products.

[iii] Conservative estimate based on incomplete information – figure based on the assumption that 80% of products containing zinc used in agricultural practices leach into soil. In the Waikato region alone, a 2011 report suggested the use of zinc in facial eczema remedies was between 5,000 and 8,000 tonnes per year.

[iv] About 14% of zinc has low risk to migrate to the environment given its use in structural building products, which are contained inside the building envelope.

[v] Incomplete information. In Māngere WWTP alone, the combined waste from municipal and trade waste effluents produces in average of 19 tonnes of zinc in biosolids per annum.

[vi] Incomplete information to estimate loads of zinc reaching surface waterbodies across New Zealand. The only data available are from the roofing and gold mining sectors, urban load estimates from the FWMT model developed for the Auckland region, and estimated road traffic runoff loads from Porirua, Wellington.

[vii] Conservative estimate based on loads of zinc from data modelled for Auckland, Porirua and Christchurch.

[viii] Combined information of zinc contained in tyres and sludge from wastewater treatment sent to landfill.

[ix] Figure includes new retail products and used tyres for fuel or material recovery. Information is not specific to zinc weight.

Figure 5.5: Semi-quantitative mass flow diagram for zinc imported and used in New Zealand in 2019. Information from the use pattern field was mainly sourced from predominant industries using zinc in New Zealand.

Environmental fate and exposure to non-target organisms

As a (non-radioactive) chemical, zinc is persistent and unable to degrade or break down any further into metabolites. It can, however, take different forms (e.g. free zinc ions, zinc hydroxide or zinc sulphate) depending on environmental conditions (e.g. pH, dissolved organic matter). The form of zinc will determine its toxicity, with free zinc ions (Zn^{+2}) being the most available and toxic form to organisms.

Zinc may be incorporated into organic compounds – for example, the pesticide Zineb. When the organic compound degrades, the zinc is released. This means it has the potential to accumulate in receiving environments such as soils and sediments.

The main source of zinc in the urban environment is stormwater runoff, which carries both particles containing zinc, and dissolved zinc (Zn^{2+}_{aq}) from worn tyres, galvanised and coated roofs and painted houses. Further anthropogenic sources of zinc are treated effluents and sludges from wastewater treatment plants. In agriculture, zinc-based pesticides and animal medicines (e.g. facial eczema remedies) are key sources of zinc entering soil and surface water. In the absence of hard data, a study carried out in the Waikato region in 2011 estimated between 5,000 and 8,000 tonnes of zinc used in facial eczema remedies per year.[116] These figures are significantly higher than those obtained from industry for 2019.

Once released in the environment, zinc behaves in different ways depending on the characteristics of the environment (e.g. salinity and the ambient pH).[117] In water, for example, these characteristics will determine if zinc is in a freely dissolved form, as an inorganic complex or is attached to sediment. In waters with neutral pH (~7), the majority (60–80%) of zinc is attached to suspended sediment, with the remainder in dissolved forms, including inorganic complexes. In acidic waters (with pH values of five or lower) zinc tends to dissolve and be in a free form, which becomes available to fish.[118] Zinc can also be released from sediments under low-oxygen conditions.

In soils, zinc can be distributed through different compartments – water between soil particles (porewater), soil particles, organic ligands,[119] and primary minerals. Zinc tends to form strong bonds with soils (at a pH of five or higher), resulting in low mobility. However, when the pH is below 5.5, the bioavailability of zinc in soils to plants and microorganisms tends to increase. Although most metals are relatively insoluble, zinc is known as one of the most soluble. While many organisms have mechanisms that regulate zinc adsorption and excretion, exceedances of zinc may affect their physiological responses.[120]

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[116] Sowry, 2011.

[117] CCME, 2018.

[118] See Appendix 7.6 for information on the influence of water chemistry on the bioavailability of zinc to aquatic species.

[119] A ligand is an ion or molecule that creates strong bonds with metals such as zinc (e.g. oxide or hydroxides, or humic acids).

[120] Rainbow, 2002.

Ecotoxicity and environmental threshold values

The toxicity of zinc to biota is well studied and understood, including how variable it is across organisms and different geographical regions. In freshwater bodies, water fleas are the most sensitive species to zinc, with reproductive rate impairment observed at concentrations of 5.5 micrograms per litre, followed by green microalgae, fish (salmon and brown trout), crustaceans and aquatic snails (Table 5.8).[121]

In the marine space, sea anemones have the highest sensitivity to zinc, with reproduction rate impairment observed from 17 micrograms per litre. Taonga fish species such as tarore (sole), kahawai and pātiki (flounder) have shown higher sensitivity when compared to their counterpart species in Australia and North America, with lethal concentration values ranging between 1,800, 2,600 and 2,700 micrograms per litre, respectively.[122,123]

Table 5.8: Acute and chronic toxicity of zinc to standard test species, as expressed by the effective concentration (EC_{10} and EC_{50}) or lethal concentration (LC_{50}) that adversely affects 10 or 50 per cent of test organisms (parts per billion as μg/L).

Zinc toxicity measurement – freshwater	Water flea (μg/L)[i]	Algae (μg/L)[ii]	Fish (μg/L)[iii]	Snail (μg/L)[iv]
EC_{50}/LC_{50}	34	36.2	149	161
Zinc toxicity measurement – marine	**Sea anemone (μg/L)[v]**	**Algae (μg/L)**	**Fish (μg/L)**	**Mollusc (μg/L)[vi]**
EC_{50}/LC_{50}	17	84	> 1,800	175

Notes:

[i] *Ceriodaphnia dubia* 48-hour LC_{50} (growth).

[ii] *Pseudokirchneriella subcapitata* 4-hour EC_{50} (population growth); (green algae) 72-hour EC_{50} (mortality).

[iii] *Ctenopharyngodon idellus* 28-day EC_{50} (reproduction rate).

[iv] *Physa gyrina* 30-day LC_{50} (mortality).

[v] *Aiptasia pulchella* 28-day EC_{10} (reproduction rate).

[vi] *Mytilus edulis* 48-hour EC_{50} (egg/larvae development).

The toxicity of zinc is influenced by both its chemical form and the presence of ions (largely calcium and magnesium) that compete for binding sites in biological tissues, and these effects are accounted for by using different water quality guidelines in different locations (Table 5.9).[124] The biotic ligand model is a tool now widely used to predict the effects of multiple water parameters (pH, hardness, dissolved organic matter) on the bioavailability and toxicity of zinc.[125] The biotic ligand model has been used in the derivation of water quality guidelines in some jurisdictions.[126]

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[121] CCME, 2018; Gadd and Hickey, 2016; Chen et al., 2016.

[122] Langdon et al., 2009.

[123] ANZG, 2018; Gadd and Hickey, 2016.

[124] See Appendix 7.6 for information on the derivation of water quality guidelines for zinc.

[125] Santore et al., 2002.

[126] A biotic ligand model for zinc is not used by the US EPA, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality or the Canadian Environmental Quality Guidelines.

Table 5.9: Comparison of aquatic and terrestrial exposure limits for zinc.

Water guidelines source	Media	Exposure limit (µg/L)
United States Environmental Protection Agency water quality standards (1988)	Freshwater	47[i]
	Marine	170 (short-term exposure) 58 (long-term exposure)
Canadian Water Quality Guidelines for the Protection of Aquatic Life (2018)	Freshwater	37 (short-term exposure)[ii] 7 (long-term exposure)[iii]
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018)	Freshwater	8
	Marine	15
Soil and sediment guidelines source	**Media**	**Exposure limit (mg/kg)**
Australian and New Zealand Guidelines for Fresh and Marine Water Quality – interim sediment quality guidelines (ISQGs)	Sediment	200 (ISQG-low) 410 ISQG -high)
New Zealand Ecological Soil Guideline Values (Eco-SGVs)[iv]	Agricultural soil	95 (fresh) 190 (aged)
	Non-food production soil	800 (fresh) 170 (aged)
Canadian interim sediment quality guidelines (2001)	Freshwater sediment	123
Netherlands maximum permissible concentration (2000)	Soil	160
	Sediment	620

Notes:

[i] Hardness adjustment of (0.83 [ln (hardness)] + 1.95). For example, at hardness of 50 mg/L as calcium carbonate, the concentration of total recoverable zinc should not exceed 180 g/L at any time.

[ii] Applies at a hardness of 50 mg/L as calcium carbonate and dissolved organic carbon concentration of 0.5 mg/L.

[iii] Applies at a pH of 7.5, hardness of 50 mg/L as calcium carbonate and dissolved organic carbon concentration of 0.5 mg/L.

[iv] Cavanagh, 2019. Developed for zinc in fresh and aged typical soils. Guidelines pending for regulatory adoption.

In New Zealand, ecotoxicological data are also used by the EPA to derive EELs.[127] In the absence of these limits, prescriptive controls are generally applied to agrichemicals. For example, additional controls have been set for the whole zinc-containing fungicide ESTEEM (polyoxin D zinc salt), which include:

- restricting application to ground-based methods and prohibiting application into, onto or over water
- setting a maximum application rate, maximum number of applications and maximum frequency of applications
- label requirements for maximum application rate and methods of use.

The incidental presence of zinc in such a formulation may be part of the toxicity assessment, but is generally not a fundamental driver.

While the toxicity of zinc in its different forms has been widely studied, not much is known about the behaviour and bioavailability of zinc nanoparticles (particles equal to or smaller than 100 nanometres), found in a wide range of products, including cosmetics and sunscreens. It has been identified that some forms of zinc nanoparticles have toxic characteristics, however the extent to which they can affect the environment is yet to be to be studied.[128]

Key environmental concerns

Worldwide, contamination of soils with anthropogenic zinc has become evident in some agricultural sectors, such as dairy farming and horticulture.[129] A New Zealand study assessing the environmental risks associated with the use of zinc in pastureland suggests the accumulation of this metal in a wide area of the Waikato region over the last 30 years. The study further shows that around 12 per cent of soils assessed exceed 100 milligrams per kilogram, an indication of the potential toxicity to the functioning of microorganisms when compared with guideline limits (Table 5.9), which can further drive the deficiency of other essential elements needed by plants.[130]

Additionally, depending on the type of soil, zinc can migrate from farmland to freshwater and groundwater bodies. The most significant concern for freshwater lakes is related to the ability for zinc to partition to bed sediments, where over time it may gradually build up to pass ecotoxic thresholds for macroinvertebrates and other bed-dwelling organisms, which are integral components of aquatic ecosystems. Accumulation of zinc in sediments from rural lakes is now evident in the Waikato region. While 86 per cent of lakes assessed have at least twice background concentrations, three lakes presented values above the interim sediment quality guideline low value of 200 milligrams per kilogram (meaning that further investigation is required to assess the extent of risk posed by the chemical).[131,132,133]

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[127] Although there are default EELs for zinc (as a single compound), these are often deleted. Conversely, EELs can be set for a substance for which ecotoxicity data are available.

[128] Prato et al., 2020. See Appendix 7.6 for more information about zinc nanoparticles.

[129] Ali et al., 2018.

[130] Vermeulen and Kim, 2016.

[131] ANZG, 2018. See https://www.waterquality.gov.au/anz-guidelines [accessed 10 June 2021].

[132] Lake Parkinson, Lake Serpent and the urban lake Te Koutu.

[133] Vermeulen, 2015.

Natural concentrations of zinc in the water of freshwater lakes and rivers are low and range between 0.04 and 1.6 micrograms per litre. Comparatively, concentrations of anthropogenic zinc in urban freshwater bodies have been found at much higher levels, between 5 and 200 micrograms per litre, with higher concentrations peaking during rain events.[134]

In urban areas, stormwater has been identified as one of the main sources of zinc reaching the environment. In 2012, the National Institute of Water and Atmospheric Research (NIWA) set up the Urban Runoff Quality Information System, a national database with stormwater and urban stream quality data.[135] The system was designed to collate data collected from around New Zealand to improve understanding of water contamination patterns resulting from different land uses. The information was also used in modelling for stormwater treatment systems (which previously relied on overseas estimates). However, it has not been regularly updated to include newly acquired data, limiting its utility for understanding discharges nationwide and the contributions of zinc from specific anthropogenic sources.[136]

A final environmental concern is the strong pattern of co-occurrence between zinc and the development of antimicrobial resistance in microbes in different environments.[137] This is because bacteria, when exposed to zinc (even at sub-toxic concentrations), activate resistance mechanisms that transport harmful compounds outside of the cell. In the process of removing zinc, other toxic substances, including antimicrobials, are removed. In this respect, zinc is considered to act as an inducer and co-selector of antibiotic resistance genes. The influence of zinc on antimicrobial resistance has been identified in microbes at wastewater treatment plants, in manure, and in soils.[138]

Regulation

The use pattern of zinc compounds dictates the type of controls applied and the agencies granting approval. To date, the EPA has approved 81 substances containing zinc, many of which have been transferred to group standards.[139] Antifouling paints containing zinc have retained their individual approval given the lack of group standards suitable for them. Strengthened controls for the use of antifouling paints were imposed in 2013 following a reassessment review.[140]

Products containing zinc in veterinary medicines are registered on the ACVM list, administered by MPI. The registration occurs in parallel with the EPA's approval of the active ingredient. In New Zealand, 110 products containing zinc are registered as veterinary medicines (antimicrobials, antibiotics, endoparasiticides, antifungal products, and as pre-antidotes to deactivate a fungal toxin in an animal's bloodstream),[141] with most of the formulations used to treat facial eczema in cattle, sheep and deer.[142]

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[134] Reid et al., 1999; Holland and Buckthought, 2015; Perrie et al., 2012; Gadd and Hickey, 2016.

[135] See https://urqis.niwa.co.nz [accessed 28 July 2021].

[136] Some councils have started developing models to address that knowledge gap, but their accuracy will depend on the quality of monitoring data.

[137] Li et al., 2022.

[138] Peltier et al., 2010.

[139] Groups standards include Class 4 substances; veterinary medicine group; schedule toxic substances; active ingredient group; other groups; and pesticide formulation. See EPA (2021b) and https://www.epa.govt.nz/industry-areas/hazardous-substances/rules-for-hazardous-substances/approvals/ [accessed 19 July 2021].

[140] EPA, 2013.

[141] See https://eatsafe.nzfsa.govt.nz/web/public/acvm-register [accessed 8 July 2021].

[142] An additional 20 products are registered under the ACVM Act with the fungicidal active ingredient Mancozeb, which contains between 1.6% and 2.5% of zinc.

Zinc-containing pesticide products are registered under the ACVM for agricultural use. These include two pesticides used in pip and stone fruit. Nine non-agricultural active ingredients approved by the EPA are currently contained in 124 registered pesticides. These active ingredients have general conditions for the use and disposal of the chemicals. Table 7.6.1 in Appendix 7.6 summarises the HSNO default controls applied to some products containing zinc for their main uses.

Zinc compounds are further used in nutritional products for human consumption, which are exempt from ACVM registration. Instead, they are regulated by Medsafe under the Dietary Supplements Regulations 1985, and by MPI under the Food Act 2014.

The HSNO Act approval process for zinc-containing products such as veterinary treatments and antifouling paints (e.g. zinc bacitracin and zinc oxide) only requires rapid qualitative risk assessments, given their reduced hazard profile and the similarity with risk profiles of other reference substances approved by the Environmental Risk Management Authority and transferred into the HSNO regime in the early 2000s.

Some chemicals containing zinc, such as antibiotics or facial eczema remedies used in veterinary or human medicines, do not have controls for the management of waste containing traces of the chemical, or the potential for accumulation in receiving environments (e.g. eczema treatment in soils).

Regional council requirements

In most regions the discharge of collected agricultural effluents is a permitted activity that does not require resource consent but needs to comply with the standards and terms set by each regional council. This therefore covers effluent that contains agrichemicals and veterinary products containing zinc.

Discharges of stormwater from urban settings and wastewater effluents from industrial or trade-waste facilities generally require resource consents. In many instances, a condition on the maximum allowable loading of zinc is stipulated. For example, the Māngere Wastewater Treatment Plant has a maximum daily load of zinc of 15.2 kilograms for its 117 trade-waste consent holders.[143] The monitoring of metals generally occurs on an annual basis, and this includes monitoring of sewage sludge and pond effluents. However, consent conditions vary, some requiring the monitoring of zinc in the receiving environment (dissolved zinc in water and total zinc in sediments), while others only assess concentrations in the effluent.

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[143] CH2M Beca, 2006.

A report commissioned for this review identified multiple breaches of zinc concentration limits at wastewater, stormwater and leachate discharge points.[144] While a key focus of zinc loading is placed on trade waste, monitoring has shown that zinc from other domestic and commercial sources has a significant influence on the total amount of zinc reaching wastewater treatment plants.[145,146]

Regional councils also monitor zinc in receiving surface waters, groundwater, and coastal environments as part of their SoE monitoring programmes. Monitoring across councils is variable. For example, zinc in coastal areas is monitored by 15 councils, but is only monitored in groundwater by six councils and by five in freshwater bodies. Zinc is monitored in soils at dairy and drystock sites.[147] However, it is not one of the main indicators routinely monitored under soil quality SoE reporting. Overall, SoE data are reported by each regional council on an annual basis and are collated and presented by the Ministry for the Environment and Stats NZ every three years. To date, SoE monitoring does not yet extend to the state of lakes or groundwater in agricultural areas.

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[144] See Table 10 in Conwell (2021).

[145] CH2M Beca, 2006.

[146] See Appendix 7.6 for more information about contribution of zinc from other sources and reduction targets for trace elements.

[147] Stevenson and McNeill, 2020.

6


Cranfillia nigra

Implications for environmental regulation

From the preceding chapters, several issues emerge concerning the questions our regulatory system currently asks or does not ask about the environmental fate and impact of chemicals in New Zealand. The case studies also invite discussion about how comprehensive and connected the regulatory system is as a whole. Based on these findings, a number of shortcomings are identified together with recommendations to address them.

Ensuring that environmental contamination is properly prioritised

New Zealand's system of approving and managing the use of chemicals is very complex. This review has not set out to question the wisdom of that complexity. Rather, it has been focused on the extent to which that complex system asks sufficient questions to enable us to be confident that we are managing the most important environmental risks well. But it seems fair to conclude that the more complex a system is, the greater the chance of issues falling between agencies and the greater the need for cooperation and collaboration.

Overall, this review has found there is a disjointed and patchy system for asking, and answering, questions about the environmental fate and impact of chemicals and keeping the answers up to date. It is worth repeating the numbers cited earlier in the report: While there are roughly 150,000 substances approved for use in New Zealand (made up of an estimated 30,000 chemicals), there are only 3,500 substances that are the subject of individual approvals, and only a few hundred have been fully reassessed. Fewer than 200 chemicals are regularly the subject of monitoring in receiving environments. While not all of the chemicals present in New Zealand will present a high level of concern, there are many unknowns.

The environment itself represents a highly complex system, and the different ways in which we intersect with it reflect the complexity of our society and economy. So, without in any way avoiding the shortcoming in current arrangements, any critic would have to concede that *any* institutional arrangement will find chemical management challenging. The sheer number of chemicals that have potential to contaminate the environment guarantees that. For that reason, any chemical management system needs to be able to target its regulatory effort to those contaminants and uses that raise the most serious issues.

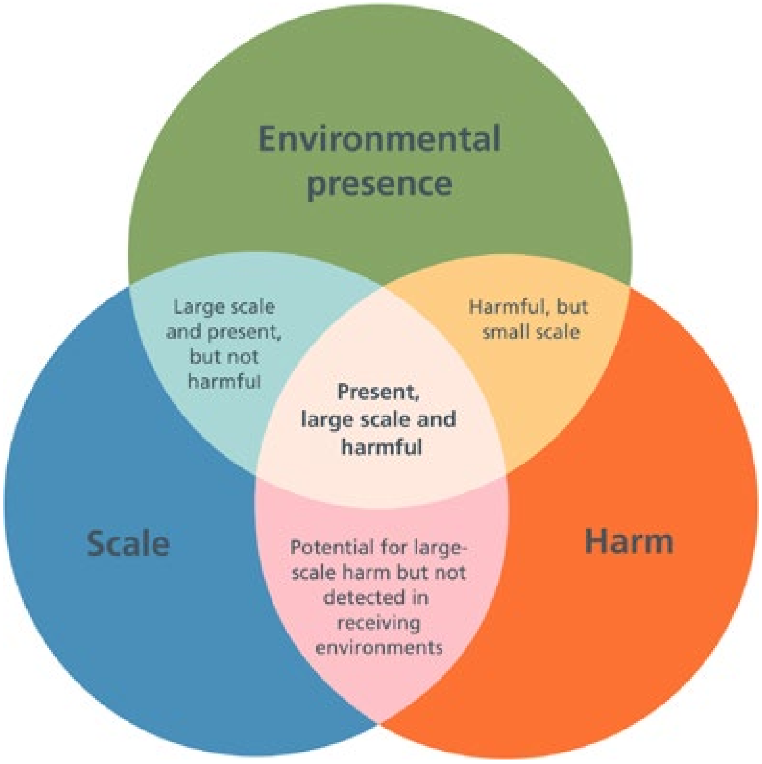
Identifying these can be helpfully thought about in these terms:

> "Environmental contamination issues vary widely in their reach and consequences … it is reasonable to define the most serious issues as those of the largest scale, which grow worse over time, exert deleterious effects (to humans, ecosystems, productive capacity, an economy, or resource capacity) and are irreversible."[1]

Knowing where to direct the attention of regulators and environmental monitoring requires a conceptual framework that can bring together three key considerations that will determine the relative seriousness of contamination issues. The following conceptualisation has been suggested by Dr Nick Kim of Massey University (with some adaptation):

- **Scale:** the geographic extent and quantity of chemical use.
- **Environmental presence:** actual detection of chemical substances in one or more receiving environments through sampling efforts (either occasional or routine).[2]
- **Harm:** the potential for chemicals to cause toxicity or other adverse effects based on evidence or their intrinsic properties (including their potential to persist or bioaccumulate).

Figure 6.1 provides a conceptual framework through which these considerations can be brought together.



Source: PCE

Figure 6.1: A framework to help focus regulation and monitoring on the most important environmental contamination risks.

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[1] Kim et al., 2020, p.6.

[2] In some cases, modelling is used to predict environmental exposure.

The current chemical management system provides reasonable visibility for some elements of this picture but not others. Visibility at a system level also varies between different chemicals. As a result, there are things we do not know and questions we are not asking which we should.

Regulators' ability to factor in the **scale** of use is particularly constrained because there is little information gathered on *how much* of a chemical is used in New Zealand, or *where* it is released into the New Zealand environment and the consequent potential for contamination. A lack of chemical quantity data has been noted as a limitation in screening and assessing chemicals for reassessment, as well as targeting effective compliance and enforcement interventions.[3]

In terms of **harm**, the Environmental Protection Authority (EPA) considers this at the approval stage as part of its role in balancing risks, costs and benefits when a substance is assessed or reassessed.[4] But because individual substance assessments happen infrequently or are not undertaken at all because substances are covered under group standards, controls are not always appropriately tailored for the risks posed. The EPA also screens chemicals for reassessment using a tool that considers their potential adverse effects (both hazard and exposure) and has been working on developing other data visualisation tools.[5]

The potential to cause harm is considered at the regional level through regional planning processes (e.g. when deciding whether to consent a new wastewater treatment plant). Regional processes rely on the availability of guideline values that indicate levels of a chemical above which ecological harm may occur. These values are based on the sensitivity of a range of species to toxic thresholds and have not been derived for every chemical in use.

With respect to **presence**, evidence of a chemical's presence in the environment, and consequent exposure to biota and ecosystems, can be understood best through consistent data collection that illustrates trends in contamination or impact on receiving environments, including ecological processes.

The EPA uses models to predict the likely presence of a contaminant in the receiving environment in arriving at conditions for use as part of the approvals process. However, there is no direct link between EPA processes and the monitoring efforts of councils. Such monitoring is focused on discharge consents along with state of the environment (SoE) reporting, which varies considerably between regions. The ability to interpret monitoring results is also dependent on the availability of guideline values mentioned above.

The framework in Figure 6.1 could be used to identify the chemicals we should be most concerned about and tailor management interventions accordingly. It would clearly make sense for the greatest focus to be on chemicals that fall within the centre of the image: those that are used on a large scale, which are known to cause harm, and whose presence is detected in the environment. But beyond that, the existence of two of the three factors (scale, harm and presence) can indicate the need for taking a focused interest. For example:

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[3] EPA, 2018b; EPA, 2015c.

[4] The approval process also takes into account **presence** where monitoring data are available – for example, in the context of a reassessment.

[5] The chemical map is a visualisation of the hazards, exposure and harm associated with chemicals. At present it is not a geographical map, and it remains under development.

- **The use of a substance on a large scale is known to be harmful but is not known to be occurring.**

  Monitoring for its presence can indicate changing use patterns and emerging risks. Information on where chemicals are being used and in what quantities can also help focus environmental monitoring.

- **A substance is being widely used and its presence is being detected in the environment but it is not known to be harmful.**

  Keeping abreast of any emerging evidence of ecotoxicity is the key to being alerted to the possibility of emerging risks, which could feed into a reassessment of the need for tighter controls.

- **Use of a substance is on a small scale but contamination is confirmed and known to be harmful.**

  Monitoring the ongoing scale of use will be vital to ensure that the level of environmental risk remains at a manageable level.

In different ways, the four case study chemicals illustrate that we know something about harm, scale and presence in each case but – at least when it comes to the environment – not necessarily in a comprehensive way.

Chemical contamination issues do not only affect the biophysical domain. They have social and cultural dimensions. For example, considerations of harm might take into account whether taonga species are particularly sensitive to a chemical. Environmental presence may be of particular concern to tangata whenua if it occurs in relation to mahinga kai sites.

Ideally, the consideration of scale, harm and presence should be iterative and enable changes to chemical management in the light of new evidence. Knowledge of a change in the scale of use can inform the priority for monitoring. Increased detection of contaminants can inform those responsible for imposing controls on use. Developing science on potential harm can inform both monitoring and regulation. Updated knowledge about the quantities used can enable more informed assumptions about the extent of harm. With so many new chemicals and so much research on their impacts, any regulatory system needs to be able to stay abreast of new information and adapt to it.

From an environmental contamination point of view, the management of chemical use in New Zealand needs to be able to integrate these considerations to ensure that it is focusing on the most important risks. If we are to persist with multiple entities being responsible for chemical management, then a common conceptual framework along the lines outlined above needs to be adopted. Using it, agencies should be able to arrive at a common understanding of how serious the environmental risks posed by any given chemical might be, and to target proportionate interventions.

Recommendation 1: Require all agencies dealing with chemicals to develop a common framework based on the scale, potential harm and environmental presence of chemicals to prioritise their efforts to consider, and manage, the environmental impacts of chemical use. The design of any such framework should involve Māori.

The balance of this chapter makes specific recommendations that would need to be implemented to make this possible.

Understanding the scale of chemical release into the environment

Quantities of chemicals imported, manufactured and sold

A starting point for understanding how much of a chemical is used, and therefore potentially released into the environment, is through records of the quantities of chemicals imported, manufactured or sold. It is also helpful to understand where they are used and for what purposes. However, New Zealand has no comprehensive national database that records this information. To obtain a full picture of the physical flows of the four case study chemicals across their lifecycle, information had to be sought from a variety of public and industry sources. The collation of these data was a time-consuming process. To the extent that the data collected are incomplete, they will suffer from a degree of uncertainty.

At the import phase, some data are publicly available from Stats NZ through import records collected by the New Zealand Customs Service in accordance with tariff obligations based on a harmonised international system.[6] This system arranges all goods in a systematic order, which is internationally consistent to a certain point, but the degree of resolution of import information for different goods varies. This is illustrated by the case study chemicals.

- Several separate categories exist for recording import volumes of zinc and articles containing zinc.
- Specific tariff codes exist for antibiotics, including tetracyclines, but volume information is not sufficiently detailed to understand how much is imported annually.[7,8]
- No specific tariff code exists for insecticides containing neonicotinoids (nor for the several active ingredients within this class). Rather, they are listed as ‘other’ under the broader category ‘insecticides’.
- A specific tariff code exists for triazine herbicides, with additional resolution for atrazine and simazine (both included in one category),[9] but not for terbuthylazine.

For a regulator or other party interested in import volumes, non-specific tariff codes or insufficient volume data limit the insights that can be gained because it is not always possible to isolate information about specific active ingredients.

The resolution of chemical classifications within the New Zealand tariff system could be increased, but obtaining meaningful insights about the quantity of chemicals within imported goods would still be challenging because of the lack of metrics recorded for imported products (e.g. weight, package size, and concentration of chemical within the finished product).

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[6] New Zealand is a signatory to the International Convention on the Harmonized Commodity Description and Coding System Nomenclature, commonly known as the Harmonised System Tariff (HS Tariff) (Customs NZ, 2021).

[7] The New Zealand Customs Service (and Stats NZ) does not always record specific volumes of goods imported under specific tariff codes, as the importer is not required to provide the weight for these goods when lodging the import entry.

[8] The Ministry for Primary Industries also collects data on antibiotics – as is covered in chapter five.

[9] Including even further resolution with the groups ‘atrazine and simazine’ and ‘other’ (i.e. all other triazine herbicides).

It should be noted that the tariff codes only capture data on imported chemicals, not those that are manufactured here in New Zealand. An alternative approach would be to require importers and manufacturers to report the volumes of hazardous substances imported or manufactured directly to the regulator. Such an approach has been advanced by the EPA. In 2015, against a background of low compliance with Hazardous Substances and New Organisms Act 1996 (HSNO Act) controls such as safety data sheet rules,[10] it consulted on the requirement for importers and manufacturers to report on the identity and volumes of substances to the EPA, depending on the risks they posed. The EPA argued that this would enable them to improve compliance, identify key areas of risk and ensure that interventions were proportionate. A summary of submissions revealed mixed views on the proposal and the EPA did not reach a conclusion, proceeding with more minor changes consulted on at the time.[11] No further proposals have been made.[12]

Data collected at the point of import or manufacture could contribute substantially to a better understanding of risks. The situation in New Zealand contrasts with the practice of some comparable overseas regulators, particularly among those charged with industrial chemical management. For example:

- In the United States, the Chemical Data Reporting rule enables the United States Environmental Protection Agency to collect and, subject to data confidentiality claims, make public, information on the import, manufacture and use of chemicals (including mixtures).
- The European Chemicals Agency (ECHA), under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation, requires registrants to estimate quantities manufactured and imported. Registrants may then place chemicals on the market within a certain tonnage band and must notify ECHA if they move to a higher band. Producers and importers of articles containing substances of very high concern must also notify ECHA about the volume of these chemicals in articles.[13]
- The Australian Industrial Chemicals Introduction Scheme (formerly the Industrial Chemicals Notification and Assessment Scheme (NICNAS)) links permitting requirements with the annual import quantity and/or requires reporting of volumes.[14]

With respect to pesticides, some jurisdictions also collect usage and sales statistics. For example:

- In the United Kingdom, data on the usage of pesticides have been collated for 50 years and enable publication of data on pesticide use (including seed treatments) by area and weight. Its database includes the ability to break down pesticide use by region.[15]

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[10] "A 2012 EPA survey of 400 businesses found that 75% of businesses were not compliant with all eight key HSNO controls assessed by the survey. Less than one third of the SDS [safety data sheets] reviewed in this survey contained the HSNO approval number or the title of the group standard, which are required under the HSNO Act." Further, a 2013 EPA audit of 200 safety data sheets identified that none were completely compliant with the existing HSNO Act requirements (EPA, 2015b, p.7).

[11] Under the Hazardous Substances (Importers and Manufacturers) Notice 2015, the name and contact details of a business must be supplied to the EPA the first time a hazardous substance is imported or manufactured (EPA, 2021o).

[12] EPA, 2015c.

[13] Article 7 of REACH requires notification to ECHA if substances of very high concern are contained at or above 0.1% w/w (weight to weight) in an article. https://reachonline.eu/reach/en/title-ii-chapter-1-article-7.html [accessed 10 December 2021].

[14] Categories of permits and certificates are described in pp.35–36 of the NICNAS handbook (NICNAS, 2014).

[15] The programme of pesticide usage surveys is commissioned by the independent expert committee on pesticides and funded by the chemicals regulation directorate. Data are collected by the pesticide usage survey teams at Fera Science Ltd, the Scottish Agricultural Science Agency and the Agri-Food and Biosciences Institute of Northern Ireland. See https://secure.fera.defra.gov.uk/pusstats/index.cfm [accessed 10 December 2021].

- The California Department of Pesticide Regulation requires registrants, pest control dealers and brokers of pesticides to report the value and volume of products sold in California.[16]

In the United States, pesticide use data have been used effectively in combination with data generated from a nationally consistent pesticide monitoring framework for surface waters established by the US Geological Survey. Regionally specific pesticide use data enable the prediction of where pesticide contamination is likely to occur, which can be verified by concentrations detected in monitoring. Monitoring results are also able to be interpreted against risk-based guideline values to provide an assessment of potential toxicity to aquatic organisms. Overall, the combined value of these data provide a comprehensive picture of pesticide distribution, presence, and potential risk in surface waters in the United States.[17]

Quantities of chemicals released into the environment

Technically, information concerning some chemical releases from some industrial activities is available through individual regional councils where data are collected through resource consent conditions. For example, monitoring is performed to check compliance of point source discharges of certain chemicals at wastewater effluent points. However, the accessibility of information on companies breaching their consents is limited, sometimes on the questionable grounds that it is private. In addition, its comprehensiveness depends both on whether monitoring and data collection were conditions of the resource consent and the degree to which monitoring actually takes place.

The Parliamentary Commissioner for the Environment's (PCE) 2019 letter to the Minister for the Environment explored the potential value of a Pollutant Release and Transfer Register (PRTR).[18] Subsequently, the EPA has begun to explore the value of a PRTR for New Zealand. This has identified two key substances that could be used to pilot a PRTR – methyl bromide and 1080 – where considerable data are already collected.[19] Among the considerations that need to be addressed in examining the feasibility of a PRTR are whether collation of data on priority releases would require legislative change and where the database should be housed.

A PRTR would raise important questions about linkages with other public databases and with SoE reporting. Relevant considerations here include the current lack of time series data and the quality and standardisation of data collection, validation and analysis. The recommendations in the PCE report *Focusing Aotearoa New Zealand's environmental reporting system* are relevant here.[20]

Addressing some of the data gaps on the releases of chemical contaminants into the environment could, in turn, improve our understanding of likely impacts and the effectiveness of management practices. An incremental approach focusing on pollution pressures that are most relevant to New Zealand's environment and economy would be the most appropriate way forward.

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[16] See https://www.cdpr.ca.gov/docs/mill/nopdsold.htm [accessed 10 December 2021].

[17] Stackpoole et al., 2021.

[18] PCE, 2019b.

[19] Proposed to be piloted through the chemical map tool, this tool remains under development (EPA, pers. comm., October 2020).

[20] PCE, 2019a.

Key issue

Data gaps throughout the chemical lifecycle impede regulators' ability to understand the scale of potential environmental contamination and prioritise appropriate regulatory interventions. These gaps are evident with respect to quantities of chemicals imported, manufactured, sold and released.

Recommendation 2: The Ministry for the Environment should develop regulations to require and empower the EPA to collate, collect and report on the quantity and use of chemicals in New Zealand.

In particular, the EPA should:

- require importers and manufacturers to report to the EPA the annual quantities of chemicals imported and manufactured, respectively, with the EPA publicly reporting the information as aggregated figures
- require those selling chemicals to report regional sales quantities to the EPA, with the EPA publicly reporting the information as aggregated figures
- collect data on use and environmental fate with a focus on priority releases
- develop a data platform that connects the dots of import, sale, release and evidence of environmental fate gathered from monitoring.

Understanding the environmental presence of chemical contaminants

The monitoring of chemical contaminants in the environment is essential to understand where pollution pressures are occurring, the extent of contamination and the effectiveness of regulatory intervention. Monitoring is used by regional councils and unitary authorities in respect of specific releases to check compliance against conditions, and for the purposes of monitoring receiving environments under the Resource Management Act 1991 (RMA).[21] Monitoring controls may also be imposed by the EPA at the national-level approval stage, but this is rare in practice. Monitoring is also important from a cultural health perspective.

Scope of monitoring

A review of consents covering discharge activities, including landfill leachate, wastewater and stormwater, found that while there is routine monitoring of heavy metals across all discharge activities, very few organic contaminants are subject to an equivalent level of scrutiny. Some potentially harmful contaminants such as pharmaceuticals and per- and poly-fluoroalkyl substance (PFAS) compounds may be screened in the process of reconsenting but are not typically controlled through the consenting process.[22] Aside from groundwater, few chemical contaminants are routinely monitored in receiving environments through SoE monitoring programmes covering surface waters, soils and coastal environments. Similar to consent-based monitoring, heavy metals are routinely monitored across receiving environments, whereas many organic compounds are not.

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[21] Regional councils and unitary authorities are mandated under section 35 of the RMA to gather information, monitor, and keep records about the SoE monitoring. The RMA specifies that information must be compiled and reviewed at least every five years. This monitoring can include chemical contaminants.

[22] Conwell, 2021, p.iv.

Regional councils and unitary authorities have an important and challenging role in deciding which contaminants to prioritise for monitoring based on their relative risk, receiving environment pressures and the resources and analytical capability available to the councils. Beyond that, national-level monitoring is also possible. For example, since 1990, surveys to determine the level of pesticides in groundwater have been conducted every four years.

However, there are notable gaps that could be addressed. For example, there is a lack of nationwide monitoring for pesticides in other key receiving environments, including surface waters and soils. This is a gap that should be addressed.

Efforts have been made by some councils, in collaboration with researchers, to target their monitoring efforts. For example, researchers have recommended a tiered approach to sampling in aid of future monitoring effort. They have selected a range of chemicals that are most representative of their chemical class and cover the main sources (sewage, stormwater, landfill, recreation and agricultural practices). There is also a focus on chemicals that persist in sediment and/or bioaccumulate in bivalves such as oysters and mussels.[23]

Cultural impacts monitored

Some cultural health research and sampling has been conducted but in an ad hoc manner. Monitoring has been infrequent, inconsistent and often only initiated by iwi.[24] Furthermore, there is no requirement to conduct cultural health monitoring or research by the EPA or any other responsible agency unless agreed to by the iwi and responsible agency.

In some instances, environmental indicators other than the species themselves are used as a proxy for mahinga kai species. These may not, however, provide an actual indicator of risk if that mahinga kai species is consumed. Regional council freshwater monitoring programmes often use measurements of contaminants in water to assess the risk to humans from consumption but do not test for the bioaccumulation of contaminants in the flesh. Flesh testing is not a part of most regional councils' regular monitoring regimes. Monitoring programmes of commercially grown or harvested seafood exist for exported goods but are not monitored at all sites where wild food is harvested by the general public.[25] Most monitoring programmes, whether ad hoc or not, fall short of providing any responsible agency with information on whether chemical contaminants will have impacts of concern to Māori.

Across Aotearoa, however, hapū and iwi are developing their own cultural health monitoring programmes (e.g. Cultural Heath Index, State of the Takiwā, Mauri model) to provide them with better information on the health of the environment from a Māori perspective.[26] These could be used to support their submissions on chemical applications. However, the use of cultural health monitoring programmes remains very limited at present.

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[23] Stewart et al., 2016, p.76.

[24] MfE, 2017. Further, a review conducted by Bishop (2019) revealed 16 different monitoring programmes all still in their review phase with the need for further improvement.

[25] NZFSA, 2010, p.8.

[26] Awatere and Harmsworth, 2014.

Limitations of current modelling used in risk assessments

The modelling of predicted environmental concentrations of chemicals is only as accurate as the data that go into a model and the way a model uses them. Some of the models used by the EPA in quantitative risk assessments of chemicals have limitations in terms of the parameters that can be included, and the ability to include scenarios specific to New Zealand.

An example of a limitation with the EPA's current modelling capabilities is the inability to directly incorporate metabolites. Metabolites can be as, or sometimes more, persistent and toxic than the parent compound and it is important to consider their environmental fate and toxicity in quantitative risk assessments. This is illustrated by the example of modelling terbuthylazine concentrations in groundwater, described in Box 5.2.

If New Zealand had more up-to-date modelling capabilities, better informed decisions around agrichemical risk would be possible. Instead, the limitations of the models used in quantitative risk assessments mean there is greater uncertainty about the potential for chemicals to cause environmental contamination, the extent of which could be over or underestimated as a result.

Key issue

Some of the models used in the EPA's risk assessments are outdated and lack specificity for New Zealand's environmental context.

Recommendation 3: The EPA should be specifically funded to improve its modelling capabilities in line with international best practice and to incorporate New Zealand-specific environmental exposure scenarios.

Understanding the harm caused by chemical contaminants

Guideline values and limits

Numeric values defining tolerable concentrations of chemicals in environmental media, set either as guidance or in regulation, are an important tool. They indicate a given level of species protection, are necessary to interpret monitoring results and are commonly used internationally, from environmental quality standards in Europe to aquatic life benchmarks for pesticides in the United States. There are avenues to set such values through either national or regional regulation in New Zealand, and guidelines do exist for some specific chemicals in air, freshwater, coastal waters, sediments and soils. However, there are limitations with respect to their scope and practical application.

National level limit setting

Numeric limits for contaminants are not a new concept in New Zealand environmental regulation. The National Policy Statement for Freshwater Management and accompanying National Objectives Framework set out levels of nutrients and microbes and include monitoring requirements to check progress.[27] Another example is the Ministry of Health's *Drinking-water Standards for New Zealand 2005 (Revised 2018)*, which set a maximum acceptable value of contaminants, including pathogens and chemicals, in drinking-water with a clear process for monitoring.[28] By contrast, the use and implementation of limits on chemical contaminants for environmental protection is less well established.

The EPA can set environmental exposure limits (EELs) at the national level.[29] However, these are rarely set, implemented, or subject to compliance monitoring. A key issue with the use of EELs is that they are set for individual substances at the point of an approval, rather than for active ingredients. This means that an EEL control imposed on an individual substance will not automatically apply across all approvals that contain the active ingredient (although this could be addressed through a reassessment).

The EELs set for neonicotinoid-containing substances illustrate how this substance-by-substance approach is problematic and results in inconsistencies in the setting of these values across substances containing the same active ingredient. The EPA has set EELs for four imidacloprid-containing products:[30] two flea treatments for pets, a bed bug powder and a wood preservative product. However, no agricultural insecticide formulations containing imidacloprid have EELs set for them despite use patterns that make environmental exposure far more likely to occur than the four products for which there are EELs. Thiamethoxam, on the other hand, has EELs for an agrichemical product.[31] There are also no EELs set for the other neonicotinoid insecticides (clothianidin, thiacloprid and acetamiprid), despite the fact that they carry an aquatic ecotoxicity classification.

A more consistent and functional approach would be to set an EEL for an *active ingredient* (e.g. imidacloprid) at the first approval of a substance containing that ingredient, which would subsequently apply to all approvals containing that ingredient.

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[27] Regional councils are required to set a target attribute state that is above the national bottom line and identify limits on resource use to achieve it within a certain timeframe. The National Objectives Framework identifies levels of nitrogen, phosphorous, and *E. coli* that are to be achieved.

[28] When water suppliers find any chemical in the distribution system at greater than 50% of its maximum acceptable value, they must note this in the water safety plan and monitor the chemical at least annually until they find its concentration to be less than 50% of its maximum acceptable value in three consecutive samples and identify a reason for the drop in concentration (Ministry of Health, 2018).

[29] These are sometimes based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

[30] Imidacloprid has EELs for 'soil/sediment' of 1 μg/kg dry weight and for 'water' of 0.038 μg/L (EPA, 2018a).

[31] Thiamethoxam has EELs for 'freshwater' of 0.35 μg/L and for 'marine' of 69 μg/L, which have been applied to a foliar spray used in horticulture and in-furrow planting in potatoes (EPA, 2018a).

The EPA does not currently have an operational policy in place covering the use of EELs and does not typically set them in practice. A detailed method for deriving EELs was set out in the Hazardous Substances (Classes 6, 8, and 9 Controls) Regulations 2001, but these were revoked in 2017. While EELs can still be set under the HSNO Act, a detailed methodology to guide their formulation is yet to be developed.

An additional concern raised by the EPA is that taking enforcement action on an EEL exceedance is in practice difficult because of the need to identify sources and their respective contribution to an exceedance. This could be challenging detective-work in a catchment-based context. The EPA has little control over such investigative monitoring.

In the absence of setting EELs on approved substances, maximum application rates are set as a key control to manage their environmental risk. But without setting an EEL in conjunction with an application rate, there is no imperative to measure concentrations in the environment and therefore assess the efficacy of this control in terms of environmental impact.

In the absence of a functional EEL system, regional councils routinely rely on the use of New Zealand and overseas-developed risk-based guidelines, where these exist.

Guidelines used at the regional level

A range of guideline documents from New Zealand and overseas is also available to regional councils. Among these, the Ministry for the Environment's environment guideline value database document provides guidance to national and regional regulators on the appropriate hierarchy of environmental guidelines available to use on contaminated land.[32]

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality set default guideline values that are available to regional councils, as well as guidance for deriving site-specific trigger values. However, gaps exist in terms of what chemicals are covered (most emerging contaminants are not), the process to update default guideline values is slow and costly, and the setting of trigger values by regional councils varies in practice. Furthermore, even if a guideline value exists, it may not be used by a regional council in respect of those chemical uses – such as pesticides – that are diffuse. Permitted uses are often not subject to compliance monitoring even if the permitted activity is subject to conditions. The absence of EELs makes it even harder to make the link between the adequacy of national controls and what is occurring on the ground.

The derivation of default guideline values for specific chemicals can be proposed by both Australian and New Zealand governments or by third parties. Deriving default guideline values follows an approved method, and if the chemical has been proposed by a third party, it is responsible for providing the required funding.[33] This can be a costly process and a lengthy one, especially if funding is periodically withdrawn.

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[32] See https://environment.govt.nz/facts-and-science/land/environmental-guideline-value-egv-database/ [accessed 2 November 2021].

[33] ANZG, 2018. See pathway for toxicant default guideline value publication in https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/draft-dgvs [accessed 2 August 2021].

By way of example, the process for deriving zinc and copper default guideline values provides an insight into an almost interminably lengthy process. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality have been under review since 2014. From a priority list of chemicals, the Ministry for the Environment funded the derivation of values for zinc and copper for both marine and freshwater systems. However, the resources needed to complete the work were directed elsewhere before peer review comments had been received. Independent funding then had to be found to progress both zinc and copper marine guidelines.[34]

The marine zinc guidelines were submitted in 2018 and were published for public comment in July 2020. The reviewed version has gone through the publication approval process for a second time and was accepted in September 2021 as the final default guideline value. The marine copper guideline is still going through the initial reviewing process. On the other hand, the derivation of *freshwater* guideline values for zinc and copper has recently been funded by Environment Canterbury and Christchurch City Council. On the basis of the time taken for the marine guidelines to be revised, it is expected that the freshwater guidelines will not be available for use until after 2024 – a full decade after the review commenced.

With respect to pesticides, several have default guideline values and third parties have proposed several others for the derivation process, including the two pesticides in our case studies: imidacloprid and terbuthylazine.[35] The waiting list for reviewing third-party proposals currently includes 31 chemicals that will be processed based on an assessment of priority and budget availability. Priority may be escalated where third parties are able to fund the development of a default guideline value.

There is a need to fill key gaps in the guidelines soon (such as freshwater zinc) because some regional councils need these numbers for the next iteration of council plans due by 2024. That the Ministry for the Environment has failed to see the finalisation of default guideline values through to a timely conclusion suggests a serial lack of priority, follow up, and resourcing that has been allowed to persist over successive governments.

Guidelines are important in combination with environmental monitoring to enable scientists and authorities to identify when the level of a chemical is reaching potentially problematic levels and provide feedback to regulators to aid environmental protection efforts. Addressing some of the issues identified with the funding, development and implementation of guideline values would help to improve the effectiveness of their use in chemical management.

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[34] NIWA’s funding. Jenni Gadd, Aquatic Chemist, NIWA, pers. comm., 1 July 2021.

[35] See https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/draft-dgvs#third-party-process-for-proposing-default-guideline-values [accessed 10 December 2021].

Key issues

Guideline values and monitoring are essential to understanding chemical presence in receiving environments and determining how much is too much in a given environmental medium. Currently:

- Limitations are evident with respect to the scope of chemicals monitored, the range of receiving environments monitored, and the monitoring of cultural health.
- A range of guideline values for environmental protection is available for guidance or regulation, but several challenges remain. There are also significant challenges with implementing environmental exposure limits.

Recommendation 4: The Ministry for the Environment should develop guidance on best practices to be followed in monitoring the environmental fate of chemicals covering both EPA and regional council roles.

Specifically, that guidance should include advice on:

- who is responsible for setting guideline values and monitoring against these values
- how monitoring effort and guideline value development should be prioritised
- the scope of receiving environments to be monitored and the frequency of monitoring
- the way national and regional levels of regulation should support one another, including:
    - how national-level data on where and how much a chemical is used should assist regional councils to target their monitoring
    - how regional-level monitoring data should be fed back to the EPA to improve national-level regulatory controls
- adapting to new information about chemical pressures (by increasing/decreasing priority for monitoring)
- how best to support the development and implementation of Māori cultural monitoring as a vehicle for providing cultural perspectives and data that could be incorporated into the determination of threshold values.

Recommendation 5: The EPA should give higher priority to the development and use of environmental exposure limits (EELs).

In particular, the EPA should:

- develop and publish a policy, including a methodology, for setting EELs
- provide guidance to enforcement agencies for requirements for monitoring and reporting to demonstrate compliance
- set EELs for priority chemicals of national concern. This may be particularly important for chemicals that arise from diffuse discharges that are not routinely monitored through consent-based monitoring at a local scale.

Specific sources and pathways

While harm (or risk) is well captured by current regulatory processes for some chemical contaminants and some receptors, there are areas where improvements could be made in regard to some specific sources and pathways.

The national-level regulatory system for hazardous substances led by the EPA under the HSNO Act assesses and models the potential environmental harm posed by some chemicals in a detailed and thorough way, whereas many other chemicals are subject to a cursory risk assessment or very little oversight. Likewise, regional council processes under the RMA tend to focus on some contaminant discharge types more than others.

The regulation of *hazardous substances* under the HSNO Act, and *contaminants* under the RMA, are based on contrasting paradigms – with the former focusing on the potential adverse effects of specific individual substances based on their intrinsic properties and estimated exposure, and the latter focused on their effects in receiving environments. As a result, the environmental fate of some contaminants may be thoroughly considered at the national level, but then subject to little monitoring at the local level (such as agrichemicals). Others may not be considered extensively at the national level but are only captured to some degree at a regional level (such as wastewater discharges).

In many cases the degree of scrutiny across the system appears to correspond closely with the potential harm posed, but this is not the case for all forms in which chemicals can reach the environment. Within certain source categories – such as agrichemical use – there are pathways that may require additional scrutiny, such as for animal wastes and seed treatment. There are also several 'outliers' to the current regulatory system, such as additives that are imported within manufactured articles and mixed wastes. These need to be addressed to ensure that the level of regulatory oversight offered matches the level of harm posed.

Key issue

Some sources and pathways of chemical contaminants receive insufficient attention in the approval process resulting in inadequate oversight of their potential for contamination.

Recommendation 6: The EPA should develop policies to address specific pathways and other forms in which chemicals may contaminate the environment, such as animal wastes, accumulation of contaminants in agricultural soils, human pharmaceuticals in wastewater, some manufactured articles and by-products.

Recommendation 7: The EPA should expedite an update of its policy regarding treated seed as a manufactured article to ensure appropriate regulation before its current reassessment of neonicotinoids is finalised.

How Māori engagement should underpin chemical approvals

The EPA recognises that impacts, issues and aspirations can be specific to whānau, hapū and iwi, and that mātauranga Māori in its essence is local knowledge. The EPA also encourages early engagement by applicants with local whānau, hapū and iwi that may be affected by an application. The EPA is concerned with not only encouraging the use of mātauranga Māori as part of its decision-making process but also building, supporting and maintaining relationships between the EPA, Māori and applicants.[36] There are, however, some processes that may come into conflict with this. An example is the development of Māori impact assessments produced by the EPA's Kaupapa Kura Taiao team.

Māori impact assessments are not required to be prepared by the EPA but are a part of its routine documentation when processing applications. The assessments undertaken by Kaupapa Kura Taiao are not whānau, hapū or iwi specific but take a national view of the impact on Māori. They often describe a range of issues and impacts that are generic to Māori and serve as a placeholder for submissions from whānau, hapū and iwi. Because HSNO applications to the EPA are nationally focused, this may mean that it is easier for Māori impact assessments to be considered during the decision-making process than a submission from one iwi due to impacts being more localised.[37]

As part of its responsibilities, Kaupapa Kura Taiao should ensure that local mātauranga Māori has a voice in the application process. Kaupapa Kura Taiao could prioritise its work to be a 'friend of Māori submitters'. Regional councils commonly provide assistance to submitters on large resource consents through a 'friend of the submitter' role. They help to explain and support submitters through the process and can assist in finding experts.[38] The EPA has previously been directed to undertake that role or find someone who can by the Board of Inquiry for the Waterview Connection proposal.[39]

The EPA is required to consider the cultural impacts of chemicals, yet there is very little research conducted, or monitoring information used, to determine this impact through the application process.[40] Cultural impacts are not limited to just the physical or environmental domains but span the spiritual and human health domains as well. Determining the impacts of chemicals on the spiritual state of Māori and Māori values is particularly difficult given the empirical evidence-driven risk assessment model that is employed by the EPA. Similarly, epidemiological evidence to investigate cause-and-effect relationships between the presence of a chemical(s) and the determinant of a specific health impact is very difficult given the complexity of physical, cultural and spiritual factors that can be at play.[41]

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[36] EPA, 2016.

[37] See https://www.epa.govt.nz/news-and-alerts/latest-news/korero-to-kintsugi/ [accessed 10 December 2021].

[38] MfE, 2021.

[39] Board of Inquiry Waterview Connection Proposal, 2010.

[40] Although there has been some development of cultural health indicators for freshwater especially, these monitoring programmes are still being refined (Stewart-Harawira, 2020).

[41] See Awatere and Harmsworth (2014) for frameworks and monitoring tools that utilise mātauranga Māori.

The EPA needs to consider how its risk assessment framework can meet the expectation of Māori that reference to the incorporation of mātauranga should be visible in its determinations. This extends to ensuring that assessments of impact can be related to taonga species rather than simply rely on foreign standard test species.[42]

Key issue

In the current approval process for chemicals, cultural impacts are only considered at a national level, which dilutes the concerns of tangata whenua even if they may be directly impacted by local use of a chemical.

Recommendation 8: The EPA Kaupapa Kura Taiao team should consider focusing some of its resources on providing ‘friends of submitters’ services to Māori (whānau, hapū, iwi and other Māori entities).

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[42] Sutherland, 2014b.

7


Thelypteris confluens

Appendices

Appendix 7.1: Different international approaches to modelling

Models and their use in risk assessment processes are rarely harmonised across countries, partly because of the varying data requirements mandated by national regulatory agencies. While the provision of physical, chemical and fate data is commonly expected across jurisdictions, predicted data are only required by the United States and Canada.

Models used for hazard assessments are extensively applied by these two countries. In Canada, these modelled data are used as part of its weight of evidence approach, together with measured and surrogate data. In comparison, Australia, Japan, Switzerland and the United Kingdom do not include ecotoxicology modelling data in their assessment, mainly because measured data are readily available. Table 7.1.1 presents models used by different jurisdictions for hazard assessment.[1]

In New Zealand, ecotoxicological models are not conducted, given that over 90 per cent of hazardous substances assessed are pesticides for which toxicological information is available. Models are used instead to calculate predicted environmental concentrations and exposure pathways for surface waters.[2] Conversely, predicted environmental concentrations for New Zealand's soils are not based on models but on straight calculations.

But the transport of chemicals is not restricted to one way or direction and can occur via multiple pathways (e.g. spray drift, runoff, and movements through groundwater systems). To account for this, Canada, Switzerland and the United Kingdom use a multicompartmental approach in which they assess toxicity to sediment, soil and terrestrial compartments. Conversely, Australia and the United States only conduct effect assessments on aquatic compartments.[3] Table 7.1.1 shows different types of exposure assessment models used across international jurisdictions.

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[1] OECD, 2004.

[2] EPA, 2020g.

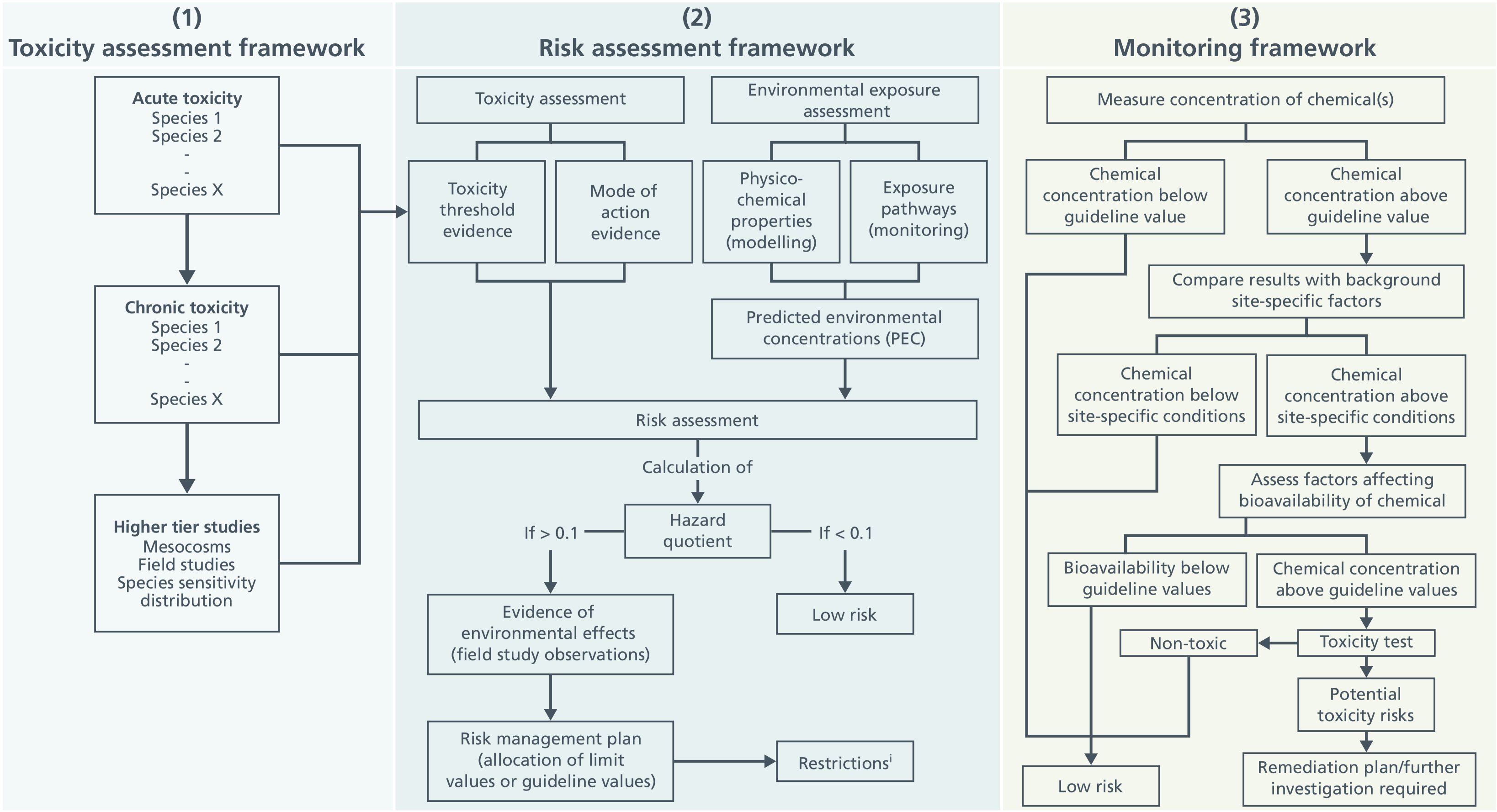
[3] OECD, 2004; OECD, 2012; https://www.oecd.org/chemicalsafety/risk-assessment/oecdpovandlrtpscreeningtool.htm [accessed 10 November 2021].

Table 7.1.1: Existing models used by international agencies in environmental risk assessments. Types of models are divided by hazard or exposure assessment.

Categories	Model	Use of model
Hazard assessment		
Generating new data	Quantitative Structure–Activity Relationships (QSAR) (USA, Canada)	Estimate properties of a chemical from its molecular structure. Have potential to inform the probable hazard of chemicals.
Assessing hazard data	Ecological Structure–Activity Relationships (ECOSAR) (USA)	Predict the aquatic toxicity of industrial chemicals.
	Estimation Program Interface (EPI) Suite (USA and Canada)	Estimate physical, chemical and environmental fate properties of a chemical.
	ClogP (Canada)	Estimate octanol/water partitioning coefficient (K_{ow}) of a chemical.
	HYDROWIN (USA, UK)	Estimate the rate at which a chemical will react with water.
	Chemsteer (USA)	Estimate workplace exposures and environmental releases for chemicals used in industrial settings.
	Toxicity prediction by computer assisted technology (TOPKAT) (USA, Denmark)	A QSAR model that predicts chemical toxicity.
	ECOSAR (USA)	Estimate aquatic toxicity.
	Biotic ligand models (BMLs) (USA)	Estimate bioavailability of metals in aquatic organisms, and their toxicity.
Exposure assessment		
Environmental and fate pathways	The Exposure and Fate Assessment Screening Tool (E-FAST) (USA)	Estimate concentrations of chemicals released to air, surface water, landfills, and consumer products. Focus on human and aquatic environmental exposure.
	Environmental persistence (POV) and long-range transport potential (LRTP) of organic chemicals Screening Tool (OECD countries)	Estimate persistence of a chemical in the environment and long-term transport potential.
	Metabolic pathway model CATABOL (Canada)	Estimate transformation products and degradation.

Environmental and fate pathways	Biodegradation Probability Program for Windows (BIOWIN) Ultimate Survey Model (USM) (USA, Canada)	Estimate biodegradation of organic chemicals in presence and absence of oxygen.
	ChemCAN (Canada)	Chemical fate model that estimates average concentrations of chemicals in different environments and biota.
	SimpleTreat model (European Union)	Model the fate of substances in wastewater treatment plants.
	Mackay's level I fugacity model (Australia)	Estimates the environmental behaviour of chemicals by determining the relative concentration of a chemical in air, water, and soil phases at equilibrium.
	The Forum for the Co-ordination of pesticide fate models and their Use (FOCUS) suite, Pesticide Leaching Model (PELMO), Pesticide Root Zone Model (PRZM) (European Union)	Estimate transport and transformation of chemicals in roots and unsaturated soils.
	Surface water concentration calculator (SWCC) (USA)	Estimates concentrations of pesticide in water following pesticide application to land.
Predicted environmental concentration (PEC)	FOCUS suite (European Union) Generic Estimated Environmental Concentration (GENEEC) model, Agricultural drift (AgDRIFT) model, Agricultural dispersal (AgDISP) model, Ratio to exposure toxicity (RexTox) model (New Zealand, USA)	Estimation of pesticides in surface waters.
	FOCUS suite (European Union)	Estimation of pesticides in soil and sediments.
	PELMO (European Union)	Estimation of vertical movement of pesticides and presence in groundwater.
	Sci-Grow (New Zealand)	Screening model to predict concentration of pesticide in groundwater.

Appendix 7.2: Frameworks used in environmental risk assessment of chemicals



Source: Modified from Simpson et al, 2013 and ANZECC guidelines

Notes:

[i] May not be relevant to some metalloids (selenium and arsenic) and metals (e.g. mercury).

Figure 7.2.1: Frameworks used in environmental risk assessment of chemicals.

Appendix 7.3: Neonicotinoid supplementary information

Methods used to minimise dust formation during seed drilling

An advantage of applying neonicotinoids as seed treatments is that environmental exposure from spray drift is avoided. However, contaminated dust drift can occur during the drilling of neonicotinoid-coated seed. To reduce exposure to contaminated dust, polymers and fluency powders are now added during the seed treatment process to minimise abrasion of the insecticide off the seed during planting.[1] Improvements in planting technology, including using pneumatic (air pressured) seed drilling machines and air deflectors, can also reduce dust drift by precisely planting seeds in the ground and directing exhaust air back towards the soil.[2]

Neonicotinoid residues in non-target plant tissues

The systemic activity of neonicotinoids can result in high concentrations in pollen, nectar and guttation (sap) droplets of both treated crops and non-target plants.[3,4] Due to their high aqueous solubility, neonicotinoids can travel through groundwater and runoff and be taken up by wild plants growing at the margins of fields. Therefore, wild flowering plants can present an exposure route of neonicotinoids to pollinators even when the target crop might not flower or be attractive to pollinators.[5] In some cases, field-margin plants have even been found to have higher concentrations of neonicotinoids than the nearby treated crop.[6] If present in the field, flowering arable weeds growing in treated crop fields are another possible neonicotinoid exposure route to bees.[7] Neonicotinoid concentrations in honey and pollen collected by bees are typically in the range of one to ten parts per billion (nanograms per gram) and approximately correspond to the concentrations found in the pollen and nectar of wildflowers.[8]

Ecotoxicity to honeybees and other terrestrial invertebrates

Estimates of toxicity to bees depend on a range of factors, including exposure route (e.g. oral versus contact exposure), environmental conditions during testing and the condition of tested bees.[9] These factors can cause considerable variation in the determined toxicity level, by a factor of up to 100 (5–500 nanograms per bee) for imidacloprid. It has therefore been suggested that lethal dose (LD_{50}) values should only be used to compare levels of toxicity among pesticides, rather than drawing conclusions about the risk of mortality posed to honeybees via environmental exposure.

A range of sublethal effects of neonicotinoid exposure to honeybees have also been demonstrated, including impaired foraging activity, mobility, metabolism, early life-stage development, behaviour, learning, memory and orientation. Any sublethal effect on individual fitness and foraging efficiency reduces the food storage and reproductive potential of a colony, thus posing a risk to the colony’s survival and also to agricultural food production reliant on pollination.

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[1] EFSA, 2013a, b, c.

[2] Godfray et al., 2014.

[3] Girolami et al., 2009; Tapparo et al., 2011; Krupke et al., 2012; Stoner and Eitzer, 2012.

[4] Botías et al., 2015; David et al., 2016.

[5] Krupke et al., 2012; Botías et al., 2015.

[6] Botías et al., 2016.

[7] Wood and Goulson, 2017.

[8] Bonmatin et al., 2015.

[9] Pisa et al., 2015.

Ecotoxicity to other non-target terrestrial invertebrates has also been assessed for bumblebees, solitary bees, butterflies, moths, hoverflies, wasps, beetles, spiders, mites and earthworms.[10] Some of these beneficial insects are predators of pests. In cases where neonicotinoid exposure routes cause predators to take up the chemical, biological control of pests can be disrupted, leading to reduced crop yields from neonicotinoid use.

For example, the trophic transfer of thiamethoxam from less-sensitive pest slugs (*Deroceras reticulatum*) to the more sensitive predatory beetle (*Chlaenius tricolor*) resulted in the impairment or mortality of more than 60 per cent of beetles in the laboratory. Field trials using thiamethoxam-treated soybean seeds demonstrated that reduced slug predator densities in the field resulted in 19 per cent lower soybean densities and five per cent lower yields compared to non-treated crops.[11] A recent review of studies investigating the effect of pesticides on soil organisms found neonicotinoids negatively affected more than 75 per cent of responses tested (475 parameters tested in total).[12]

Ecotoxicity to New Zealand native species

The existing ecotoxicity data for New Zealand native species are for freshwater invertebrates. This includes laboratory studies with two stream-dwelling mayfly species, *Deleatidium* spp. and *Coloburiscus humeralis. Deleatidium* is found in streams across the country, and had 28-day lethal concentration (LC_{50}) values of 0.28, 1.36 and greater than 4 micrograms per litre (the highest concentrations tested) for imidacloprid, clothianidin and thiamethoxam, respectively.[13] A further study demonstrated the time-cumulative effects of imidacloprid on impaired swimming ability and mortality of *Deleatidium* mayfly nymphs when exposed to 0.4 micrograms per litre over six weeks,[14] just over half the average concentration of imidacloprid found in 33 surveys of streams worldwide (0.73 micrograms per litre).[15]

A recent study utilising stream mesocosms tested the effects of pulsed imidacloprid exposure on stream macroinvertebrate communities.[16] Three 48-hour pulses of imidacloprid (10 days apart) at concentrations from 0.1 to 4.6 micrograms per litre significantly disrupted the stream invertebrate community. The total number of invertebrates overall was reduced by imidacloprid, with even stronger effects on mayflies and caddisflies.

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[10] Pisa et al., 2015.

[11] Douglas et al., 2015.

[12] Gunstone et al., 2021.

[13] Macaulay et al., 2019.

[14] Macaulay et al., 2021b.

[15] Sánchez-Bayo et al., 2016.

[16] Macaulay et al., 2021a.

Controls tables

Table 7.3.1: Summary of Hazardous Substances and New Organisms Act 1996 controls relevant to environmental hazards of selected imidacloprid-containing products. See table notes for the Globally Harmonized System 7 classifications (ecotoxicity classifications shown in bold).

Please note, this table is only indicative of the controls under substance approvals current at the time of writing and does not override official regulations.

	Use pattern				
	Seed treatment	**Foliar spray**	**Sheep lice control**	**Domestic pet flea treatment**	**Wood preservative**
Environmental Protection Authority (EPA) approval example (either individual approval or group standard)	Suspension concentrate containing 600 g/L imidacloprid-iconcentrate containing 600 g/L imidacloprid[i]	Suspension concentrate containing 350 g/L imidacloprid (e.g. Confidor)[ii]	NTNCS2 (e.g. Zapp Encore[iii]	E.g. Advantage Multi[iv]	E.g. FramePro Plus
Labelling, packaging and safety data sheet notices[v]	√ Includes label statement to protect bees	√ Includes label statement to protect bees	√	√	√
Disposal Notice[vi]	√	√	√	√	√
Hazardous Property Controls (HPC) Notice requirements (where relevant)	√	√	√	√	√
HPC Notice Part 4B: Use of substances that are hazardous to the environment					
General duty to avoid adverse effects	√	√	√	√	–
Equipment must be appropriate (applies to workplace)	√	√	√	√	√
Record of application if > 3 kg applied within 24 hrs	√	√	–	–	–
Environmental exposure limits (EELs) must not be exceeded	No EEL set	No EEL set	No EEL set	√	√

Must not be applied into or onto water	√	√	–	–	√
Protections for terrestrial vertebrates – all reasonable steps taken to avoid adverse effects (plus specific requirements for baits, granules and seed)	√	√	√	√	√
Protections for terrestrial invertebrate pollinators – application plot must not include any bees that are foraging, flowering plants or plants likely to flower and be visited by non-target invertebrate pollinators	–	√	–	–	–
HPC Notice Part 4C: Qualifications required for application of substances that are hazardous to the environment	√	√	N/A as veterinary medicine	N/A as veterinary medicine	N/A

Additional or varied controls relevant to environmental risks of the substance	Protections for terrestrial invertebrate pollinators (clause 58 of the HPC Notice Part 4B) does not apply to seed treatment uses.	–	–	–	This substance shall only be used as an agent in the preservation treatment of timber at industrial sites inside a closed treatment system. Timber treated with this substance, when that timber is for use in New Zealand, shall be managed in accordance with the requirements of NZS 3602:2003 and have a treatment specification meeting the requirements of NZS 3640:2003 or an accepted alternative (e.g. AS/NZS 1604 series). The concentration of each of the impurities cadmium, lead, mercury and arsenic in the sodium tetraborate pentahydrate and boric acid used in the manufacture of this substance must not exceed 10 ppm for each element.

Notes:

[i] Classifications: Acute oral toxicity Category 3; Eye irritation Category 2; Skin sensitisation Category 1; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to soil organisms; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2021h).

[ii] Classifications: Acute oral toxicity Category 4; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to soil organisms; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2021d).

[iii] Classifications: Flammable liquid Category 4; Skin irritation Category 2; Eye irritation Category 2; Reproductive toxicity Category 1; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to soil organisms; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2020ij).

[iv] Classifications: Acute oral toxicity Category 4; Acute inhalation toxicity Category 4; Eye irritation Category 2; Skin sensitisation Category 1; Reproductive toxicity – additional effects on or via lactation; Specific target organ toxicity (repeated exposure) Category 1; Hazardous to soil organisms; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2020hi).

[v] Clauses 19–25 of the Labelling Notice detail label statements relevant to ecotoxic hazards, including for instance the circumstances in which harm might occur, kind and extent of harm, and steps to be taken (EPA, 2021p).

[vi] The Disposal Notice includes specific controls relevant to ecotoxic substances, including a requirement to avoid exceedance of environmental exposure limits (EPA, 2021m).

Table 7.3.2: Summary of Hazardous Substances and New Organisms Act 1996 controls relevant to environmental hazards of selected products containing clothianidin, thiamethoxam and thiacloprid. See table notes for the Globally Harmonized System 7 classifications (ecotoxicity classifications shown in bold).

Please note, this table is only indicative of the controls under substance approvals current at the time of writing and does not override official regulations of each respective regulator.

	Active ingredient and use pattern			
	Clothianidin (seed treatment)	**Thiameth-oxam (seed treatment)**	**Thiacloprid (foliar spray)**	**Acetamiprid (ornamental plant insecticide)**
EPA approval example (either individual approval or group standard)	Suspension concentrate containing 600 g/L clothianidin[i]	Suspension concentrate containing 600 g/L thiamethoxam[ii]	Suspension concentrate containing 480 g/L thiacloprid[iii]	E.g. Crown 225SL Systemic Insecticide[iv]
Labelling, packaging and safety data sheets notices	√ Includes label statement to protect bees	√ Includes label statement to protect bees	√ Includes label statement to protect bees	√ Includes label statement to protect bees
Disposal Notice	√	√	√	√
HPC Notice – requirements (where relevant)	√	√	√	√
HPC Notice Part 4B: Use of substances that are hazardous to the environment				
General duty to avoid adverse effects	√	√	√	√
Equipment must be appropriate (applies to workplace)	√	√	√	√
Record of application if > 3 kg applied within 24 hrs	√	√	√	√
EELs must not be exceeded	No EEL set	No EEL set	No EEL set	No EEL set
Must not be applied into or onto water	√	√	√	√
Protections for terrestrial vertebrates – all reasonable steps taken to avoid adverse effects. (Plus specific requirements for baits, granules and seed)	√	√	√	√

Protections for terrestrial invertebrate pollinators – application plot must not include any bees that are foraging, flowering plants or plants likely to flower and be visited by non-target invertebrate pollinators	√	√	√	√
HPC Notice Part 4C: Qualifications required for application of substances that are hazardous to the environment	–	–	√	√
Additional or varied controls relevant to environmental risks of the substance	Protections for terrestrial invertebrate pollinators (clause 58 of the HPC Notice Part 4B) does not apply to seed treatment uses.	Protections for terrestrial invertebrate pollinators (clause 58 of the HPC Notice Part 4B) does not apply to seed treatment uses.	–	Crown 225SL Systemic Insecticide may only be applied to ornamental plants. A maximum application rate for Crown 225SL Systemic Insecticide is set at 0.05 kg acetamiprid/ha, with a maximum of 3 applications per season and a minimum interval between applications of 7 days.

Notes:

[i] Classifications: Acute oral toxicity Category 4; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to soil organisms; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2021f).

[ii] Classifications: Skin sensitisation Category 1; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment chronic Category 2 (EPA, 2021g).

[iii] Classifications: Acute oral toxicity Category 4; Carcinogenicity Category 2; Reproductive toxicity Category 2; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to soil organisms; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2021e).

[iv] Classifications: Acute oral toxicity Category 4; Aspiration hazard Category 1; Reproductive toxicity Category 1; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to soil organisms; Hazardous to terrestrial vertebrates; Hazardous to terrestrial invertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2021b).

Appendix 7.4: Tetracyclines supplementary information

Development of antimicrobial resistance

Bacteria can develop resistance to antibiotics either by DNA mutation and spread of clones, or by acquiring genes from other bacteria or plasmids – known as horizontal transfer.[1] The main drivers identified for the spread of antimicrobial resistance are the use of antibiotics in human, companion animals and production animals. An increase in bacterial resistance to antibiotics suggests a higher risk of infections to human and animals, and a decrease in effective treatment options.

Alternative pathways for the movement of tetracyclines

An additional pathway for tetracyclines is through the disposal of unused and expired medications to landfill or wastewater system. In New Zealand, community collection, treatment and disposal schemes are in place for most regions (excluding Northland District Health Board (DHB), which operated its own scheme, and Whanganui DHB, Tairāwhiti DHB or West Coast DHB). In these schemes, antibiotics are treated with high temperature steam. Unfortunately, all medicine wastes are mixed in batches, which limits the capacity to identify the quantity of tetracyclines collected for treatment. Further, concerns have been raised about the effectiveness of the treatment to deactivate medicines in general.[2]

Factors affecting degradation of tetracyclines in receiving environments

Degradation of tetracycline can also be influenced by their sorption to soils – the process where a substance becomes attached to a solid sorbent such as soil or sediment.[3] Adsorption of tetracyclines to different types of soils is estimated mainly on the basis of organic carbon content, along with pH, metal oxide and the capacity of soil particles to retain positive ions (cations). The influence of values of these parameters varies among media, therefore the degradation rates (or persistence) of tetracyclines are media-specific, as shown in Table 7.4.1.

Unlike other agricultural or industrial chemicals, the distribution and adsorption of tetracyclines is not dictated by their water affinity (hydrophilicity, also referred to as log K_{ow}), an aspect to be considered when running environmental modelling tools to derive environmental exposure limits.[4]

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[1] Checcucci et al., 2020.

[2] Svahn and Björklund, 2015; Thomas, 2015.

[3] Thiele-Bruhn, 2003.

[4] Kümmerer, 2008.

Table 7.4.1: Fate/persistence of tetracyclines in different substances and receiving environments. Data presented in degradation half-life (DT_{50} values) in days.[5]

	Tetracycline compound	DT50
Manure	Chlortetracycline (chicken manure)	> 30
	Oxytetracycline (cattle manure)	< 30
Soil	Oxytetracycline	16–18
	Chlortetracycline	24–35
	Tetracycline	10–180
Water	Oxytetracycline	< 9
	Tetracycline	0.13
Marine sediment	Oxytetracycline	> 1,800

Accumulation and toxicity of tetracycline compounds in terrestrial and aquatic biota

First generation tetracyclines (i.e. tetracycline, chlortetracycline, oxytetracycline) have moderate accumulation capacity in plants and terrestrial species, and present higher toxicity than other antibiotics (e.g. sulfamethazine or erythromycin), affecting the growth of bacterial communities and plants. While effects of tetracyclines have been suggested for microbes, there is a lack of information about the impact they may have on microbial biomass, or activities associated with carbon and nutrient cycles.[6]

In aquatic environments, the risks of tetracyclines' toxicity are considered low, given their relatively quick fixation to sediments.[7] However, studies have shown that at environmentally significant concentrations (145–500 µg/L), tetracyclines can be toxic to common carp and zebrafish embryos, causing tail and heart malformations, pericardial edema, and general developmental delays.[8]

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[5] Boxall et al., 2008.

[6] Santás-Miguel et al., 2021.

[7] Kemper, 2008.

[8] Escobar-Huerfano et al., 2019.

Controls table

Table 7.4.2: Summary of Hazardous Substances and New Organisms Act 1996 controls relevant to environmental hazards of selected products containing tetracyclines. See table notes for the Globally Harmonized System 7 classifications (ecotoxicity classifications shown in bold).

Please note, this table is only indicative of the controls under substance approvals current at the time of writing and does not override official regulations.

	Use pattern		
	Veterinary medicine		**Human medicine**
Environmental Protection Authority (EPA) approval example (either individual approval or group standard)	Solid containing oxytetracycline hydrochloride (10%)[i]	Liquid containing oxytetracycline dihydrate (26–38%)[ii]	Minocycline hydrochloride (capsule of 50 and 100 mg). No EPA approval required.
Labelling, packaging and safety data sheets notices[iii]	√	√	–
Disposal Notice[iv]	√	√	–
Hazardous Property Control (HPC) Notice – requirements (where relevant)	√	√	–
HPC Notice Part 4B: Use of substances that are hazardous to the environment			
General duty to avoid adverse effects (agrichemicals)	√	√	–
Equipment must be appropriate (applies to workplace)	√	√	–
Record of application > 3 kg applied in 24 hrs (agrichemicals, not fertilisers, vet meds)	–	–	–
Environmental exposure limits (EELs) must not be exceeded	–	–	–
Must not apply into or onto water (agrichemicals but not vet meds, fertilisers, fumigants or vertebrate toxic agents)	–	–	–
Protections for terrestrial vertebrates – general steps to avoid adverse effects, and specific requirements for baits, granules and seed	–	–	–

Protections for terrestrial invertebrate pollinators (agrichems applied to plants)	–	–	–
HPC Notice Part 4C: Qualifications required for application of substances that are hazardous to the environment	–	–	–
Additional or varied controls relevant to environmental risks of the substance	[additional labelling control], where the substance is available to the general public, the following precautionary statements must appear on the label— (a) "Keep out of reach of children"; and (b) "For animal treatment only".	[additional labelling control], where the substance is available to the general public, the following precautionary statements must appear on the label— (a) "Keep out of reach of children"; and (b) "For animal treatment only".	–

Notes:

[i] Classifications: Hazardous to the aquatic environment chronic Category 2. Approved via group standard approval (EPA, 2020h).

[ii] Classifications: Acute dermal toxicity Category 4; Acute inhalation toxicity Category 4; Eye irritation Category 2; Reproductive toxicity Category 1; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1. Approved via group standard approval (EPA, 2020h).

[iii] Clauses 19–25 of the Labelling Notice detail label statements relevant to ecotoxic hazards, including for instance the circumstances in which harm might occur, kind and extent of harm, and steps to be taken (EPA, 2021p).

[iv] The Disposal Notice includes specific controls relevant to ecotoxic substances, including a requirement to avoid exceedance of environmental exposure limits (EPA, 2021m).

Appendix 7.5: Terbuthylazine supplementary information

Controls table

Table 7.5.1: Summary of Hazardous Substances and New Organisms Act 1996 controls relevant to environmental hazards for selected terbuthylazine products: suspension concentrate and water dispersible granule products containing terbuthylazine (concentrations from 150 to 900 g/L or g/kg).[i]

Please note, this table is only indicative of the controls under substance approvals current at the time of writing and does not override official regulations.

Control	Requirements
Labelling, packaging and safety data sheet notices	Yes
Disposal Notice	Yes
Hazardous Property Controls (HPC) Notice 2017	**HPC Notice Part 4B: Use of substances that are hazardous to the environment**
	• General duty to avoid adverse effects • Equipment must be appropriate (applies to workplace) • Record of application if > 3 kg applied within 24 hrs • Limiting exposure to ecotoxic substances: – No environmental exposure limits (EELs) are set at this time and the default EELs are deleted • Maximum application rates, frequency and intervals • Buffer zone distances for spray application • Must not be applied into or onto water • Protections for terrestrial vertebrates – all reasonable steps taken to avoid adverse effects • Protections for terrestrial invertebrate pollinators – application plot must not include any bees that are foraging, flowering plants or plants likely to flower and be visited by non-target invertebrate pollinators
	HPC Notice Part 4C: Qualifications required for application of substances that are hazardous to the environment
	• Aerial application qualification requirements • Qualified contractor applying agrichemical requirements • Requirements for a person other than a contractor applying agrichemicals • Approved handler requirements
Additional or varied controls relevant to environmental risks of the substance	• Maximum application rate (9.9kg/ha)

Note:

[i] For example, suspension concentrate containing 500–650 g/litre terbuthylazine. Globally Harmonized System 7 classifications (with ecotoxicity hazards shown in bold): Acute oral toxicity Category 4; Hazardous to soil organisms; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1 (EPA, 2021q).

Appendix 7.6: Zinc supplementary information

Influence of water chemistry on the bioavailability of zinc to aquatic species

In water, the form of zinc and several aspects of water chemistry (e.g. pH and mineral content that defines water hardness) determine the movement, bioavailability and toxicity of zinc to aquatic organisms. This is because zinc competes with calcium and magnesium cations for receptor sites in organisms (e.g. fish gills). The higher the water hardness, the lower the availability of zinc to aquatic organisms. However, irrespective of hardness, water acidity (pH) influences the fate of zinc too – under low pH values, zinc converts into a free form, which can be taken up by fish and may become toxic. Furthermore, many soils and aquatic organisms have physiological factors that regulate zinc adsorption and excretion of excess zinc to maintain a balance in the body.[1]

Water quality guidelines for zinc

Information on the toxicity of zinc to freshwater and marine species from different trophic levels (e.g. bacteria, algae, invertebrates, fish) is used by scientists as a basis to derive default toxicity limit values that aim to protect 95 per cent of species present in both types of systems. Default guideline values for zinc for non-pristine or highly modified ecosystems have also been derived to aim for protection of 90 per cent and 80 per cent of species respectively. Toxicity guideline values for zinc in freshwater, marine water and sediment ecosystems in New Zealand are provided under the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.[2] Guideline values of zinc for both marine and freshwater systems are currently under review. Updated values will include adjustments for pH and hardness. These guidelines provide a framework for deriving site-specific trigger values.

The process for deriving zinc and copper default guideline values provides an insight into an almost interminably lengthy process. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality have been under review since 2014. From a priority list of chemicals, the Ministry for the Environment funded the derivation of values for zinc and copper. However, funding for the project was exhausted well before peer review comments had been received, and by that point the Ministry for the Environment's resources were directed elsewhere.[3] Independent funding was then used to progress both zinc and copper marine guidelines.[4]

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[1] Rainbow, 2002.

[2] ANZG, 2018. See also https://www.waterquality.gov.au/anz-guidelines [accessed 20 September 2021] and Simpson et al. (2013).

[3] There were talks about funding options for the completion of zinc and copper guideline values, which included suggestions to derive National Objectives Framework attributes for copper and zinc. Unfortunately, discussions were inconclusive.

[4] NIWA's funding. Jenni Gadd, Aquatic Chemist, NIWA, pers. comm., 30 June 2021.

The marine zinc guidelines were submitted in 2018 and were published for public comment in July 2020. The reviewed version went through the publication approval process for a second time and was accepted in September 2021 as the final default guidelines value.

On the other hand, the derivation of *freshwater* guideline values for zinc has recently been funded by Environment Canterbury and Christchurch City Council. On the basis of the time taken for the marine guidelines, it is expected that the freshwater guidelines will not be available for use until after 2024.

Zinc limit values derived for water and sediment quality are regularly used within monitoring programmes for freshwater and marine environments (e.g. Auckland Council's Regional Sediment Contaminant Monitoring Programme).[5] As an illustration, a study monitoring the concentration of dissolved zinc (among other indicators) in urban freshwater bodies in Auckland, Christchurch and Wellington showed that 24 of 55 freshwater sites exceeded the dissolved zinc median concentrations default guideline values for the protection of 95 per cent of species. The study further found a relation between the concentration of dissolved zinc and urban land coverage. Higher concentrations of zinc were evident at sites with more than 30 per cent of urban coverage.[6]

Zinc nanoparticles

The industrial use of zinc nanoparticles has increased over the last 20 years. This is because of their biocompatibility with biological receptors, low price and low toxicity compared to bulk zinc. Knowledge gaps about zinc nanoparticles include a lack of understanding of the effects of long-term exposure on sessile marine organisms such as shellfish and bottom feeders. These species are more likely to consume and bioaccumulate nanoparticles in tissues. Filling these knowledge gaps would allow for better water and sediment quality guideline limits and help to improve regulation of the use and release of zinc nanoparticles.

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[5] Mills and Allen, 2021.

[6] Gadd et al., 2020.

Controls tables

Table 7.6.1: Summary of Hazardous Substances and New Organisms Act 1996 controls relevant to environmental hazards of selected zinc-containing products across different use patterns. See table notes for the Globally Harmonized System 7 classifications (ecotoxicity classifications shown in bold).

Please note, this table is only indicative of the controls under substance approvals current at the time of writing and does not override official regulations.

	Use pattern					
	Veterinary antibiotic	**Facial eczema treatment**	**Antifouling paint**	**Fungicide**	**Fertiliser**	**Zinc supplement (human use)**
Environmental Protection Authority (EPA) approval example (either individual approval or group standard	150 g/kg zinc bacitracin for pigs and poultry[i]	Solid containing 75–100% zinc oxide[ii]	Antifouling paint containing 754 g/L cuprous oxide and 550 g/L zinc oxide[iii]	ESTEEM 5% w/w Polyoxin D zinc salt[iv]	Zinc sulphate monohydrate containing 30% elemental zinc (e.g. for fertiliser use)[v]	Zinc gluconate 105 mg equiv. zinc 15 mg (human health supplement)
Labelling, packaging and safety data sheets notices	√	√	√	√	√	–
Disposal Notice	√	√	√	√	√	–
Hazardous Property Controls (HPC) Notice requirements (where relevant)	√	√	√	√	√	–
HPC Notice Part 4B: Use of substances that are hazardous to the environment						
General duty to avoid adverse effects (agrichemicals)	–	√	–	√	√	–
Equipment must be appropriate (applies to workplace)	–	√	√	√	√	–
Records of application > 3 kg applied in 24 hrs (agrichemicals, not fertilisers, vet meds)	–	–	–	–	–	–

Environmental exposure limits (EELs) must not be exceeded	–	–	–	–	–	–
Must not be applied into or onto water	–	–	–	√	–	–
HPC Notice Part 4C: Qualifications required for application of substances that are hazardous to the environment	–	–	√	√	–	–
Additional or varied controls relevant to environmental risks of the substance	Use restriction: must only be used as a veterinary medicine.	–	Label statements directing user to enclose spray area, and to ensure waste from maintenance does not enter the environment. Use restriction: "No person may use this substance for any purpose other than as an antifouling paint…" PPE requirements.	Application rate, frequency, and interval. Application method restriction and label statement to specify ground-based methods only.	–	–

Notes:

[i] Classification: Skin sensitisation Category 1. Approved via individual approval (EPA, 2021i).

[ii] Classification: Hazardous to terrestrial vertebrates; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1. Approved via Veterinary Medicines Limited Pack Size Finished Dose Group Standards (EPA, 2020h).

[iii] Classification: Flammable liquid Category 3; Acute oral toxicity Category 4; Acute inhalation toxicity Category 4; Aspiration hazard Category 1; Eye irritation Category 2; Skin sensitisation Category 1; Specific target organ toxicity (repeated exposure) Category 2; Hazardous to the aquatic environment acute Category 1; Hazardous to the aquatic environment chronic Category 1. Approved via individual approval (EPA, 2021a).

[iv] Classification: Skin sensitisation Category 1; Hazardous to the aquatic environment chronic Category 3. Approved via individual approval (EPA, 2021c).

[v] Classification may vary depending on concentration of active ingredient. Approved via group standard approval (EPA, 2020c).


Polystichum cystostegium

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This report has been produced pursuant to subsections 16(1)(a) to (c) of the Environment Act 1986. The Parliamentary Commissioner for the Environment is an independent Officer of Parliament, with functions and powers set out in the Environment Act 1986. His role allows an opportunity to provide Members of Parliament with independent advice in their consideration of matters that may have impacts on the environment.

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