NRL
National Radiation Laboratory

(Robertson, M., 1996: 14)

1974

Radioactive waste disposal - policies and practices in New Zealand

M K Robertson

1996/2
NRL Report

MINISTRY OF HEALTH
MANATŪ HAUORA

3rd

Report NRL 1996/2
ISSN 0111-753x

RADIOACTIVE WASTE DISPOSAL
– POLICIES AND PRACTICES IN NEW ZEALAND

M K Robertson

National Radiation Laboratory
Ministry of Health
P O Box 25-099
Christchurch
New Zealand

February 1996

Published with the permission of the Director-General of Health

CONTENTS

1. INTRODUCTION

The management of radioactive waste and its ultimate disposal have been a significant problem for the nuclear industry. A lot of resources have been devoted to developing management and disposal systems. As well as being one of the major technical problems, it has been a very significant public relations issue. Public concern about risks associated with disposal of radioactive waste has been on a global scale. It has focused on local issues in some countries, but general attitudes have been common worldwide. Great differences exist between countries in the scale and aspects of nuclear technology in use. In particular the presence or absence of a nuclear power programme, and to a lesser extent of any nuclear reactors, greatly influence the magnitude of the waste disposal problem. Nevertheless, public perceptions of the problem are to some degree independent of these differences.

What radioactive wastes are there in New Zealand? Is there a hazard to the New Zealand public or the New Zealand environment from current radioactive waste disposal practices? What policies are in place to control these practices? This report seeks to provide some information on these questions. It also brings together in one document the waste disposal policies followed by the National Radiation Laboratory for different uses of radioactive materials.

Except for some small quantities which are exempt from most controls, radioactive material can be used in New Zealand only under the control of a person holding a licence under the Radiation Protection Act 1965[1]. All requirements of the Radiation Protection Regulations 1982[2] must also be observed. More detailed safety advice and further mandatory requirements are contained in codes of safe practice[3,4]. Compliance with one of these is a condition on most licences. These provisions are administered by the National Radiation Laboratory (NRL) of the Ministry of Health.

2. THE GLOBAL SCENE

The global inventory of radioactive waste is totally dominated by the waste products from nuclear reactor operation. Originally, most of these reactors were sited in the nuclear weapons states and were used to produce plutonium for nuclear weapons programmes. Waste disposal was not always attended to as diligently as it could have been. There has been some minor environmental contamination in the USA, where significant quantities of this waste still remain in storage. In the former Soviet Union, there has been serious environmental contamination in some areas. Although plutonium production for nuclear weapons has virtually ceased, a legacy of undisposed waste and some environmental contamination remains.

Although the production of radioactive waste from military reactors has reduced, reactor waste production is now significantly greater in many countries, from nuclear power reactors for electricity generation. Nuclear power programmes have not been characterised by the same degree of secrecy as military operations, and over the last 40 years, the growth of the nuclear power industry has been paralleled by the growth of the environmental movement. Consequently, disposal of radioactive waste is scrutinised closely by diligent environmental authorities in some countries. The lapses of the earlier military programmes are less likely to be repeated today.

Radioactive waste is produced at all stages of the nuclear fuel cycle, commencing with the mining and milling of uranium ores and terminating with the final disposal of the unwanted artificial radioactivity produced. Different stages of the nuclear fuel cycle produce radioactive waste of widely varying concentrations and in different forms, posing a range of disposal problems.

2.1 Mining and milling waste

Uranium is the original fuel for nuclear reactors. It is a very long-lived naturally occurring radioactive material. Small traces of it are found throughout the environment, in the ocean and in all soils and rocks. Concentrations as high as two percent have been found in some mineral ores. Concentrations above a fraction of a percent have been economic for mining, but lower concentrations have been separated as a byproduct from mining other minerals. In nature it exists with similar quantities (if measured in units of radioactivity) of the other 13 radioactive elements of its decay chain. When the ore is milled to remove the uranium, these other radioactive materials may be chemically or physically released from the ore. The mill tailings are a low activity radioactive waste, from which the radioactivity may be released by ground water leaching, weathering, or other natural effects. The total quantity of radioactivity, measured in radioactivity units, in this waste is only moderate. However, if we measure the mass in tonnes, then this could be considered the most significant source of waste in the nuclear fuel cycle. This waste can be managed, treated, and disposed of in ways which have many parallels in other mining industries. Because of the large volumes, the cost of treatment and disposal can be significant. Compromises are possible between the containment of low level waste and these costs.

The refined uranium may undergo a variety of further processes in the course of being converted into reactor fuel. Some further low level waste may be generated by these processes. Most of today's power reactors require the uranium to be enriched. That is, the proportion of uranium-235 by weight must be increased from 0.7 percent to several percent. For every tonne of enriched uranium produced, there are a few tonnes of depleted uranium, in which the uranium-235 proportion has been reduced to about 0.3 percent. This depleted uranium has no value as a fuel in the present generation of reactors. It is a very dense metal and for this reason there are limited applications for it, but quantities of it are stockpiled around the world. It is not generally regarded as radioactive waste. Provided the metal does not burn there is no significant radiation hazard associated with it. Its management is relatively simple.

2.2 High level waste

Energy is produced in a nuclear reactor when uranium atoms fission (split) into smaller atoms. These “fission products” are very highly radioactive. After a proportion of the uranium in reactor fuel has been used, the fuel must be removed. It emits intense radiation, and operator safety is the most significant issue in its management. Fission products are a mixture of many different radioactive materials, and many of these are short-lived. It is normal for fuel, in the form of fuel rods, to be stored for periods ranging from months to years before any further treatment is contemplated. The radiation emitted by the fuel rods is then significantly reduced. It is still intense but its management is less of a problem than with freshly irradiated fuel.

One long-term option for what to do with irradiated fuel is the “throw away” option. The possibility of retrieving unused uranium and plutonium (another radioactive material produced in the reactor operation) which both have value as reactor fuel, is abandoned. The fuel rods are placed in long-term storage. The intense radioactivity does present some management problems but containment of the radioactive material in the untreated fuel rods is a much cheaper option than containing it after fuel rods have been processed.

The other option is “reprocessing”. The highly radioactive fuel is dissolved in acid so that various components can be chemically separated. The object is to remove the valuable uranium and plutonium for recycling as fuel. To be weighed against this is the economic cost of managing and ultimately disposing of the highly radioactive unwanted fission products. There are a variety of options for treating this waste material. The option most favoured by the nuclear industry is to vitrify (convert into glass) the waste. The glass form is resistant to leaching by water and retains the radioactive components more effectively than most other forms. Blocks of the glass are then sealed in stainless steel canisters. In this form, the waste material is probably more securely sealed than if it is left untreated in the original fuel rods. However, it must be subjected to considerable expensive processing to get to this stage. A lot of the expense is necessary to safeguard workers, and to prevent any leakage of highly radioactive liquid.

Whether the waste material is in the form of untreated fuel rods or canisters of vitrified waste, a long-term disposal site is necessary. The fission products are decaying and after a thousand years or so, the concentration of radioactivity in any fuel rod or canister is comparable with naturally occurring concentrations in the original ore. However, in addition to the fission products, the waste contains traces of uranium and plutonium, together with a number of other toxic elements (the transuranic elements, or actinides) which are much longer-lived than the fission products. Figure 1 shows the composition of high level waste as it reduces with time. It is considered necessary for the waste to be well contained for perhaps some thousands of years, to prevent leakage of these toxic elements.

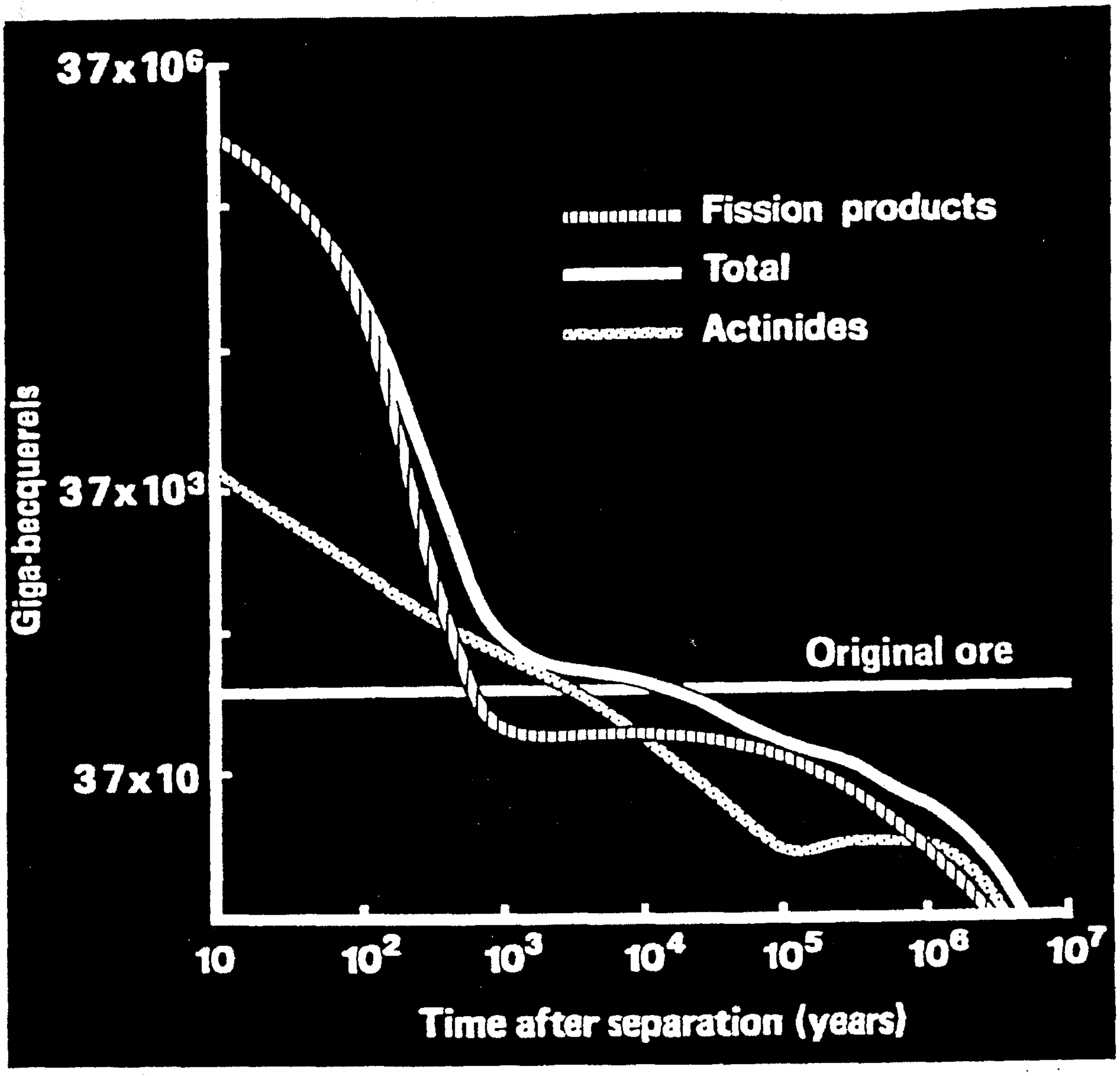

Figure 1. The radioactivity of high-level waste declines steadily over time, most dramatically over the first hundreds of years. Eventually the radioactivity level will be lower than that of the natural uranium ore from which the spent fuel originally came. The graph shows the levels of radioactivity in waste products for one tonne of fuel (reproduced from the *IAEA Bulletin*, vol 31 no 4, 1989).

More than 99 percent of the radioactive waste produced from reactor operation is contained in this high level waste. However, it is very concentrated. If we measure all waste produced by a nuclear power station by volume (in cubic metres rather than in activity units), then this high level waste would be a very small proportion. (A 1000 megawatt nuclear power station each year would produce about three cubic metres of this concentrated high level waste. In comparison, a 1000 megawatt coal fired power station could produce up to 300 000 cubic metres of fly ash per year. The sheer bulk of this mildly toxic waste presents a significant disposal problem.) The fact that this waste has such a small volume means that very sophisticated and expensive measures can be built into any long-term storage sites.

Nuclear power organisations in several countries have been seeking to establish long-term deep underground repositories for their high level waste. They have investigated in detail the long-term geological stability and the ground water flows (or absence of them) of potential sites. As much or more effort has gone into political activity to gain some measure of public acceptance and any necessary official approvals. In some countries with advanced nuclear power programmes, proposals to develop underground repositories for nuclear waste have been characterised by a continuing standoff between the nuclear power industry and environmental groups. Well intentioned people on both sides of this question have made little progress towards a compromise. Some repositories in Europe have commenced operating, but most of the high level waste generated by nuclear reactors up to this time remains in above ground storage, awaiting resolution of these issues.

2.3 Low level waste

The routine operation of nuclear reactors produces significant volumes of slightly radioactive waste material. The processing of irradiated fuel rods, while it concentrates nearly all of the radioactivity in a very small volume, also produces a much greater volume of waste contaminated with a low level of radioactivity. The 1000 megawatt nuclear power station operating for a year could be expected to produce about 500 cubic metres of this sort of waste. The radiation it emits is low level and is not a significant hazard to workers. However, the radioactive material itself should be contained so that it does not significantly contaminate the environment, nor enter the human food chain. It has been standard practice to embed this waste in concrete or bitumen, encased in industrial 200 litre steel drums. Large numbers of these drums have accumulated in stores at power stations and processing plants. There was some uncoordinated disposal of this type of waste in the ocean in the earlier days of the nuclear power industry. In the 1960s and 1970s there was an organised collaborative programme under which several European countries disposed of large numbers of these drums at a nominated site in the North Atlantic. After 1972 these disposals were done in compliance with the “London Convention”, an international treaty which prohibited or controlled the ocean disposal of various materials. In the early 1980s Japan proposed a similar low level radioactive waste disposal operation in the North Pacific. Oceanographic and other characteristics of the proposed site were investigated and the proposals were discussed with other Pacific nations. For a variety of reasons, this programme was abandoned. The London Convention prohibited the ocean disposal of high level radioactive waste but did permit disposal of low level waste, subject to special dumping permits which specified monitoring and surveillance requirements. All ocean disposals of packaged low level radioactive waste have been abandoned since signatories to the London Convention declared a moratorium on the practice in 1983. In 1993 the

London Convention itself was revised and the prohibition was extended to low level materials.

A number of countries have proposals for establishing shallow repositories for the disposal by burial of low level waste. The quantity of radioactivity is very small relative to that in high level waste, but the volumes are much greater. Proposals for these shallow repositories have been opposed as vigorously as those for the deep repositories for high level waste, or the earlier ocean dumping practices. Until a number of such repositories are established, significant volumes of packaged low level waste will remain in above ground storage.

2.4 Radioactive waste from other practices

Electricity generation by nuclear power certainly dominates production of radioactive wastes, but there are numerous other activities which use radioactive material in industry, medicine, and scientific research. The waste arising from these practices is incidental to the waste arising from nuclear power generation and can be added to it in those countries with a nuclear power programme. In countries such as New Zealand with no nuclear power programme, these very much smaller quantities of waste are the only radioactive wastes being generated.

3. THE NEW ZEALAND SCENE

The use of radioactive material in New Zealand has similarities to other developed countries if nuclear reactor operation is excluded. These uses and the wastes they generate are described in the following paragraphs.

3.1 Radiochemicals

The fate of different substances in chemical and biological processes can be followed if the substance is radioactive, by detecting the radiations emitted. This radiation can be detected with extreme sensitivity, and the quantities of radioactive material used are generally small. In nuclear medicine, the fate of radiopharmaceuticals administered to patients is a valuable diagnostic tool. There are a number of routine analytical tests using radioactive tracers in agricultural, forensic, and other types of laboratory. In most of these applications some of the radioactive material ends up as waste. Liquid waste from nuclear medicine patients and from laboratory procedures ends up in sewage systems. Solid waste such as contaminated tissues, broken glassware, etc and the carcases of laboratory animals become solid waste, which may be disposed of at refuse sites or by incineration. On rare occasions, gaseous waste may be discharged from laboratory fume cupboards.

3.2 Mining

At present there are no mining activities in New Zealand which produce radioactive wastes. However, there are proposals for mining and processing ilmenite which has the potential to produce mill tailings contaminated with naturally occurring uranium and thorium. The concentration of these radioactive elements in New Zealand mineral sands is not sufficient to cause a problem unless options for extracting other byproducts are followed.

3.3 Sealed radioactive sources

A sealed radioactive source is a quantity of radioactive material sealed in a metal capsule. The radioactive material itself is securely contained but the radiation can be emitted. The capsule is like a tiny x-ray machine. It needs no electrical hardware and its small size makes it very useful for some purposes. However, unlike an x-ray machine, it cannot be switched off.

Historically, sealed radioactive sources were used for medical applications in the treatment of cancer. Some still are used in this way. However, a variety of industrial uses now predominate. They are used for industrial radiography, for inspecting welding on construction projects. By measuring how much radiation is absorbed in passing through matter, it is possible to measure the thickness or density of that matter. This principle has widespread applications in the measurement of density of material in pipelines, the level of the contents inside large tanks, the level to which beverage cans have been filled, the thickness of paper or plastics and numerous similar measurements. Portable instruments containing a radioactive source are used by construction engineers to measure the density and moisture content of soil on road construction. Similar instruments are used to measure soil moisture for irrigation purposes. A very widespread use of very small radioactive sources is in domestic smoke detectors.

Most of these sealed sources ultimately end up as waste. Usually this is because the equipment incorporating them breaks down or becomes obsolete and is replaced. If for no other reason, sealed radioactive sources are ultimately withdrawn from use when they are 30 years old, to comply with NRL requirements in Codes of Safe Practice. This waste has quite different characteristics from wastes arising from radiochemistry, and its management is therefore different.

4. NEW ZEALAND POLICY AND PRACTICES FOR RADIOACTIVE WASTE MANAGEMENT

In the absence of nuclear reactors, it could be argued that only waste sealed radioactive sources require any measure of control on their disposal. The concentrations of liquid radioactive waste arising from radiochemical use, for example, are low and the consequences of dispersal in the environment are insignificant when compared to other more toxic materials whose uncontrolled disposal in much greater quantities is readily accepted. Such arguments ignore the political realities of the public perception of this subject. This public perception is international in character, and it is probable that while there are unresolved issues relating to the disposal of radioactive waste from nuclear power reactors in other countries, there will be public concern about radioactive waste disposal generally in New Zealand. This will necessitate some degree of restriction and supervision of all radioactive waste disposal.

4.1 Waste arising from radiochemicals and nuclear medicine

A variety of radioactive materials is used for these purposes. However, the usage is dominated by four radionuclides, iodine-125, iodine-131, technetium-99m, and phosphorous-32. These nuclides are relatively short-lived, with half-lives of 60 days, 8 days, 6 hours and 14 days respectively. There is no long-lived radioactivity in waste arising from the use of these four nuclides. Most of the radioactivity has disappeared by the normal process of radioactive decay during its use, before it becomes waste. If necessary, waste can be stored for further decay before disposal. A few other nuclides are used occasionally, but the total quantity used is small compared with the above four nuclides. There are only two nuclides used in New Zealand which are sufficiently long-lived to be of environmental significance. These are tritium and carbon-14 with half-lives of 12 years and 5700 years respectively. Both of these nuclides are produced naturally by the absorption of cosmic rays in the upper atmosphere. Traces of them are present naturally throughout the environment. Further substantial quantities have been released into the environment from nuclear weapons and nuclear power programmes. The quantity used as radiochemicals is insignificant relative to that naturally present in the environment.

The International Atomic Energy Agency has published a comprehensive safety document International Basic Safety Standards for Radiation Protection[5]. This includes a table of the maximum activity (measured in becquerels) and the maximum concentration (measured in becquerels per gram) of all radionuclides which, if totally uncontrolled, would in the worst case deliver a radiation dose of 10 microsieverts to any individual. (This is about 0.5 percent of the average annual natural radiation dose to which the human race is subject.) This activity or concentration is proposed as the lower limit below which no controls are justified. Limits for waste disposal specified in the Code of Safe Practice for the Use of Unsealed Radioactive Material[3] are designed to limit the concentration of radioactivity in any waste entering the environment to less than the exempt concentration listed for each nuclide in the Basic Safety Standards, at the point where it enters the environment before any further dilution occurs, and at the time it enters the environment before any further decay occurs. Licensees are permitted to dispose of waste below these limits without further approvals. Authorisation for disposal of higher concentrations, or abnormal volumes within the limits, could be considered if the need arose, but any such approval would be subject to additional conditions.

Disposal of solid, liquid, and gaseous waste is described in the following sections, and limiting concentrations are shown in Table 1.

4.1.1 Solid waste

Radiochemistry and nuclear medicine laboratories generate a small volume of solid waste contaminated with radioactivity. This includes broken glassware, tissues, rubber gloves, etc, carcases of laboratory animals, and nuclear medicine patients' excretions. The level of contamination of this waste arising in New Zealand is sufficiently low that it is normally all below the limit for uncontrolled disposal.

If disposal of greater concentrations of radioactivity in solid waste is ever necessary, then the Radiation Protection Regulations prohibit the disposal without the consent of, and subject to conditions specified by, the Director-General of Health. Conditions could be specified requiring long lasting packaging, burial at a specified depth, and long term supervision of the disposal site. If this situation arose, it is likely that disposal at a multipurpose hazardous materials disposal site would be considered.

If solid waste is combustible, disposal by incineration is an option. Unless it is definitely known that all radioactive contamination will be discharged with the gaseous effluent from the incinerator it must be assumed that it will all remain in the ash. Incineration is therefore a convenient way to dispose of the bulk of the waste, but it is a concentration mechanism for non-combustible contamination. Therefore the permitted concentration of radioactivity in waste for incineration has been set at 0.1 percent of the exempt concentration. However, recognising that the contamination of the ash is likely to be diluted by ash from uncontaminated waste being incinerated at the same time, it is permitted for the limit to apply to the contamination averaged over a total of one tonne of waste (assumed to result in 1 kg of ash). If all the contamination is known to be combustible, (eg isotopes of hydrogen, carbon, sulphur, phosphorous, etc) then the quantity of contamination which can be incinerated can be greater, provided the limits for discharge of gaseous waste are not exceeded.

4.1.2 Liquid waste

Most radiochemistry and nuclear medicine waste is in this form. The limit for discharge into any sewage system is the Basic Safety Standards exempt concentration. It is permitted to average the concentration over one day for each establishment. However, even if there is a much greater dilution within an establishment drainage system, there is a further limit of 100 000 times the exempt concentration at the point where waste is tipped down the drain. This limit is imposed as an occupational radiation protection measure.

An issue which arises from time to time is how to dispose of accumulated liquid scintillation counting fluid. It is erroneous to view this as a radioactive waste problem. The concentration of radioactivity in these fluids is negligible.

However, as most of these fluids are toxic and flammable solvents, it is a chemical waste disposal issue. These solvents should not be put down the drain. It is recommended practice not to accumulate this waste. If the fluids are used in plastic liquid scintillation counting vials, small batches can be regularly disposed of by incineration.

4.1.3 Gaseous waste

The need to discharge radioactivity in gaseous form directly to the atmosphere (other than by incineration) is an infrequent situation. The limiting concentration has been set at the numerical value of the exempt concentration in becquerels per gram, converted directly to becquerels per litre of gas. It is permitted to average this concentration over each discharge, provided the maximum instantaneous concentration does not exceed one hundred times the average.

Table 1. Unsealed waste limits

Nuclide	Waste limits					
	Uncontrolled		**Liquid**		**Gas**	**Burn**
	activity (Bq)	conc. (Bq/g)	at drain (Bq/l)	at sewer (Bq/l)	(Bq/l)	(Bq/g)
H-3	1 GBq	1 MBq/g	100 TBq/l	1 GBq/l	1 MBq/l	1 kBq/g
C-14	10 MBq	10 kBq/g	1 TBq/l	10 MBq/l	10 kBq/l	10 Bq/g
P-32	100 kBq	1 kBq/g	100 GBq/l	1 MBq/l	1 kBq/l	1 Bq/g
P-33	100 MBq	100 kBq/g	10 TBq/l	100 MBq/l	100 kBq/l	100 Bq/g
S-35	100 MBq	100 kBq/g	10 TBq/l	100 MBq/l	100 kBq/l	100 Bq/g
Ca-45	10 MBq	10 kBq/g	1 TBq/l	10 MBq/l	10 kBq/l	10 Bq/g
Cr-51	10 MBq	1 kBq/g	100 GBq/l	1 MBq/l	1 kBq/l	1 Bq/g
Co-57	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
Co-58	1 MBq	10 Bq/g	1 GBq/l	10 kBq/l	10 Bq/l	0.01 Bq/g
Se-75	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
Sr-89	1 MBq	1 kBq/g	100 GBq/l	1 MBq/l	1 kBq/l	1 Bq/g
Y-90	100 kBq	1 kBq/g	100 GBq/l	1 MBq/l	1 kBq/l	1 Bq/g
Mo-99	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
Tc-99m	10 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
In-111	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
I-123	10 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
I-125	1 MBq	1 kBq/g	100 GBq/l	1 MBq/l	1 kBq/l	1 Bq/g
I-131	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
Xe-133	10 kBq	100 kBq/g	100 GBq/l			1 Bq/g
Sm-153	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
Au-198	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
Tl-201	1 MBq	100 Bq/g	10 GBq/l	100 kBq/l	100 Bq/l	0.1 Bq/g
Th-nat	1 kBq	1 Bq/g	100 MBq/l	1 kBq/l	1 Bq/l	0.001 Bq/g
U-nat	1 kBq	1 Bq/g	100 MBq/l	1 kBq/l	1 Bq/l	0.001 Bq/g

4.1.4 Uranium and thorium wastes

Compounds of uranium and thorium are occasionally used as chemicals in industrial and educational chemistry laboratories. Their radioactivity is incidental and irrelevant to their use, but must nevertheless be taken into account before disposal. In this context, they are to be regarded as radiochemicals, subject to the relevant disposal limits. Before uncontrolled disposal of these materials, they must be mixed with other waste to reduce the concentration to less than 1 Bq/g if they are in a dry dusty state. If there is no possibility of inhalation of dust, this dilution can be relaxed to 100 Bq/g. If the waste is soluble in water, it can be disposed of as liquid waste if the concentration at the entry to the sewer is less than 1 kBq/l. (For these purposes, the specific activity of uranium can be taken as 25 kBq/g, and of thorium as 8 kBq/g.)

4.2 Mining and milling wastes

This category of radioactive waste has never arisen in New Zealand, but some mining activities have been proposed which could cause a potential radioactive waste problem. The proposals have been for the mining of mineral sand deposits and the extraction of ilmenite from them. Some of these sands contain low concentrations (but higher than the average in New Zealand soils) of uranium and thorium. When some minerals are extracted from the sand, the concentration of these elements in the tailings increases. It is possible that even then, the concentrations of uranium and thorium will be of little significance, and the disposal of the waste stream will be dictated by other factors, with no special consideration being given to radioactivity. Although this situation would be likely if any proposals were proceeded with, it is possible that pockets of higher than average radioactivity in the ore may be encountered. It is also conceivable that further processing may be done to extract other minerals from the sand, in the process further enriching the concentration of radioactivity in the waste stream.

While applications have been lodged for mining licences (distinct from and not to be confused with licences under the Radiation Protection Act) no proposals for mineral sand mining have yet been proceeded with in New Zealand. NRL has negotiated with mining inspectors about the need for a licence under the Radiation Protection Act and the provision of radiation protection measures as conditions on a mining licence. These matters are unlikely to be taken further unless and until more positive moves are made toward a producing mine. It is then likely that radiation protection will be considered along with other occupational safety and environmental issues common to most mining operations. It could well be catered for by conditions on the mining licence and a brief section in a comprehensive code of practice. Among other things this might require monitoring of radiation and radioactivity levels. If a predetermined action level was exceeded, consideration would be given to further requirements under the Radiation Protection Act.

If it was possible that mill operators could receive significant radiation doses or ingest significant quantities of radioactivity, then a detailed radiation protection code of practice for mining operations would be written and compliance with it would be required as a condition on a licence under the Radiation Protection Act. This sort of situation has arisen in some overseas mineral sands operations. Given the much lower concentration of radioactivity in investigated New Zealand mineral sands, it is unlikely to arise here.

4.3 Sealed radioactive sources

By far the most common use of sealed radioactive sources in New Zealand is in domestic smoke alarms. There is a very large number of these each containing a very small quantity of radioactivity which is exempted from the Radiation Protection Act licensing requirements. The total quantity of radioactivity is also small. In contrast nearly all the artificial radioactivity in New Zealand is contained in one sealed radioactive source (actually a small number of capsules in one plant). Policies for controlling the disposal of obsolete sources must provide for a very wide range of potential hazard between these two extremes.

4.3.1 Smoke detectors

Some fire alarm systems in commercial and industrial premises have incorporated smoke detectors using up to about five megabecquerels of the alpha radiation emitting radionuclide americium-241, sealed in an inert metal foil. Any of these detectors whose content exceeds 0.3 megabecquerel of americium-241 is required to be under the control of the person holding a licence under the Radiation Protection Act. The licence does not permit uncontrolled disposal. As part of a nationwide service, NRL accepts withdrawn smoke detectors and removes the radioactive sources for storage and ultimate controlled disposal.

In the early 1970s, domestic smoke detectors (as distinct from the commercial models) were first introduced to the market. Installation of these in homes has been actively promoted by the Fire Services and today they are very common. Because of the secure binding of the radioactive material in the metal foil, these radioactive sources are much less hazardous than the same amount of americium-241 in liquid or powder form. They have been exempted from the licensing provisions of the Radiation Protection Act by a clause in the Radiation Protection Regulations. The conditions of exemption require that the device shall carry an approved label and approved written instructions about safe use and ultimate disposal. As a cautionary measure, NRL has in the past required even the small radioactive sources in the domestic smoke detectors to be returned to the supplier or to NRL for disposal. NRL still receives many smoke detectors, and the sources are removed. However, there is no longer any restriction on the disposal of domestic smoke detectors. Disposal of smoke detectors with domestic rubbish is accepted practice in other countries, eg the United Kingdom[6]. The average alpha emitting radioactivity (similar to americium-241) which occurs naturally in New Zealand soils is equivalent to about 13 smoke detectors in every cubic metre. The dispersal of smoke detectors, even in large numbers, through refuse landfill sites will not be significant in comparison.

4.3.2 Industrial and medical sealed sources

There are many industrial and some medical applications for sealed radioactive sources described in 3.3 above. Several radionuclides are used and a quantity of radioactive material in each encapsulation varies from about 10 megabecquerels to about one terabecquerel (1 000 000 megabecquerels). Uncontrolled disposal is not permitted for any of these encapsulated sources.

The primary emphasis of NRL's policy for the management of these sources is to ensure that each and every source is always accounted for. There have been incidents overseas when members of the public have found attractive looking metal objects and carried them on their person, and then left them around their home. Some incidents have had fatal consequences. In other overseas incidents, industrial radioactive sources have been melted down in scrap metal foundries. The economic costs of locating and recalling contaminated production, and of decontaminating the foundry site have been enormous. There is a risk of such incidents after equipment containing sources becomes obsolete, if the equipment is left in storage for a long period, through staff and organisational changes, and its radioactive contents are forgotten about. Responsibility for keeping track of all radioactive sources rests with licensees. However, NRL maintains a database of all these sources, and continually updates it on the basis of advice from licensees. An important part of NRL policy is the provision of a service whereby NRL will receive all sealed radioactive sources which are obsolete, damaged, or unwanted for any reason. This service is free of charge, apart from freight costs incurred in transporting sources to NRL in Christchurch. NRL then assumes responsibility for subsequent supervision, storage, and ultimate disposal of these sources. The only significant exception to this service is in the case of high activity sources described in 4.3.5 below.

Historically, from the 1920s through in some cases until the 1980s, New Zealand hospitals used encapsulated sources of radium (a naturally occurring radioactive material) for cancer treatment. Treatments have changed and any treatments using encapsulated sealed sources now use cheaper and technically superior artificial radioactive materials, mostly caesium-137. Virtually all New Zealand hospital stocks of radium have been sent to NRL for disposal.

There are several radionuclides used industrially. Small numbers of sources of relatively low activity are used in industrial laboratory instruments. Three sources containing quite significant activities of plutonium-239 have been received for disposal from a university. There are some medical and a greater number of industrial sources of strontium-90 and a proportion of these have been received for disposal. Currently, sealed radioactive sources used industrially and being received by NRL for disposal are dominated by four radionuclides, caesium-137, cobalt-60, americium-241 and krypton-85. (Although smoke detector sources comprise the greatest number of americium-241 sources, the radioactivity in them is insignificant. Some industrial sources contain more americium-241 than 1 000 000 smoke detectors.) Typically in recent years between 20 and 50 such sources have been received for disposal, and the activity in individual capsules has ranged from 10 megabecquerels up to almost one terabecquerel (1 000 000 megabecquerels).

4.3.3 Disposal in the ocean

On several occasions in the past NRL disposed of accumulated waste in the ocean. (These disposals, in line with hazardous substance disposal practices of the time, were on a very small scale. There is no way they can be compared with overseas ocean disposals, on a vastly greater scale, of packaged low level reactor wastes.) Sealed radioactive sources were embedded in concrete in 20 litre steel drums. The maritime authority (the Marine Department, later the Marine Division of the Ministry of Transport) was consulted. Drums were dumped with their written authority, and subject to conditions specified by them at a waste disposal site nominated by them. With the adoption of the requirements of the London Convention in the Marine Pollution Act 1974, a special dumping permit was required for such disposals. This procedure was followed once in 1976. Following that operation, the NRL policy was changed. Packaged radioactive waste sources were to be accumulated for a prolonged period so that infrequent disposals of a larger number of drums would be required. Storage space was provided at NRL. Before any further disposals were contemplated, the Nuclear Free Zone Disarmament and Arms Control Act 1987 came into effect. This effectively prohibits any ocean dumping of this type of waste.

The radioactivity in wastes disposed of at sea up to 1976 is shown in Table 2.

Table 2. Waste sealed sources

Nuclide	Total disposals at sea up to 1976	Total received for storage at NRL 1976 - 1994
Co-60	23 GBq	68 GBq
Sr-90	3.2 GBq	48 GBq
Cs-137	1.0 TBq	2.1 TBq
Ra-226	17 GBq	90 GBq
Pu-239		185 GBq
Am-241	190 MBq	120 GBq
Cf-252		3.2 GBq

4.3.4 Present practice and policy

NRL will receive any sealed radioactive sources (apart from some high activity sources) which become surplus to requirements for any reason. It is proposed that this policy should continue indefinitely as an effective measure to reduce the possibility of stray radioactive sources, particularly in the industrial environment.

For shipping to NRL, radioactive sources must be packaged to comply with the IAEA Regulations for the Safe Transport of Radioactive Materials[7]. Shielding requirements are usually met by shipping the complete gauge or whatever item of hardware the source has been used in. On receipt at NRL, the gauge or other item is removed from its packaging and temporarily stored in a radioactive material store. When a number of these items have accumulated the items are dismantled to the extent necessary for the radioactive sources to be removed. The sources are then immersed in concrete in 20 litre drums, as was done earlier for sea disposal. The drums must comply with Transport Regulation requirements for Type A packages. This means that the contents of each drum are limited, and the radiation levels at the surface of each drum are limited. In some cases additional lead shielding is incorporated to achieve this. A metal plate on which is engraved details of the drum contents is affixed to each drum. The drums are then stacked in the store for longer term storage.

This procedure is followed for all sealed sources except those of krypton-85. This nuclide is a gas. It is contained in metal capsules, sometimes under pressure, with rugged foil windows through which the beta radiation is emitted. The intensity of the beta radiation is sufficient that an unshielded krypton-85 source presents a significant hazard. However, krypton-85 gas dispersed in the atmosphere has no associated hazard. It is an inert gas with no metabolism in the body. If the highest activity sources in New Zealand (about 40 gigabecquerels) were released in the atmosphere its concentration would reduce to the Basic Safety Standards exempt concentration in a volume of only about 400 cubic metres (a cube with 8 metre sides). In view of the relative hazards of encapsulated krypton-85 compared with the dispersed gas, NRL policy for these sources is that they are to be punctured outdoors in an open area, in at least a breeze, so that the released gas is dispersed downwind from the person doing it.

Another waste disposal problem can arise if any uranium metal (usually depleted uranium) becomes scrap. **It is imperative that uranium metal is never sent to a scrap metal foundry.** In air it is pyrophoric and can be ignited by friction. Its combustion generates toxic smoke. NRL will accept small quantities of uranium metal for disposal.

Between 1976 and 1995 the number of drums in the NRL store has increased from zero to 94. The capacity of the store is about 300. It is anticipated that the capacity of the present storage space will be fully utilised some time in the decade 2010 - 2020.

The radioactivity of the waste up to the last packaging operation in 1994 is shown in Table 2.

There are a variety of technical, political, economic, environmental and social factors which can influence the NRL policy on longer term storage. Some of these factors change with time and the policy may change too. However, in the circumstances prevailing in 1995, the NRL policy is that current practices will continue unchanged until the contents of the store on the NRL premises approach the storage capacity. Present indications are that this will not be for at least 15 years, and no attempt should be made to anticipate hazardous substances disposal practices and requirements that far in the future. The volume of the drums in which the radioactive waste is securely packaged is relatively small and one option in the future could be simply extending the storage space. If a multipurpose hazardous substances disposal facility was operational at any time the policy would be reviewed.

4.3.5 High activity sources

NRL has limited facilities for handling radioactive sources emitting high levels of radiation. Generally, any radioactive source less than the Type A transport package limit can be readily received by NRL. This will not necessarily be true, however, for higher activities. In practice, the only radioactive sources of this activity have been cobalt-60 sources being replaced at an industrial radiation processing plant, hospital teletherapy cancer treatment sources, and the sources in some laboratory irradiators. Sources from the radiation processing plant and hospital teletherapy sources have always been exported back to the supplier of the replacement source. There is a contractual obligation on the supplier to do this in some cases. Sources from an obsolete laboratory irradiator are being stored for 10 to 15 years at the laboratory, and could be shipped to NRL after the activity has decayed to less than the Type A package limit. In practice, problems of this nature have not arisen with any nuclide other than cobalt-60. It is NRL policy to recommend or require that the supplier of high activity sealed sources for future installations shall be obliged by contract to take back the sources when they are no longer required.

5. SUMMARY

Licences under the Radiation Protection Act permit uncontrolled disposal of waste contaminated with radioactivity at concentrations less than the IAEA Basic Safety Standards exempt concentration. In practice, with the low usage of radioactive materials in New Zealand, waste arising from the use of unsealed radiochemicals and radiopharmaceuticals rarely exceeds this concentration.

Controlled disposal of sealed radioactive sources in the ocean was practised prior to 1976. Since then these sources have been kept in supervised storage.

REFERENCES

1. The Radiation Protection Act 1965 (1986 Reprint).
2. The Radiation Protection Regulations 1982.
3. National Radiation Laboratory. Code of Safe Practice for the Use of Unsealed Radioactive Material. NRL, Christchurch, 1996. *NRL C1.*
4. National Radiation Laboratory. Code of Safe Practice for the Use of Sealed Radioactive Material in Industry. NRL, Christchurch, 1989. *NRL C2.*
5. International Atomic Energy Agency. International Basic Safety Standards for Protection Against Ionising Radiation and for the Safety of Radiation Sources. International Atomic Energy Agency, Vienna, 1994. *Safety series no.115-I.*
6. National Radiological Protection Board. Board Statement on Approval of Consumer Goods Containing Radioactive Substances. *Documents of the NRPB 3(2), 1992.*
7. International Atomic Energy Agency. Regulations for the Safe Transport of Radioactive Materials. 1985 edition (as amended 1990). International Atomic Energy Agency, Vienna, 1990. *Safety series no. 6.*