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NUCLEAR WASTE IN THE PACIFIC: PERCEPTIONS OF THE RISKS

University of Hawaii PH.D. 1984

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NUCLEAR WASTE IN THE PACIFIC:

PERCEPTIONS OF THE RISKS

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN GEOGRAPHY

MAY 1984

By

Iraphne R.W. Childs

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To William and Violet Childs,
my parents.

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The completion of this dissertation, and of my Ph.D. program, is the result of the good influences of many people who are now in various parts of the world.

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Finally, to Ralph, who sent the news and always encouraged me to finish the job.

ABSTRACT

This dissertation examines the problem of the disposal of high-level nuclear waste in the Pacific region. There is a consensus of scientific opinion that the technical difficulties in waste disposal can be overcome. The most acceptable solution seems to be the multi-barrier approach for deep land-based geologic disposal. A questionnare survey on the perception of nuclear and other hazards, conducted with student populations in Japan and Australia, and a survey of reporting of nuclear "events" in Pacific newspapers over the period 1946 to the 1980s, reveal that the image of nuclear weapons dominates public views on the risks associated with waste disposal in Australia, Japan, and the Pacific Islands. The problem of finding a suitable site for a nuclear waste disposal facility is to a large extent political. The capacity of anti-nuclear groups to influence waste disposal policies in Australia, Japan, and the Pacific Islands is examined. Current public attitudes toward nuclear waste disposal will delay the further development of activities connected with the nuclear fuel cycle, but this may change over time if the connection between commercial nuclear power and nuclear weapons can be severed more effectively. The most urgent problem in the region is the waste from the ambitious nuclear power programs of Japan, South Korea, and Taiwan. Regional co-operation in the waste management field among these three countries, leading to a disposal facility within East Asian territory, should be possible, and would demonstrate a willingess on the part of the East Asians to accept fully the risks, as well as the benefits of electricity generated from nuclear power.

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INTRODUCTION

Nuclear waste disposal is a complex environmental issue involving the technical problems of containing a radiation hazard, and the political problem of finding an acceptable site for a hazardous waste facility. This dissertation examines the nuclear waste problem in the context of the Pacific region, and argues that, although a unique problem in certain respects, nuclear waste disposal can be examined within the traditional framework of research on other environmental hazards.

The Pacific Ocean is not only the largest of oceans, but it is twice as large as the Atlantic, and is larger in area than the total land surface of the world above sea level (Freeman, 1951). At its widest point it extends 12,000 miles from Panama to the Malay Peninsula, almost half way around the globe. The land masses with coasts adjoining this enormous body of water, the Americas, the USSR, East and Southeast Asia, Australia and New Zealand, and the many island nations scattered across its vast expanse, comprise as wide a range of geographical environments, cultures, political systems, and levels of economic development as can be imagined. Yet, there is a logic in grouping such diverse geographical entities under the label of "region" to examine the problem of nuclear waste.

The people of the Pacific islands have always perceived the ocean as a linking force, rather than a separating one, and, increasingly, the rim countries are turning to regional co-operation to solve various economic and environmental problems. In a twist of fate, the region bearing the name "peaceful" became the theater where the development of nuclear weapons and nuclear energy has been played out. Nuclear contamination, perhaps more than any other issue, has linked groups of concerned citizens on many sides of the Pacific, and, for the first time in history, the diverse peoples of Polynesia, Melanesia, and Micronesia have been brought together in their political stand for a nuclear-free Pacific. The idea that the ocean's current and wind systems can transport the products of radioactive fallout from a weapons test on a tiny mid-Pacific atoll to the fish bought and consumed by people in San Francisco, Tokyo, or Auckland has raised the ecological consciousness of citizens in towns and cities across the "Pacific Region". Vast as it is, the ocean is not limitless, and should not be regarded as a sink with infinite capacity for waste disposal.

Coal and nuclear energy are still the leading candidates to replace oil in this century, or until nuclear fusion and solar technologies are available in the twenty-first century. The World Energy Conference of 1978 predicted a large increase in world nuclear capacity by the year 2020 (Fig. 1), despite the fact that projections for nuclear power in several countries are being continuously scaled down (Fig. 2), and orders for new plants are being cancelled. For example, in the United States, no new nuclear plants have been ordered since 1974, and, indeed,

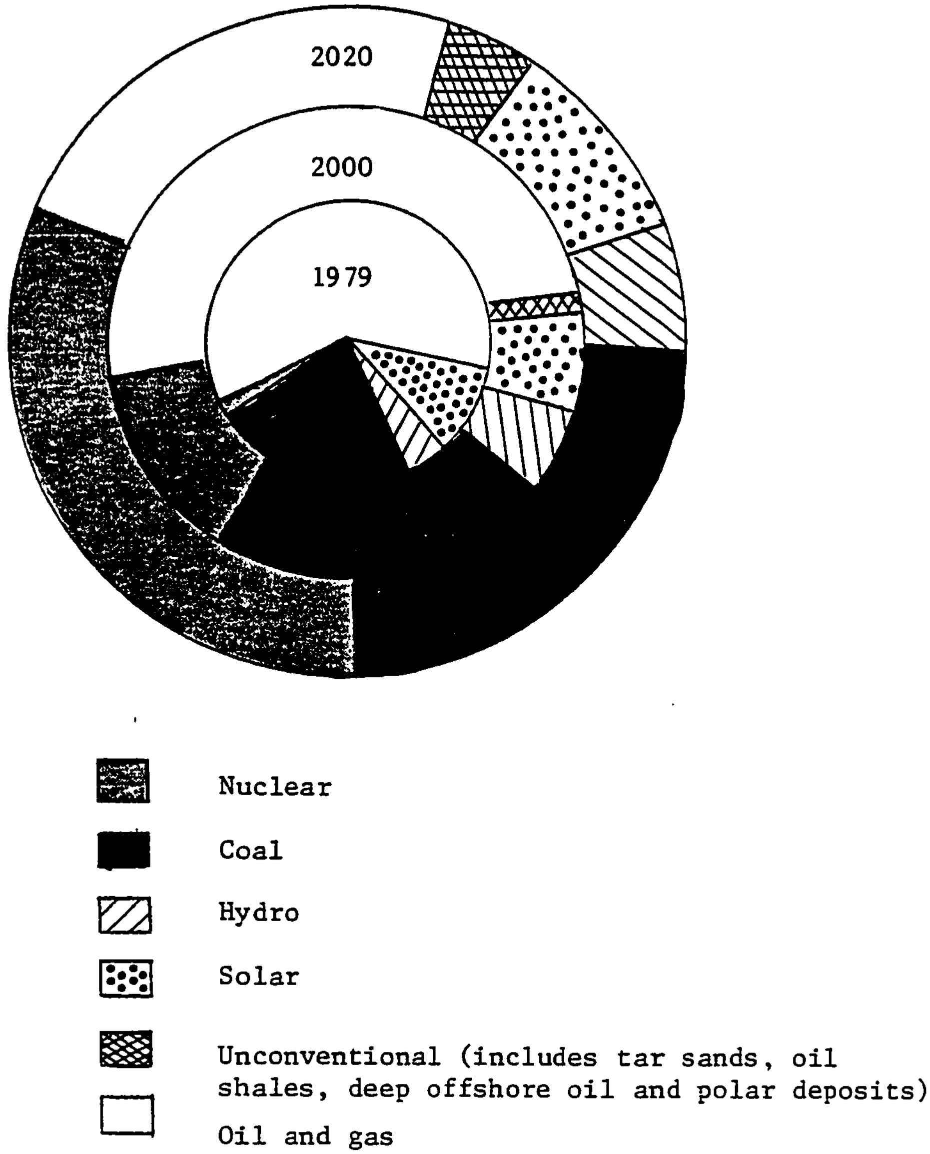


Figure 1. World Energy Sources to the Year 2020
Source of information: Sivard (1981)

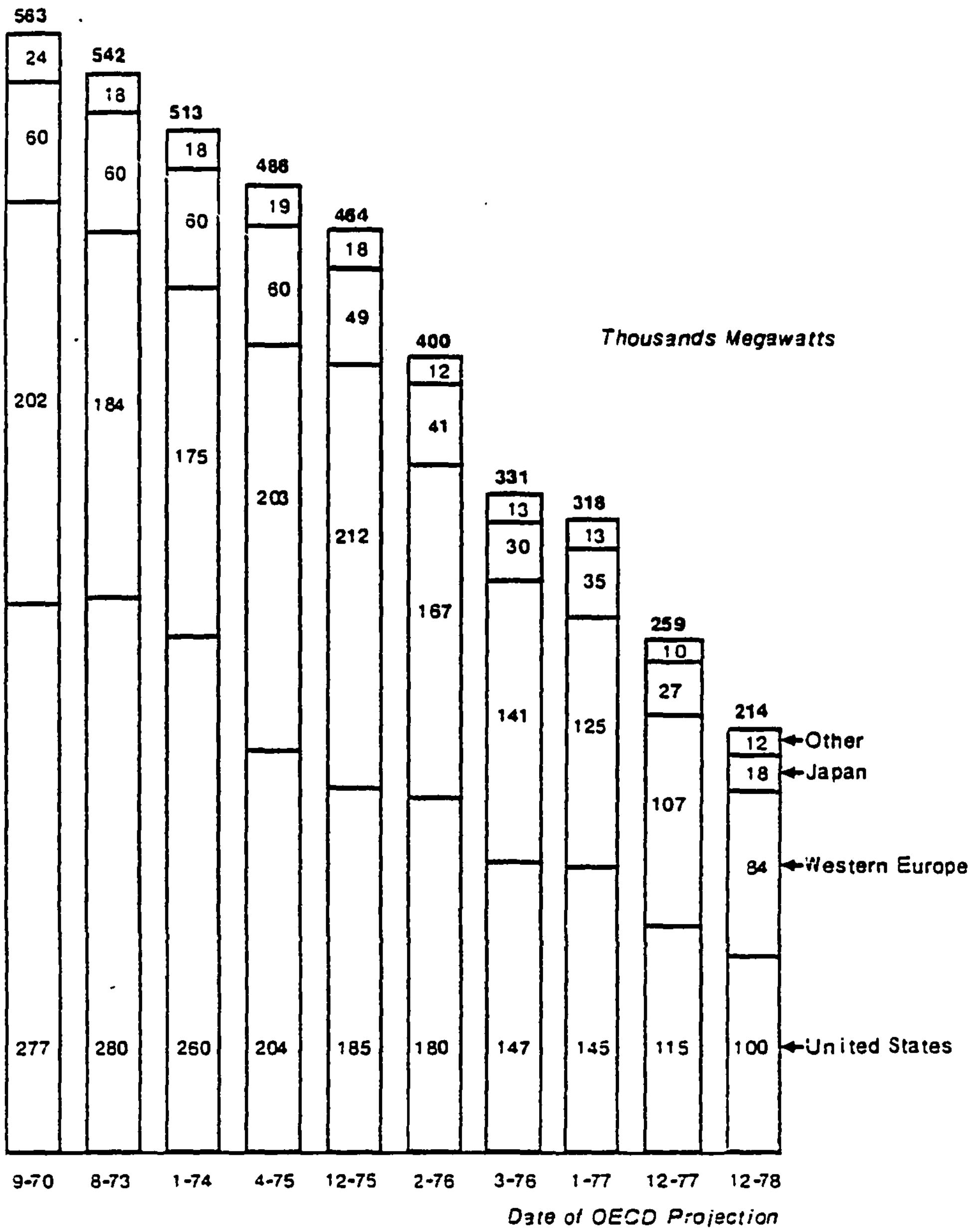


Figure 2. Past Projections of Yearend 1985 Nuclear Generating Capacity.
Source: OECD (1982) World Energy Outlook.

many partially finished plants cancelled. Both coal and nuclear power create serious hazards in production and conversion, causing problems that are unresolved in many minds.

The risks and benefits of nuclear power are perceived by many to be unevenly distributed and the price of electricity generated by nuclear power often does not include the future costs of waste management and disposal. Proposals to use sites in the Pacific for the disposal of nuclear waste from rim countries have been greeted with cries of outrage from many quarters. This study addresses the policy problems that the disposal of nuclear waste raises in the Pacific. How significant a problem is it in the region? What is the magnitude and distribution of the hazard from nuclear waste? What are the disposal options? What is the history of the nuclear hazard in the region? Whose problem is it? How do the experts and the public differ in their views of the risks involved? Is an international waste repository for the region feasible?

Methodologies used in studies of adjustment to natural hazards are inappropriate for an analysis of the nuclear waste hazard, and other technological hazards for which the locus of control is far removed from those who are affected, or who perceive themselves as being affected. Natural hazard studies consider the benefits accruing to those living in hazard zones. For example, in the case of a flood, the people living on the flood-plain are those who have to adjust to the hazard, but there may be compensating economic benefits influencing their decision to live there. In the case of nuclear waste the people who bear the risks are likely to be far from both those who receive the direct benefits of nuclear energy, and those who make decisions about disposal strategies and sites. The present research on the nuclear waste hazard will propose a general hypothesis regarding the perception of technological hazards, and will suggest possible future directions for research on the management and disposal of nuclear waste in the Pacific region.

What Is the Problem?

Nuclear power is being used increasingly in the Asia-Pacific region as a response to rising energy costs and to increase energy security. The pressure on governments to lessen their dependence on oil imports is often judged to more than compensate for the new risks of nuclear electric generation (Brown and Smith, 1980). Nuclear waste disposal creates one of the risks of nuclear electric power.

Radioactive waste from the fission of uranium in a reactor is almost entirely a human-made hazard, the result of a technology only 40 years old. In addition to power production, waste is also created through weapons production, and the use of radio-isotopes in hospitals, research institutions, and industry. Chapter I presents a picture of the magnitude and distribution of the nuclear waste problem in the Pacific region, and an estimation of the potential future problem. This includes definitions of the radiation hazard, of the various categories of waste (high-level, transuranic, and low-level), sources of different types of waste, and a discussion of indices of the risks associated with each.

The scientific controversy over dose-effect relationships of low-level radiation is critical to the general philosophy of waste management and disposal. Present disposal technologies for high-level waste emphasize the "concentrate and contain" strategy. If a threshold exists below which radiation exposure is harmless, safe disposal could be achieved by diluting the waste down to safe levels of radioactivity before dispersing it into the environment - the dilute and disperse method, that is used for some low-level waste.

Nuclear Waste Disposal and the Field of Geography

Chapter II places this study of the nuclear waste hazard in the context of geographical research. Early work in geography on environmental hazards concentrated on human adjustment to natural hazards. It is only within the past decade that the attention of geographers has turned to the perception and management of technological hazards, part of a new interdisciplinary field of "risk assessment", which has grown out of the necessity to identify, classify, evaluate, and compare the risks of living in a technological society. The risks of siting nuclear facilities, and the disposal of toxic chemical or radioactive wastes are becoming increasingly recognized as new problems for location studies in geography.

Studies of technological hazards have concentrated on western industrialized societies, particularly in North America and Europe, where these hazards were first recognized. Little has yet been published on technological hazards in the expanding urban-industrial societies of Asia or Oceania. In this context the present study of the nuclear waste hazard in Japan and Australia is a contribution to the cross-cultural literature on technological hazards.

What Is the Expert's View of the Risks?

In the United States the nuclear waste issue has been investigated by many scientists and federal agencies since the end of World War II, and has preoccupied public interest groups since the late 1970s. Resolving the questions raised by waste disposal is now a critical issue in the future growth of nuclear power in the United States, and is likely to become so in many other Asian-Pacific countries in the late 1980s and 1990s.

The scientific community and the concerned public have widely differing views on the magnitude and acceptability of the risks of nuclear waste disposal. Although there is uncertainty and disagreement surrounding the risks of low-level radiation, most experts agree on the comparative merits of various disposal methods. There seems to be a consensus of scientific opinion that technical difficulties can be overcome. Chapter III discusses disposal technologies for high-level nuclear waste, and the applicability of these options to the Pacific region.

Deep geologic land-based disposal, using the multi-barrier approach, is the method most preferred by the scientific community. Alternatives include sub-seabed, ice-cap, and extra-terrestrial space disposal. The risks at each stage of the management and disposal system are important. Too often attention is focused exclusively on final disposal to the exclusion of the risks of handling, processing, and transporting waste.

What Is the Public View of the Risks?

Scientists are accustomed to dealing with stochastic relationships but the public views the scientists' uncertainty with alarm. The gap between expert and public opinion increases partly because the public seems to perceive the risks of waste disposal as great because the maximum possible damage is great. The perception dichotomy is mentioned here as a preface to discussion of the technical aspects of disposal in order to indicate that waste diposal is both a technical and a political issue and discussion of either is meaningless without consideration of the other.

It is being increasingly recognized, both by scientists and by politicians, that the non-technical problems involved in disposal are the more difficult to overcome. In several countries, public opinion has already persuaded governments to require power companies to demonstrate waste disposal methods before proceeding with any further construction of nuclear power plants. A Danish Law (1976) on the safety and environmental impact of nuclear power plants stipulates that waste research will come first, even though at present in Denmark there are no nuclear plants operating, or even under construction. In Sweden the Stipulation Law of 1977 states that nuclear power plants may not be commissioned until the owner has shown that the waste problem can be solved in a safe manner (Ahlstrom, 1980). California and a number of other states in the United States now have similar laws. In Japan there is a law obliging electric utilities to include waste disposal in their plans, athough merely stating that spent fuel will be sent to European treatment plants has been sufficient to fulfil this requirement in the past. Some of the political problems involved in land-based disposal of radioactive wastes in Japan, Australia, and the Pacific Islands are discussed in Chapter V.

In general, people tend to be more confident of coping with familiar hazards. The unknown is feared. This seems to apply as well to technological hazards as to natural hazards. Nuclear waste scores high on media exposure, and low on public understanding.

> Radioactivity continues to present the public with unfamiliar concepts and terminology that present formidable barriers to its understanding of the subject. It is not unusual for discussions of waste disposal to involve units as small as picocuries (10^{-12}Ci), and as large as hundreds of megacuries (10^{8}Ci). This is a range of 20 orders of magnitude, a spread of values without precedent insofar as the public, and most scientists are concerned. Members of the public and their elected officials may not understand the enormous difference between picocuries and megacuries.
>
> Merrill Eisenbudd,
> Science (207), No. 4437, 21 March 1980: 1299.

The public knows little about radiation, yet has become familiar with the words "radioactive waste" or "nuclear waste" over the past few years through news reports that are often sensational. In this chapter the hypothesis is proposed that the public will perceive the risks of technological hazards to be increasingly high until such time as the pool of public information and understanding of them expands to a certain level. The risks will then begin to be perceived as lower, if a concensus is reached that the technology is acceptable.

Chapter IV discusses this general hypothesis with regard to the particular case of the nuclear waste hazard, and in the context of the study region. Popular perception of the risks of nuclear power plants and nuclear waste disposal is often exaggerated by the news media and may appear illogical in view of the public's apparent acceptance of such major hazards as road accidents. To separate what is rational from what is irrational in public attitudes toward nuclear power and nuclear waste is a major challenge.

The role of public information has important implications for the management of many technological hazards, and particularly for radioactive waste management and disposal. Certain characteristics of nuclear waste cause it to be a hazard much dreaded by the public: the association of anything labelled "nuclear" with nuclear weapons; the longevity of the potential risks; and the invisible nature of radiation. These characteristics are different from the elements of risk emphasized by the scientific experts. The public has little confidence in government's or scientists' ability to safely handle nuclear waste, and is hypercritical of site investigations relating to waste disposal. The public relies on scientific "experts" for information concerning radiation hazards, but is disappointed when the experts cannot give unequivocal answers concerning risks. Like Senator Muskie, the public seeks one-armed scientists[1]. Neglect of the problem of nuclear waste disposal and uncertainty concerning the risks are the major reasons in the past for the failure of industry and governments to formulate satisfactory waste management policies, and for the present negative public attitudes creating difficulties in finding suitable disposal sites.

Two approaches to evaluating the public perception of the risks of the disposal of nuclear waste have been chosen. The first is the "expressed preference" method that relies on asking people their opinions directly through public opinion polls and, in this case, a questionnaire survey. Secondly, the "deduced preference" method relies on the indirect experience that people receive through communication media. This is particularly appropriate since the hazards of nuclear waste are experienced directly by very few, but vicariously by many through television, radio, and newspapers. Chapter IV presents the results of a questionnaire survey conducted in Japan and Australia, and the results of a newspaper survey of specific "nuclear events" in several Pacific region newspapers, covering the transition from the warlike atom of 1945 to the accident at Three Mile Island in 1979, and proposals for waste disposal in the Pacific in the 1980s. These events have shaped the public image of things nuclear and will continue to have a profound effect on public attitudes toward nuclear waste disposal.

Whose Problem Is It?

It is the politician who is expected to evaluate the risk-benefit equation associated with nuclear power as an energy source, or nuclear waste disposal as a revenue-earning device. The problem of finding a suitable site for a nuclear waste disposal facility is to some extent technical, but to a larger extent it is political. Public opinion, formed primarily through exposure to news media, affects where the Japanese government looks for disposal sites, and whether the Pacific Islands' and the Australian governments choose to sell space for waste disposal facilities within their territories.

Policies on nuclear energy and waste disposal vary in the Pacific region depending on the resource-base, political system, and level of public participation in decision-making within individual countries. The relative strengths of political power groups at either end of the pro- and anti-nuclear spectrum also help determine the choices made by policy-makers among various nuclear waste management and disposal options. Chapter V examines the influence of these groups in the light of their social and political milieu, and the resource bases of Japan, Australia, and the island Pacific.

Is a Regional Repository Feasible?

Japan's humid climate, seismic instability, and dense population distribution are serious obstacles to the safe disposal of nuclear waste. Australia's sparsely-populated, arid and geologically stable interior provides a physically excellent environment for the disposal of nuclear waste. The Pacific also provides potential sites on isolated atolls and the ocean floor.

No one wants nuclear waste in their backyard, and locations with the least political and economic power in the region may become the most likely candidate sites for national or international waste disposal facilities. Nuclear waste cannot be discussed in isolation without considering nuclear power policies and energy security needs. Governments are involved in nuclear energy to an extent unparalleled in most other industries. Chapter VI explores the possibility of regional co-operation between Japan, and some of the economic and political blocs in the region: the East Asian trio (Japan, South Korea, and Taiwan); ASEAN; the Japan-Australia partnership; China(Peking) and Japan, and examines the advantages and disadvantages of a regional approach to the disposal problem.

The conclusion draws together the various aspects of the problem of nuclear waste disposal presented in the dissertation: the significance of the problem in the region, the technologies available for disposal, the differences in perception of the the risks between experts and lay people in the three cultures examined, and the political problems involved in regional co-operation for management of the hazard. An attempt will be made to suggest possible ways to bridge the "perception gap", and possible future directions for disposal in the Pacific region.

No country has yet proceeded to an operating disposal system after 37 years of storing nuclear waste. The average lay person who asserts that he or she is "against nuclear waste" is not grappling with the real problem, but is expressing an emotional response to radiation hazards.

Yet, even if all nuclear weapons were to somehow miraculously disappear, and all nuclear power plants were shut down tomorrow, there would still remain the inventory of nuclear waste that already exists and is awaiting disposal.

NOTES

1. Senator Ed Muskie called for "one-armed scientists" at a Senate hearing on the health effects of pollutants, because testimony from NAS was not as definitive as the senator desired. Scientists insisted on saying, "On one hand evidence is so, but on the other hand ...". Thus, the call for one-armed scientits. Reported by E.E. David, Science (189), No. 4204, 29 Aug., 1975: 679.

CHAPTER I. THE PROBLEM OF RADIOACTIVE WASTE

Science calculates
all things that live between the cosmic rays
and earthbound nitrogen in equilibrium
take in and give off carbon radiation
by rate of fifteen point three disintegrations
per gram per minute
and all dying cease to take in
give off irreplaced their whole accumulation
pulse by pulse
the steady running down runs down the ages
to a half-life past five thousand years
So scholars chronologue neolithic campfires
Mycenean graves and that swift carbonized
demise of old Pompeii.
Ann Deagon, "Carbon 14" (1974).

The Radiation Hazard

Radioactive substances have been part of Earth's composition since the planet's birth, and human beings have evolved in an environment containing radioactivity. Cosmic rays come to Earth's surface from space, and certain rocks contain radioactive elements that find their way into the food chain through the many soil-water-plant-animal-human pathways.

Radioactive waste is a hazard because it is a source of ionizing radiation which can cause damage when interacting with living matter.

> With ionizing radiation, electrons are removed from their atoms, and endowed with energies huge compared to those in ordinary chemical reactions. Such electrons maraud for great distances (compared with atomic dimensions in angstroms) and have the chemical capability to break any kind of bond one might care to visualize. In biochemical systems, reactions are carefully controlled, often by special geometric juxtaposition of the reactants. A marauding high-speed electron simply does not notice all this elegant juxtaposition - it can break anything, anywhere. And once it has ripped

> an electron out of an atom in a molecule, that molecule is itself at such a high-energy level that it can produce all kinds of chemical reactions that would never have been possible without the ionizing radiation.
>
> (Gofman, 1981).

Ionizing radiation is emitted by cosmic rays, and by naturally occurring radioactive substances which are present in the earth, air, food, water, and in the human body itself. Some radioactive materials, such as uranium, have survived the interval since the creation of the universe (primary radionuclides). These, together with their radioactive daughter products[2] (secondary radionuclides), form the "natural background" level of radiation in the environment in which human beings have evolved. Background levels vary according to geographic location, because of differences in radioactivity levels in rock types and at different altitudes. The average background radiation in the United states is 100 millirem/year[3] but in some locations, for example Kerala, in India, it is as high as 400 millirem/year. Human-made sources of ionizing radiation also contribute to exposure to low-level radiation in the population. Radiation doses from various environmental sources are shown in Table 1 and Figure 3. Medical uses of radiation contribute the largest proportion of the average public dose. For example, one X-ray exposure is equal to about 20 millirem, or one-fifth of the annual exposure in the United States. Evidence indicates that people are more radiosensitive than other organisms (Eisenbudd, 1973), and, generally speaking, if a nuclear waste disposal system is safe for people it will be safe for the environment.

Table 1. Radiation doses from environmental sources: average dose, United States' population.

Source: USDOE (1980).

	mrem/yr
Medical — diagnostic	70
Cosmic radiation	35
Terrestrial (rocks and soil, etc.)	35
Potassium-40 in food	20
Nuclear weapons fallout	4.4
Use of natural gas in homes	2
Burning of coal	1
Sleeping with another person	0.1
Nuclear power	0.1
Consumer products (TV, etc.)	0.03
Total	168

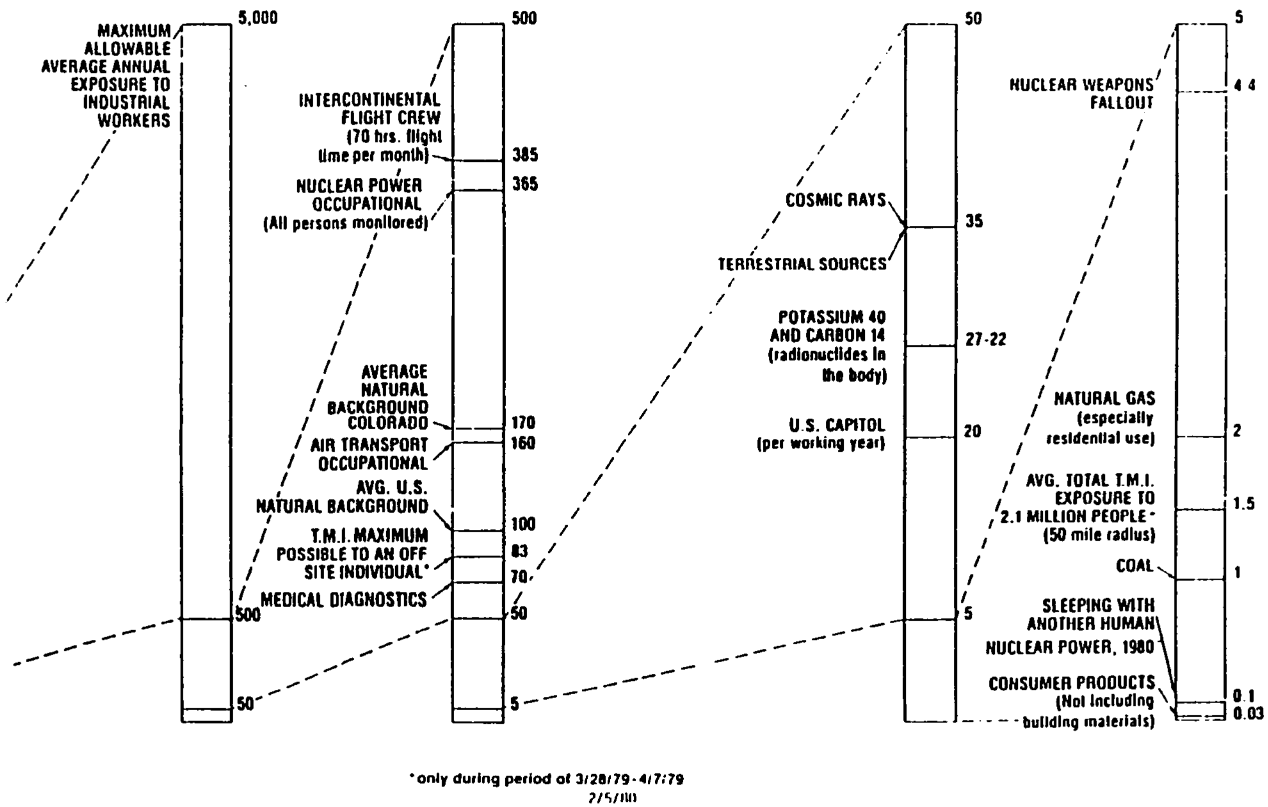
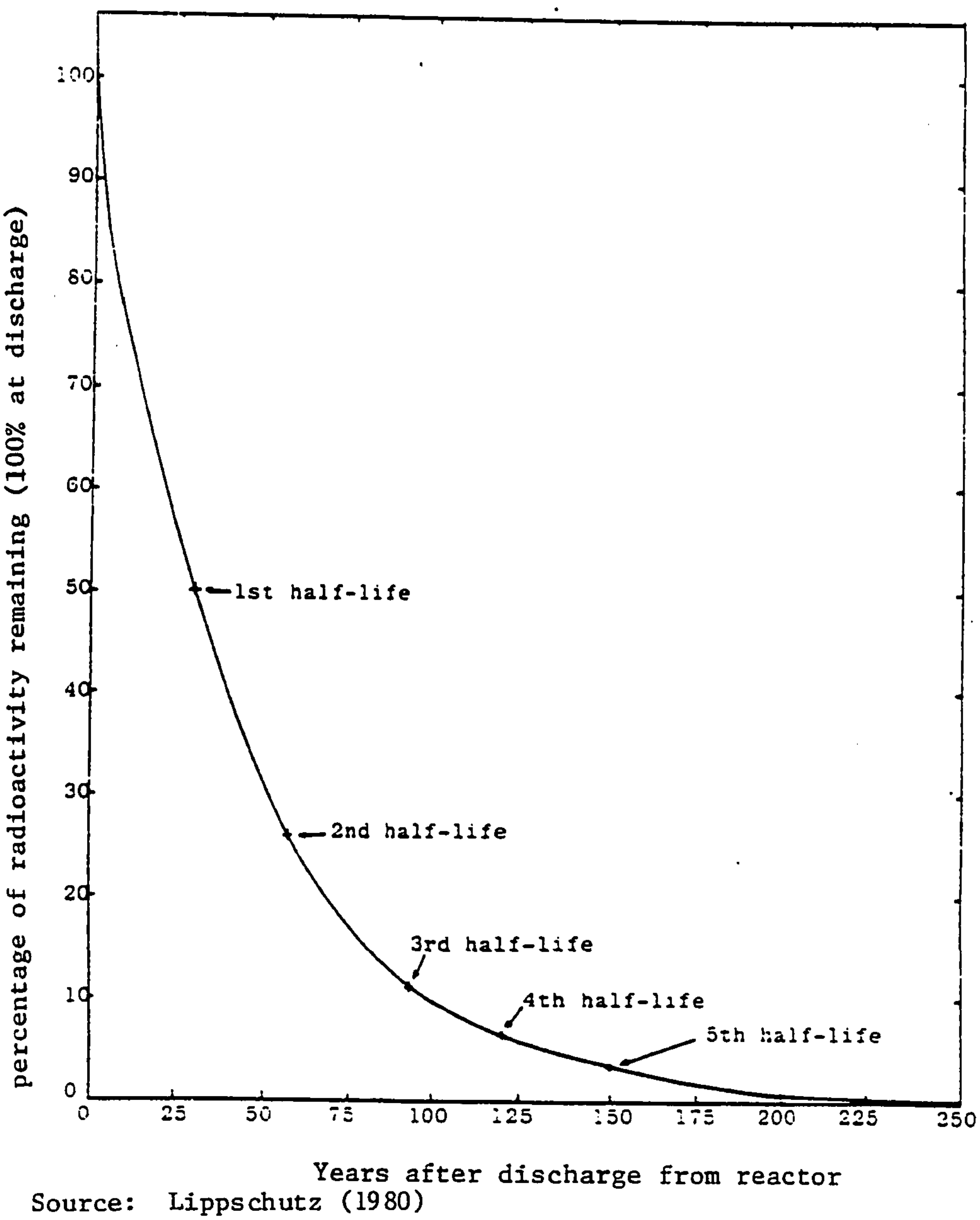


Figure 3. Low-level radiation dose rates (millirem/year).
Source: USDOE (1980)

Biological damage from ionizing radiation may occur in two ways: (a) from internal exposure to radionuclides taken into the body in food, water, or air, and (b) from external exposure to substances emitting gamma and high-energy beta rays. In the case of nuclear waste sealed in an underground repository, internal exposure from ingestion of leaked radionuclides is more likely to be a problem than external exposure.

Radioactive waste, a human-made hazard, is a pollutant that poses serious environmental and health risks. The problem is to prevent exposure from ionizing radiation emanating from the waste by keeping it away from people. The hazard from the waste is a function of the composition and properties, including half-life[4] (see figure 4) and type of radiation, of its constituent radionuclides. Different radioisotopes emit different types of ionizing radiation. Of most concern in radioactive waste management are alpha, beta, gamma, and neutron radiation. Each can penetrate matter to distances that depend on its energy. Alpha particles are relatively massive[5], and can travel only a short distance in air. Alpha radiation can be stopped by several sheets of paper and generally cannot penetrate human skin (Figure 5), but isotopes that emit alpha particles (e.g. plutonium) are dangerous if they are taken inside the body where the large energy they emit can do much damage to surrounding tissue. Beta particles are light (electrons or positrons), and are more penetrating than alpha particles. Beta radiation is most dangerous when emitted within the body, but energetic beta radiation (e.g. from krypton-85 and strontium-90) can penetrate several meters of air, or 1-2 cm. of human flesh or water (United States



Source: Lippschutz (1980)

Figure 4. Exponential decay curve for cesium-137, a radionuclide with a thirty-year half-life.

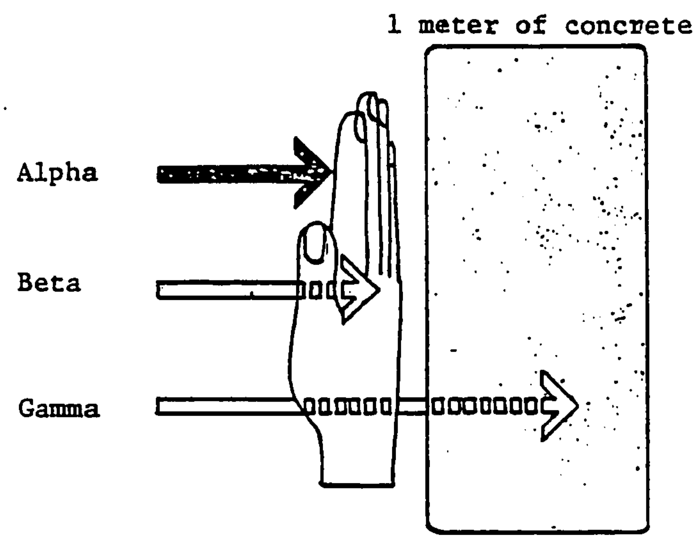


Figure 5. The Penetrating Power of Radiation.
Source: Barnaby (1980).

Office of Nuclear Waste Isolation, 1982). The most penetrating forms of ionizing radiation are neutrons and gamma rays. Relatively few radioactive isotopes emit them, but neutrons are produced in abundance in nuclear fission and nuclear fusion. Neutron shielding can be provided by water (Ibid.). Gamma rays can travel hundreds of meters in air and can penetrate solid walls. Gamma rays passing through walls reduces exposures to people inside by 70-90 percent for large commercial buildings. Dense materials such as concrete and lead are often used to provide shielding against gamma radiation. It requires about one meter of cement to stop most gamma rays. Facilities housing radioactive waste must be appropriately shielded according to the type of waste to prevent leakage of harmful ionizing radiation.

Pathways

Radioactive material may escape from waste and be released to the environment, introducing the possibility accumulation by human beings and biota. For example, in the mining process, previously inaccessible uranium and its daughter products, radium and radon, have a greatly increased probability of transport to the general environment through the leaching of radium into groundwater and radon into the atmosphere.

The degree to which the transport of radioactive materials from the waste to the biosphere may occur is the critical parameter in a waste disposal system. For high-level waste buried in solid form (see chapter III) in a repository, the most important medium of transport is groundwater. Hydrogeology is of extreme importance to high-level waste management, to ensure that the groundwater system existing in the vicinity of the repository retards transportation of radionuclides to the biosphere as far as possible. Tectonic events such as faulting, erosion, and uplift, or human interference such as accidental drilling near the repository, or improper sealing of the mine shaft, could alter the groundwater regime and allow water access to the buried waste, thus providing a pathway for release of radionuclides to the bisoshpere. Volcanic activity or the impact of a large meteorite or nuclear weapon would also provide pathways of release of radionuclides from the waste to the biosphere.

Mathematical models have been devised to calculate the effects of final storage or disposal of radioactive waste expressed in terms of doses to man. For example, the Swedish KBS[6] model ORIGEN calculated the amount of radionuclides in the waste, and the GETOUT model estimated the amount of nuclides leached out of the solidified waste (in glassform) and reaching the surface. The BIOPATH model uses the results of the GETOUT computation to calculate biological pathways through the biosphere, and doses to individuals[7].

Categories of Waste

Radioactive waste is usually divided into three broad categories that, although difficult to define precisely, are generally used in radioactive waste management and disposal[8]. These categories are:

1. low-level waste,
2. high-level waste,
3. transuranic waste.

Wastes may also be gaseous, liquid or solid.

1. Low-level waste

Low-level waste (LLW) is often defined by exclusion: i.e. LLW is all radioactive waste that is not (i) spent fuel, (ii) high-level liquid waste from reprocessing, (iii) transuranic waste, or (iv) mill tailings (United States Department of Energy, 1980). Low-level waste is also defined as containing less than one curie[9] of radioactivity per cubic foot of solid material, or less than ten nanocuries of alpha waste per gram (Ibid.). This includes a broad range of radionuclides, activity levels, and waste forms. Low-level waste may be contaminated to many times the regulation level because of mixing, and may contain "hot spots" where concentrations of radioactivity exceed the definition. Low-level waste is generated in almost all activities involving radioactive materials: the nuclear fuel cycle, scientific research, medical, industrial and agricultural applications (see below).

2. High-level waste

High-level waste (HLW) refers explicitly to the concentrated liquid mixtures of fission products arising from the reprocessing of spent fuel, and liquids produced elsewhere in the fuel cycle that have comparable radioactive concentrations. Unreprocessed spent fuel is sometimes also referred to as HLW.

3. Transuranic waste

Transuranic waste (TRUs) are those human-made elements that have an atomic number[10] greater than uranium. They are alpha emitters and most have long half-lives (more than 100 years). As currently (1983) classified TRUs contain more than 10 nanocuries of alpha emitting radionuclides per gram of waste (Majumdar et al., 1982)[11]. TRU wastes generally have sufficiently low beta and gamma activity that they can be handled without special precautions, but those that do have higher gamma and beta activity and must be handled remotely. Most TRU wastes are generated by defense-related activities, and consist of metal scrap, paper, rags, sludge and filters. The commercial nuclear power industry produces little TRU waste unless there is reprocessing. A small amount of TRU waste is generated by industrial and research activities in the form of paper trash, filters, broken glassware, rags, cleaning aids, defective equipment and materials whose surfaces have been in contact with TRU nuclides.

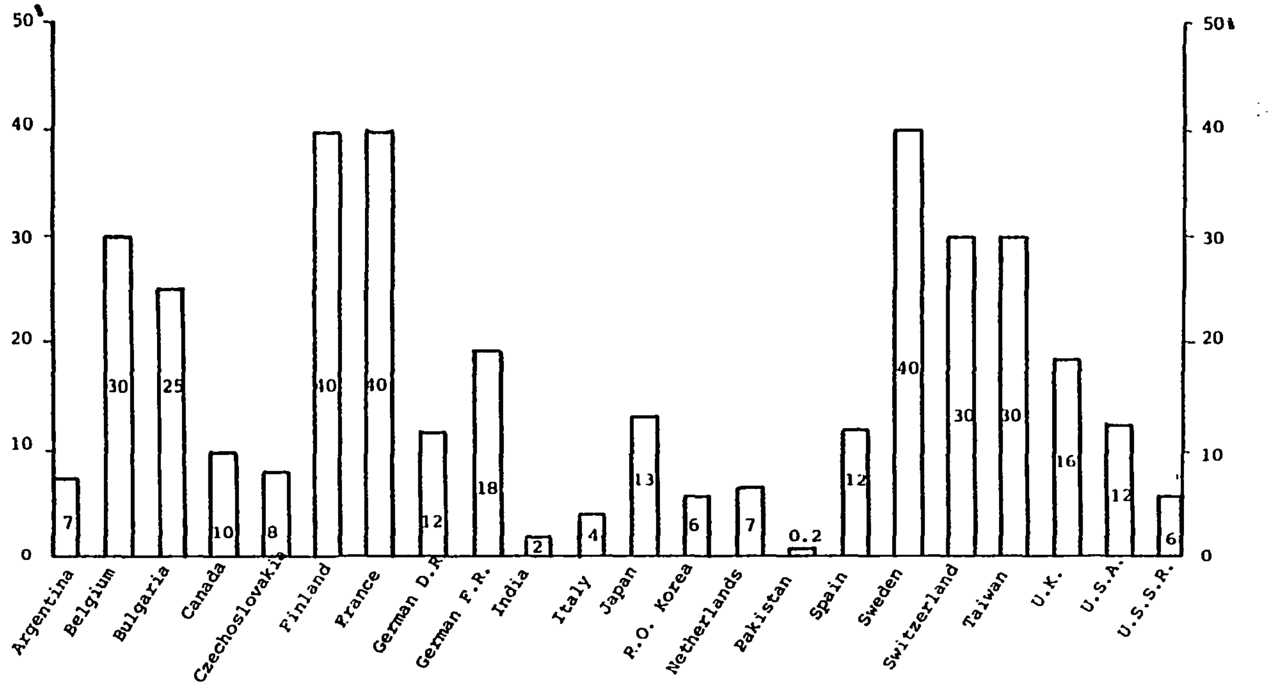
Sources of Radioactive Waste

Different uses of radioactive materials produce different types and volumes of waste.

1. A power source: the nuclear fuel cycle

Uranium is the element upon which present-day nuclear power systems are based[12]. In 1979 nuclear power provided 8 percent of the world's electricity (Sivard, 1981), and in 1981 11 percent of the OECD countries' electricity (OECD, 1982). Figure 6 shows the percentage of electricity generated by nuclear power by country in 1983.

At each stage of the uranium fuel cycle there are waste products[13] that, in varying degrees, must be adequately controlled if they are not to constitute a radiation hazard. These stages are presented



Sources: Nuclear Engineering International, August, 1983; Ministry of Foreign Affairs (Japan), 1983; Y.H. Kim, The Electric Future of China (Taipei), Japan, and Korea, East-West Center, Resource Systems Institute, Research Materials Paper, September 1983, Honolulu;

Figures given in NEI were higher than those given by other sources. In the case of Japan, Korea and Taiwan the figures used are those from sources within these countries.

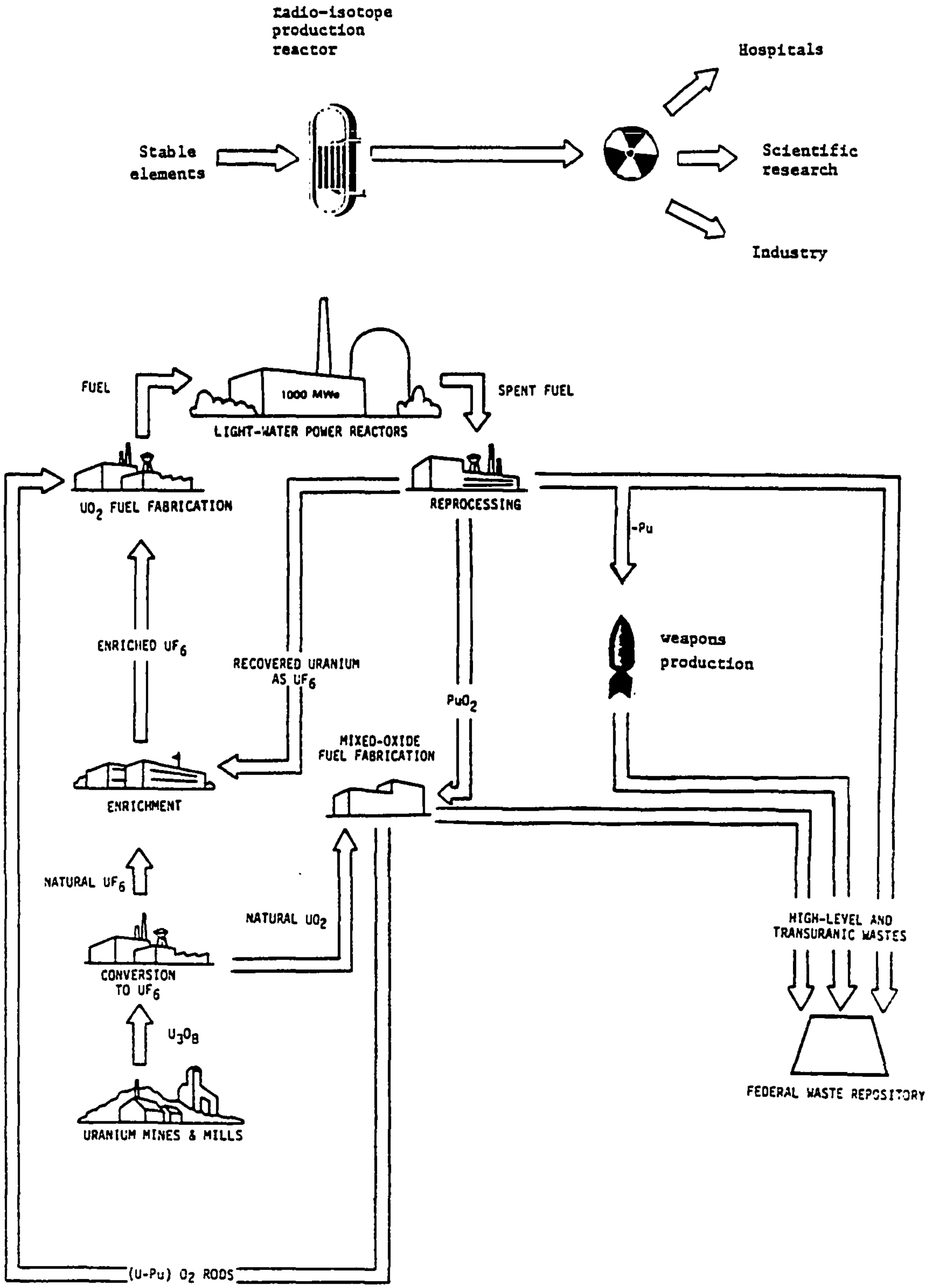
Figure 6. Percentage of electricity generated by nuclear power (1983).

diagrammatically in Figure 7.

(i) Mining. Uranium ore occurs in sedimentary rock formations. Three of the world's eight largest uranium producers (Australia, Canada and the United States,)14 are located in the Asia-Pacific region. The People's Republic of China also has uranium resources that have been used for weapons production. All uranium mines in Australia are open-cut, but in the United States there are also underground mines.

The waste product of most concern in uranium mining operations is the radioactive gas, radon-222. In an underground mine this is especially hazardous because the radon seeps from the walls into the air in the mine where it is inhaled. As a gas, it is exhaled again, but the radon atoms undergo radioactive decay and the solid daughter products polonium-218 and lead-214 (see Table 2) that can be deposited in the lungs, can cause cancer[15].

(ii) Milling. From every 1,000 kilograms of uranium ore that is mined, 2 kilograms, or less, semi-refined "yellowcake" (uranium oxide U_3O_8) is extracted. This is done at uranium mills, which are usually in close proximity to mine sites. Enormous quantities of rock residues, called tailings, remain after the milling process. Management of mine tailings is a serious environmental problem in both Australia and the United States. Under Australian law tailings piles should be kept covered by water in specially constructed ponds (see Ch.V) to reduce radon emissions and dust.



Adapted from Lippschutz (1980)

Figure 7. The nuclear fuel cycle.

Table 2 The uranium-238 to lead-206 decay chain.
Source: Lippschutz (1980)

Radionuclide	Radiation Emitted	Radionuclide[b] Half-life
Uranium-238	alpha, gamma	4,510,000 yr
Thorium-234	beta, gamma	24.1 d
Protactinium-234	beta, gamma	1.2 m
Uranium-234	alpha, gamma	247,000 yr
Thorium-230	alpha, gamma	80,000 yr
Radium-226	alpha, gamma	1,622 yr
Radon-222	alpha	3.8 d
Polonium-218[c]	alpha, beta	3.0 m
Lead-214	beta, gamma	26.8 m
Bismuth-214[d]	alpha, beta, gamma	19.7 m
Polonium-214	alpha	0.00016 s
Lead-210	beta, gamma	22 yr
Bismuth-210[e]	alpha, beta	5.02 d
Polonium-210	alpha, gamma	138.3 d
Lead-206	none	Stable

[a]There are three other decay chains: Uranium-235 to Lead-207 (Actinium decay series); Plutonium-241 to Bismuth-209 (Neptunium decay series); and Thorium-232 to Lead-208 (Thorium decay series).

[b]yr = year; d = day; m = minute; s = second.

[c]A small fraction of Po-218 decays to Astatine-216, which then decays to Bi-214.

[d]A small fraction of Bi-214 decays to Thallium-210, which then decays to Po-214.

[e]A small fraction of Bi-210 decays to Thallium-206, which then decays to Lead-206.

Source: Lippschutz (1980)

The radiotoxicity of mill tailings has been underestimated in the past. Tailings contain radium-226 which produces radon (see Table 1). The longer the half-life of an isotope, the less dangerous it is from the point of view of radiotoxicity. For example, natural uranium is considered less dangerous, gram for gram, than most other radioactive substances because of its extremly long half-life (4.5 billion years), and correspondingly slow rate of radioactive emission (Ehrlich, 1977)[16]. Tailings piles have been exposed to leaching and erosion by wind and rain in the United states, causing contamination of streams and exposure of populations down-wind of the piles.

(iii) Conversion. Concentrated uranium oxide (U_3O_8) from the mill is converted in a conversion plant to gaseous uranium hexafluoride (UF_6), or to uranium oxide (UO_3) depending on the type of reactor fuel that is required. There is some alpha-emitting dust, that may be a hazard to employees inside the conversion plant, and some fluorine which is dispersed to the environment within regulation limits. The conversion plant produces wastes that are more of a chemical problem than a radiation hazard.

(iv) Enrichment. The natural uranium that is mined is a fertile element but contains only 0.7 percent of the fissile isotope[17] uranium-235 (U-235). Before the uranium can be used as a fuel in a light-water reactor[18] the uranium-235 content of the material must be increased to about 3 percent. For weapons-grade material the uranium-235 content must be increased to 90 percent or more. The gaseous diffusion method is the most common method of enrichment[19], in which the UF_6 gas diffuses through a series of permeable membranes. Because the uranium-235 is lighter than uranium-238 (the fertile isotope makes up the other 99.3 percent of natural uranium), it diffuses through the membranes more rapidly. This is a very expensive technology that uses large quantities of electricity. Enrichment plants have been constructed only in the United States (Oak Ridge,TN; Paducah,KN; Portsmouth, OH), the USSR, the United Kingdom, and France. Low (3 percent) enriched uranium is more toxic chemically than radiologically. Waste emissions from the enrichment plant are low.

(v) Fuel Fabrication. In the most common type of nuclear fuel cycle, the enriched UF_6 gas is converted into solid uranium dioxide powder that is then compressed and made into fuel pellets for the reactor. The pellets are encased in zirconium alloy tubes that are sealed and assembled into fixed arrays called fuel assemblies. There are only modestly dangerous effluents from recently enriched uranium fabrication, but more severe problems would arise from fabrication of recycled spent fuel from reprocessing operations (see Fig. 7).

(vi) Reactor. There are routine emissions of LLW from the power plant of liquid tritium (H-3), and krypton (Kr-85) and argon (Ar-41) gases. Levels of radioactivity for these emissions are set by regulatory agencies such as the United States Nuclear Regulatory Commission (USNRC) or the Japan Atomic Energy Commission (JAEC). Radioactive activation products from the interaction of metal parts in the plant with neutrons are another source of low-level waste from the reactor. These include cobalt (CO-60) and zinc (zn-65).

A large LWR, of the type commonly in operation in the United States and Japan, contains about 90-100 tons of enriched uranium. As the chain reaction in the reactor core proceeds, uranium-235 atoms fission. The fragments from this process are intensely radioactive. Some of the nonfissile uranium-238 atoms are transmuted into heavy transuranic elements, a few of which, in particular plutonium species (Pu-239 and Pu-241), will also fission and contribute to energy generation. At the end of fuel life about 30 percent of the energy produced comes from plutonium fission (Lippschutz, 1980). The fission products, being non-fissile, build up in the reactor fuel and ultimately reach concentrations that interfere with the efficiency of the chain reaction. When the amount of uranium-235 remaining in the fuel drops below 1 percent the fuel elements are removed from the reactor core and replaced with fresh assemblies. In a typical LWR one-third of the reactor fuel load, about 30 metric tons, is exchanged annually. This spent fuel then either becomes a waste product, or is reprocessed.

(vii) Spent Fuel Storage. The spent fuel assemblies are stored in pools of water adjacent to the reactor building to allow some of the heat of radioactive decay to dissipate. Storage capacity for spent fuel is becoming an increasing problem in many OECD countries using nuclear power.

(viii) Reprocessing. The spent fuel contains significant quantities of uranium-235 and plutonium-239, both potentially usable nuclear fuels. These elements can be extracted in a chemical reprocessing plant via the Purex process. Spent fuel is chopped into small pieces exposing the highly radioactive material inside the zirconium alloy cladding. The pieces are dropped into tanks of nitric acid which dissolves the fuel, leaving behind the metal cladding. At this point plutonium, uranium, transuranic elements, and highly radioactive fission products are all present in the mixture which is then mixed with an organic solvent. Uranium and plutonium are chemically extracted from the solvent, leaving the fission products in solution. Repeated treatment in this manner removes all but about 0.5 percent of the uranium and plutonium. Reprocessing plants are presently in operation in France, India, Japan, the United Kingdom and the USSR[20]. After reprocessing the uranium is re-enriched, and then fabricated into new fuel rods.

Reprocessing operations produce all classes and forms of waste: high-level, low-level, TRUs, solids, liquids, and gases. The argument has been made that reprocessing is a necessary step in waste management. Reprocessing does remove some of the alpha-emitting TRUs, but increases the volume of low-level and medium-level wastes, and produces high-level liquid waste which is more difficult to deal with than solid spent fuel. Liquid wastes from reprocessing are at present stored in the United States in stainless steel tanks awaiting final disposal in a waste repository. Small amounts of reprocessing wastes are also stored in Japan from the Tokai reprocessing plant (see Chapter V).

(ix) Reactor Decommissioning. After an expected operating life of 30-40 years, a nuclear reactor will be shut down, cleansed of residual radioactivity, and dismantled. As the power plant grows older, the need for maintenance and repair also increases, and the more difficult it becomes to keep the occupational radiation exposures low. Nuclear decontamination is still a relatively young technology, and decommissioning experience has so far been limited to a few small, mildly radioactive experimental reactors. Whether or not commercial reactors can be decommissioned in the same way is not clear, and cost estimates of the procedure are still speculative.

In the United Kingdom a reactor at Windscale was shutdown in 1981 and will be decommissioned over a period of 10-15 years, beginning in 1985. There is no budgeted cost for the Windscale project which is intended as a research exercise, but expenditure is expected to be 45 million pounds (US$63 million) (Nuclear Engineering International, 11/82: 12). In the United States the Shippingport reactor (800MW) in Pittsburgh, Pennsylvania, has been shut down after 25 years of operation and will be the first large commercial nuclear reactor to be decommissioned. The total project cost is estimated to be $73 million (Nuclear Engineering International, 12/82:32). In Japan, dismantling of the Tokai (12MW) demonstration reactor will begin in 1986 (Nuclear Engineering International, 4/83: 6), and in France a reactor at Marcoule (40MWe) that has been in operation for 28 years will be decommissioned (Nuclear Engineering International, 8/83: 7). These decommissioning operations in various parts of the world will provide some experience in the technology and financial costs involved with larger reactors.

Several methods of decommissioning have been proposed including, (a) mothballing (removing all radioactive materials and placing the facility in protective storage), (b) entombment (mothballing, plus shipment of selected components to another site followed by sealing of all remaining highly radioactive or contaminated components within a closed structure), and (c) dismantling that requires removal from the site of all materials, including soil, that have radioactivities above guidelines established by regulatory agencies, and leaving the facility owner with unrestricted use of the site.

The disassembling and defuelling of the Three Mile Island Unit II (TMI-II) power plant[21] will be of significant value in developing decommissioning techniques, and illustrates the enormous costs that can be incurred in the process of decontaminating nuclear facilities. The total cost of clean-up and recommissioning is expected to be $2-3 billion[22], which is more than the capital cost of a nuclear power station (Nuclear Engineering International, 11/82: 9).

2. Military uses

Radioactive wastes result from plutonium production reactors for weapons manufacture and from nuclear-powered naval vessels. In the United States, where military waste has been generated over the past 35 years at government nuclear facilities[23], defense wastes are handled separately from commercial wastes. Plutonium-239 that is separated from the other fission products in the reprocessing plant, is the material used in most atomic weapons manufactured today. The Purex reprocessing method was originally designed in the United States to produce plutonium in a form pure enough for use in nuclear weapons (Metz, 1977). In a typical 1,000 MW reactor 400-600lbs. of plutonium are produced each year (Elmer, 1979). An amount as small eleven pounds is needed to manufacture a nuclear bomb.

Disposal of military waste in the United States is focused on two large and relatively short-term projects: (i) The Waste Isolation Pilot Plant (WIPP) 40 kilometers from Carlsbad, New Mexico, that is a demonstration project for the disposal of TRU waste in bedded salt[24], and (ii) The Defense Waste Processing Facility (DWPF) that is entering detailed design phase, and is scheduled to begin operating in 1989. DWPF will treat high-level liquid waste from Savannah River, and solidify the fission products into borosilicate glass (see Chapter III). Military wastes differ from commercial wastes in that they contain a different mix of isotopes. Military waste is sometimes said to be less of a problem than civilian wastes because the radioactivity of the military waste is less, the initial high level of radioactivity and high temperature in defense waste diminishes with age, but the volume is greater. Figure 8 shows the relative increase in civilian and military waste in the United States over a fifteen year period.

3. Medical applications

Radioactive and nonradioactive isotopes of elements exhibit

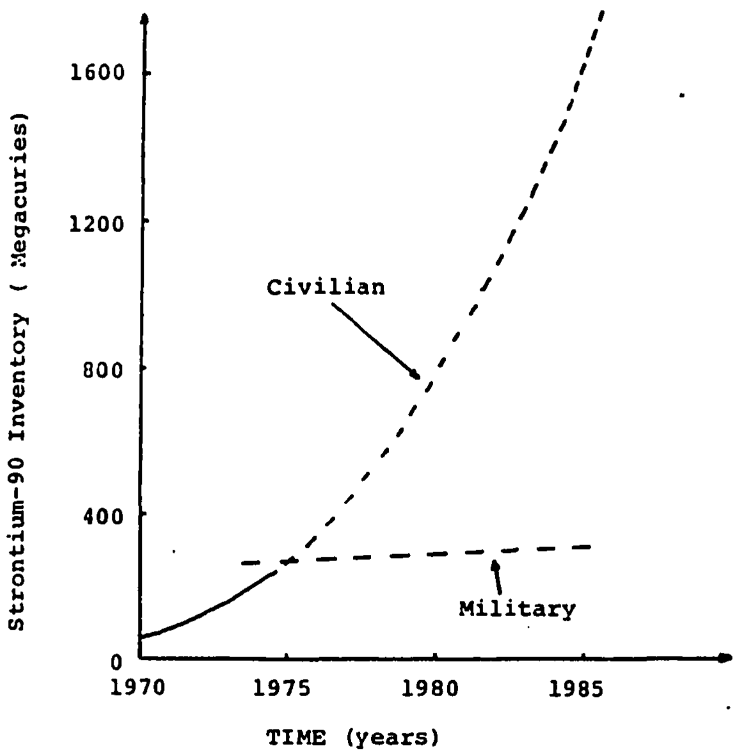


Figure 8 . Estimated Civilian and Military High Level Waste Inventories Measured in Terms of Their Strontium-90 Content as a Function of Time.

Source: Lippschutz (1980)

essentially the same chemical behaviour. This fact is used in many technical fields for sensitive tracer detection of atoms through particles emitted during radioactive decay. A variety of radio-isotopes are produced in small (less than 6 MW) reactors for use in medical and technical fields.

In medicine radio-isotopes are used for diagnostic and therepeutic purposes. The most widely used are radioiodine (I-131, I-125), used in diagnosing thyroid disorders and in scanning the brain, liver, and lungs. Mercury (Hg-203) is used for scanning the kidneys, and strontium (Sr-85) for the bone. Technetium (Tc-99), sulfur (S-35), and phosphorus (P-32) are also commonly used for various procedures.

Queens Hospital in Honolulu[25] uses iodine (I-131), gallium (Ga-67), curium (Cr-51), cerium (Ce-141), tellurium (Tl-201), and indium (In-111). A significant source (3.8ci/year) of gaseous waste emitted to air from the hospital is from xenon-133. This gas is used for investigating lung circulation abnormalities. A small amount of tritium (H-3), that is used as a liquid scintillation counter, is flushed into the sewer system within regulation limits[27].

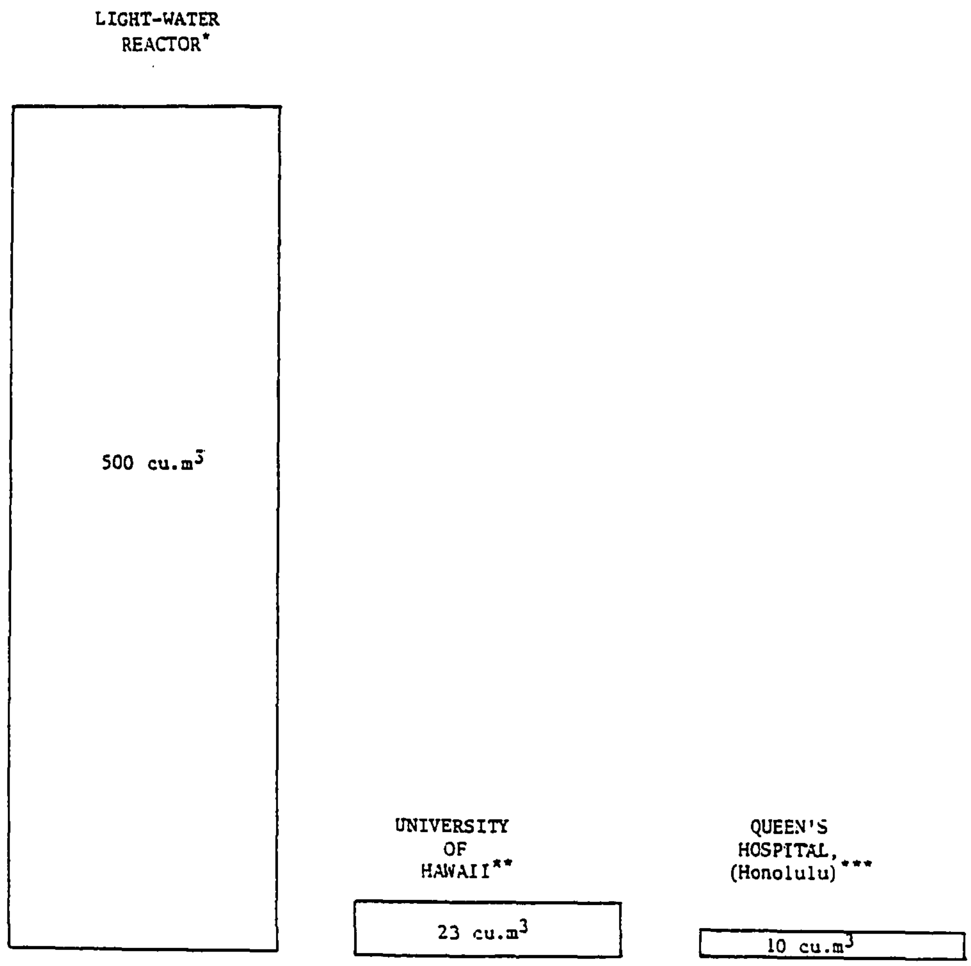
4. <u>Scientific Research</u>

The field of radiochemistry uses various radioisotopes to analyze the molecular structure of matter, and to study complex biological and chemical processes. For example, scientists reached an understanding of the process of photosynthesis through the use of radioactive tracers

(Cohen, 1974). The most common radionuclides associated with biological research are tritium (H-3), iodine (I-125), phosphorus (P-32), carbon (C-14), strontium (Sr-35), and curium (Cr-51). Tracers are also used in physics, engineering, geology[28], and other non-biological sciences. For example, in hydrology tracers are used to monitor silt and sand in dredging situations, and for tracing interconnections in groundwater aquifers. Another application is in the measurement of ocean currents (see Chapter IV). Dating of both natural and human-made objects through analysis of their radiocarbon content is a tool used in many sciences[30]. At the University of Hawaii ninety percent of the radio-isotopes used consists of tritium and carbon. Calcium, iodine, and phosphorus make up the remainder. Those isotopes with a half-life of less than 60 days are allowed to decay on the shelf in a storage area, and the rest are shipped to Richland, Washington, for disposal. There are three or four shipments every year from the university. In 1983 the total solid waste shipped amounted to 23 cubic meters. Liquid wastes are flushed into the sewer system at radioactivity levels within the NRC limits[31]. Figure 9 compares the amount of low-level waste produced in a typical LWR with the amounts produced in Queens hospital and the University of Hawaii in 1983. Most large hospitals and universities would produce similar, or larger amounts of LLW.

5. Industrial and agricultural uses of radio-isotopes

Industry uses the tracer technique in a variety of operations including the study of wear on automotive parts with radioactive iron (Fe-59) and phosphorus (P-32), and for locating leaks in complex or



* American Physical Society (1978). Report to the APS by the study group on nuclear fuel cycles and waste management, New York.

** Mr. Thomas Bauer, Radiation Safety Office, University of Hawaii.

*** Dr. Don Tolbert, Radiation Office, Queen's Hospital, Honolulu.

Figure 9 Comparison of volume of low-level waste produced from three sources.

underground plumbing systems. Phosphorus-32 is used in agricultural research to study fertilizer uptake in plants. Irradiation of food can eliminate spoilage, inactivate disease-carrying organisms, destroy insects and parasites, and delay post-harvest ripening of fruit and vegetables. Cobalt-60 and cesium-137 are the artificially produced isotopes that are usually used in food irradiation. There are no wastes from this process. Other industrial uses of radioactive materials such as luminous watch dials, video screens, measurement devices, smoke alarms, and emergency exit signs also contribute to the creation of radioactive waste.

Indices of the Nuclear Waste Hazard

Different hazard indices have been used to assess the risks of nuclear waste. Separately these indices are incomplete indicators of the total risk, and may even distort perceptions of the risks of nuclear waste relative to other hazards. The scientific community views the risks in terms of such indices as volume, heat, time, and radioactivity.

1. Volume

Volume of waste generated is often used as an index to compare the environmental effects of one energy resource with another. For example coal and nuclear power have been compared in this way. Proponents of nuclear power have stated that the volume of waste produced by a nuclear power plant is very small.

> ...an aspirin tablet (of nuclear waste) for every person (in the United States) whose electricity is provided by nuclear power plants.
> (General Electric, 1975).

This comparison is misleading both because it fails to include the total volume of waste from all stages of the nuclear fuel cycle, and because it fails to consider the toxicity of the material. As Ehrlich et al. have pointed out,

> If a tablet were an apt comparison, it would have to be a cyanide tablet - and even that would not do justice to the actual toxicity of the fission products.
> (Ehrlich, Ehrlich and Holdren, 1977:450)[32]

The Pacific region produced 52 percent of the world's nuclear-generated electricity in 1982 (Fig.10). In the year 1990 this is estimated to be 46 percent. The Pacific region has been estimated to be producing 51 percent of the world's high-level waste in the year 2000 (Cotton, 1983) (Fig.11).

Mill tailings constitute the largest volume of waste in the uranium fuel cycle, and yet they are often omitted in discussions of nuclear waste[33]. Although levels of radioactivity of mill tailings are low, their volume is very large. For a 1,000 MW light-water reactor mining and milling processes generate 40,000- 300,000 cubic meters of waste per year (Smith, 1980). In the United States 20,000 tons of ore are mined daily, from which only 40 tons of uranium oxide are extracted (Lippschutz, 1980).

Large volume is a characteristic of low-level waste. The United States Environmental Protection Agency (USEPA) has estimated that by the year 2000 approximately 1 billon cubic feet of LLW requiring disposal will have been generated. Such a volume would, roughly, cover a 4-lane

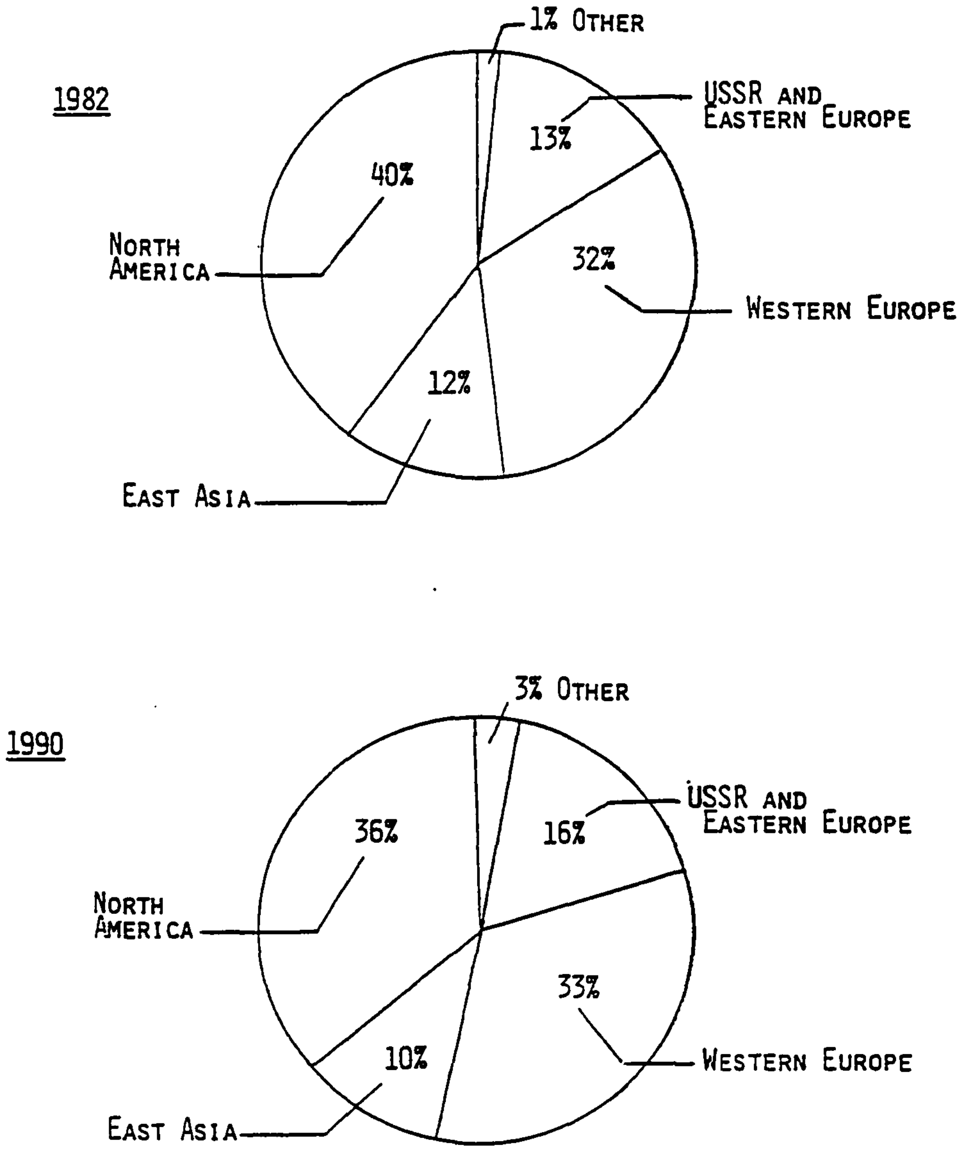
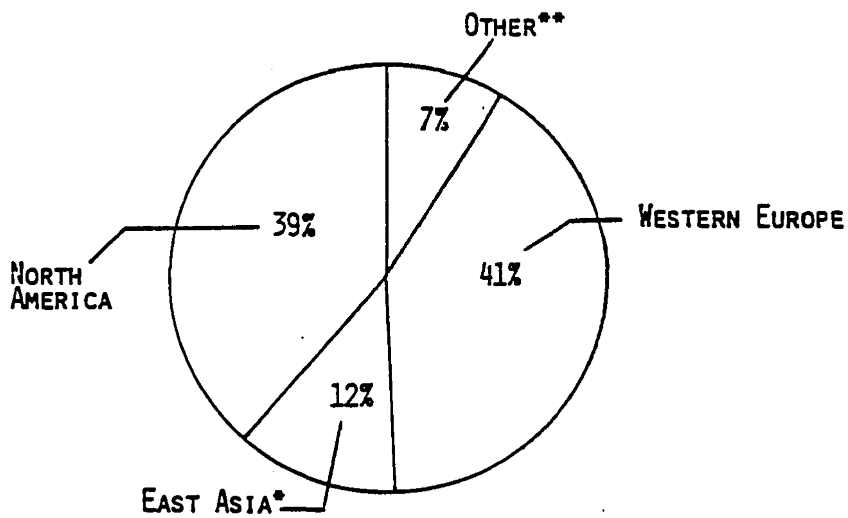


Figure 10. World nuclear generating capacity.
Source: Nuclear Engineering International, 1982.



* JAPAN, SOUTH KOREA, PHILIPPINES, TAIWAN

** ARGENTINA, BRAZIL, FINLAND, INDIA, MEXICO, PAKISTAN, SOUTH AFRICA.

Figure 11. Distribution of spent nuclear fuel - year 2000 (excluding Soviet bloc)
Source: Cotton (1983)

highway from the East coast of the United States to the West coast to a depth of one foot (Lippschutz, 1980). A comparison among the volume of LLW generated in the United States from various sources is shown in Figure 12.

2. Radiotoxicity

The most important waste characteristic from the biological point of view is radioactivity. With each kilowatt hour produced by nuclear power, radioactive contamination grows. Quantities of curies, by themselves are not very enlightening measures of risk, so it has become customary to define a measure of relative hazard, such as the number of curies of a given isotope compared to the volume of air or water that would be required to dilute that material, uniformly mixed, down to the maximum permissible concentration (MPC). The calculation of MPCs is extremly complex, involving such factors as chemical properties of each radionuclide, route of uptake, dose-response, critical organ, and maximum permissible body burden for each radionuclide.

Ultimately, hazard indices for waste management must be characterized in terms of dose to, or effects on, humans (American Physical Society, 1978). The long-term biological effects of even large doses of radiation are still incompletely understood, and to discover the effects of small doses, such as would be received in the case of leakage from a waste disposal site, is incomparably harder. The MPC is an attempt to define an acceptable level of risk by a relative hazard index, and includes pathways to human beings, the probability of taking

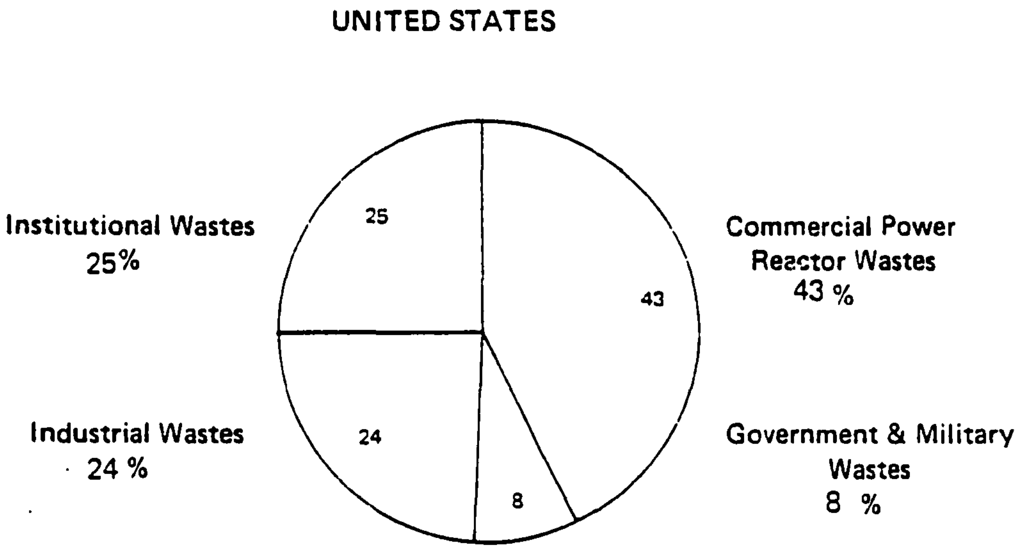


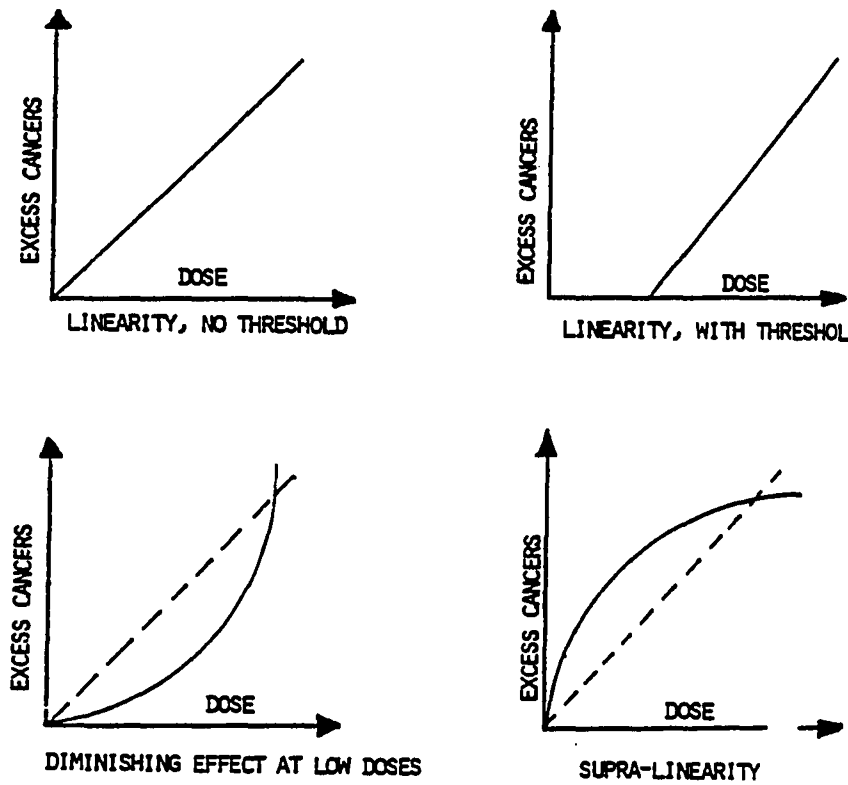
Figure 12. Total Low-Level Radioactive Waste Generated (Percentage by Sources)

Source: USDOE (1980)

a certain quantity of the nuclide into the body, the transport of nuclides through the environment, and the probability of removing concentrations of a nuclide from a burial site. The MPC values have important implications for waste disposal as they dictate whether or not the "dilute and disperse" method can be used or not.

As far as whole populations are concerned, the most important long-term effects of radiation exposure are the possibilities for carinogenic and genetic damage. One critical factor in the setting of safety standards is the threshold debate. The controversy over the effects on humans of low-level ionizing radiation has split the scientific community. The major point of contention concerns the dose-response relationship. The carcinogenic effects of radiation are not precisely known, because the construction of dose-response curves from limited data, and extrapolation from high to low doses, is difficult. The points through which the dose-response curve must be drawn contain such large margins of error, that there are many ways to extrapolate the curves down to low doses (Barnaby, 1980).

Most established scientific opinion supports the assumption that the incidence of cancer at low doses of radiation is proportional to the doses down to zero (linearity, no threshold, Fig. 13a). The International Council on Radiation Protection (ICRP)[34] follows this assumption. Some say that the incidence of cancer is less than for the linear case (infra-linear, Fig. 13c), and others assume it is greater (supra-linear, Fig. 13d)[35].



SOURCE: GOFMAN (1981), RADIATION AND HUMAN HEALTH

Figure 13. Dose-response curves: The threshold debate.

The fission products in spent reactor fuel are the source of the greatest radiological hazard in the fuel cycle. A 30-ton batch of spent fuel, typical for a 1,000 MW light-water reactor contains about 5 billion curies at the time of removal from the reactor core (Ehrlich, et al. 1977: 449). During the 150-day cooling period the radioactivity of this inventory drops to 135 million curies. The radioactivity inventories of a few of the most dangerous radio-isotopes in a LWR at shutdown are given in Tables 3a and 3b.

Strontium-90 and cesium-137 are two radionuclides of particular concern in the waste inventory because the intermediate length of their half-lives (28 and 30 years respectively) is within the range of a human lifespan, and these two are often used as a measure of the radiotoxicity of nuclear waste. An idea of the magnitude of the potential hazard of these isotopes can be obtained by considering that half the strontium-90 in a 1,000MW LWR reactor at shutdown is enough to contaminate the annual freshwater runoff of the 48 contiguous states of the United States to six times the MPC, if it were evenly distributed (Ehrlich, et al., 1977: 444). The releasable iodine-131 is sufficient to contaminate the atmosphere over the 48 states to an altitude of ten kilometers (the tropopause) to more than twice the MPC, again, if it were evenly distributed (Ibid.).

Reprocessing produces the most intensely radioactive waste of the nuclear fuel cycle. All reprocessing operations must be conducted by remote control because of the extreme radiological hazard involved in

Table 3a. Inventory of radioactivity in a 1,000MWe light-water reactor at shutdown (selected isotopes).

Isotope	*Half-life**	*Inventory (million Ci)*	*Maximum permissible concentration*** (μCi/m³)*	*Air needed to dilute inventory to MPC (km³)*
Iodine-131	8.1 d	85	0.0001	850,000,000
Strontium-89	52 d	94	0.0003	310,000,000
Ruthenium-106	1 y	25	0.0002	130,000,000
Neptunium-239	2.4 y	1640	0.02†	80,000,000
Plutonium-238	89 y	0.057	0.000001†	57,000,000
Tellurium-132	3.3 d	120	0.004	30,000,000
Cesium-134	2.1 y	7.5	0.0004	19,000,000
Xenon-133	5.3 d	170	0.3	570,000

*d = days; y = years.
**MPC in air for continuous public exposure.
†MPC for insoluble form (soluble is stricter), since this is how material is found in reactors.
Sources: U.S. Nuclear Regulatory Commission, *Reactor safety study*, Code of Federal Regulations, Title 10, Chapter 1, Part 20, Standards for protection against radiation, Government Printing Office, December 1975.

Source: Ehrlich, et al., (1977)

Table 3b. Maximum permissible concentrations for some important isotopes.

Isotope	*Ci/m³ in air*	*Ci/m³ in water*
Tritium	2×10^{-7}	3×10^{-3}
Carbon-14	1×10^{-7}	8×10^{-4}
Krypton-85	3×10^{-7}	not applicable
Strontium-90	3×10^{-11}	3×10^{-7}
Iodine-131	1×10^{-10}	3×10^{-7}
Cesium-137	5×10^{-10}	2×10^{-5}
Radon-222	3×10^{-9}	not applicable
Radium-226	2×10^{-12}	3×10^{-8}
Uranium-235	4×10^{-12}	3×10^{-5}
Uranium-238	3×10^{-12}	4×10^{-5}
Plutonium-239	6×10^{-14}	5×10^{-6}

Note: Figures are curies per cubic meter in air and water for public exposure. Where a distinction is made in the regulations between soluble and insoluble forms, the lower concentration is used here.
Source: U.S. General Services Administration, *Code of Federal Regulations.*

Source: Ehrlich, et al., (1977).

this operation. A single large reprocessing plant of the future may serve as many as 50 reactors, so the amount of radioactivity handled would be very large. Solidified salt cake from liquid wastes from reprocessing contains even higher levels of radioactivity because it is more concentrated than the liquid waste.

3. Heat

Radioactive decay produces heat. Low-level wastes emit very little heat, but spent fuel continues to generate heat long after the fission process has ceased, and requires constant cooling for a period. Heat of radioactive decay is measured in thermal power units (i.e. watts/metric ton). The thermal output of spent fuel is appreciably higher than that of high-level reprocessing waste because of the large quantity of TRUs in spent fuel. Strontium-90 and cesium-137 are among the greatest heat-producing radionuclides in high-level waste[36]. The enormous quantity of heat created inside the reactor core through the fission process is the source of energy for the generation of electricity. The core requires constant cooling. Failure of the core-cooling system can be the cause of a "meltdown", possibly the worse kind of accident that could occur in a LWR power plant, in which the nuclear fuel melts its way through the containment structure and intensely radioactive materials are released to the environment. At the time of the annual 30-ton off-loading, the spent fuel contains about 1.5 MW of thermal power (heat) per metric ton (Lippschutz, 1980). This is enough to cause a meltdown within 30 seconds if cooling is not provided. The accident at TMI-II was a serious loss-of-coolant-accident, in which, although a meltdown did not occur, significant damage to the plant's nuclear fuel and core was sustained.

Figure 14 shows the thermal power for one ton of spent fuel. The heat output of radioactive waste is an important factor in the choice of wasteform and disposal medium. Heat stress can affect the mechanical integrity and chemical composition of the material encasing the waste, and the geological medium of the repository (see Chapter III).

4. Time

The long-lived nature of the hazard of some radio-isotopes in nuclear waste is the characteristic that has most often fascinated, and seems to be most feared by, the public. Time has been frequently suggested as a criterion of radioactive hazard in the scientific literature, also, referring to the time needed for a particular radionuclide to decay down to a trivial level. The case of plutonium-239 is often cited as an example for the duration of the significant hazard of nuclear waste.

> Plutonium-239 has a half-life of nearly 25,000 years, and 10 half-lives are required to cut the radioactivity by a factor of 1,000. Thus the buried wastes must be kept out of the biosphere for 250,000 years.
>
> (Bethe, 1976).

The assumption that a radionuclide is of no real concern after it has decayed for 10 half-lives is misleading. Plutonium is not the longest-lived isotope in the nuclear waste inventory. Reduction by a constant factor without regard to the initial amount of the substance or

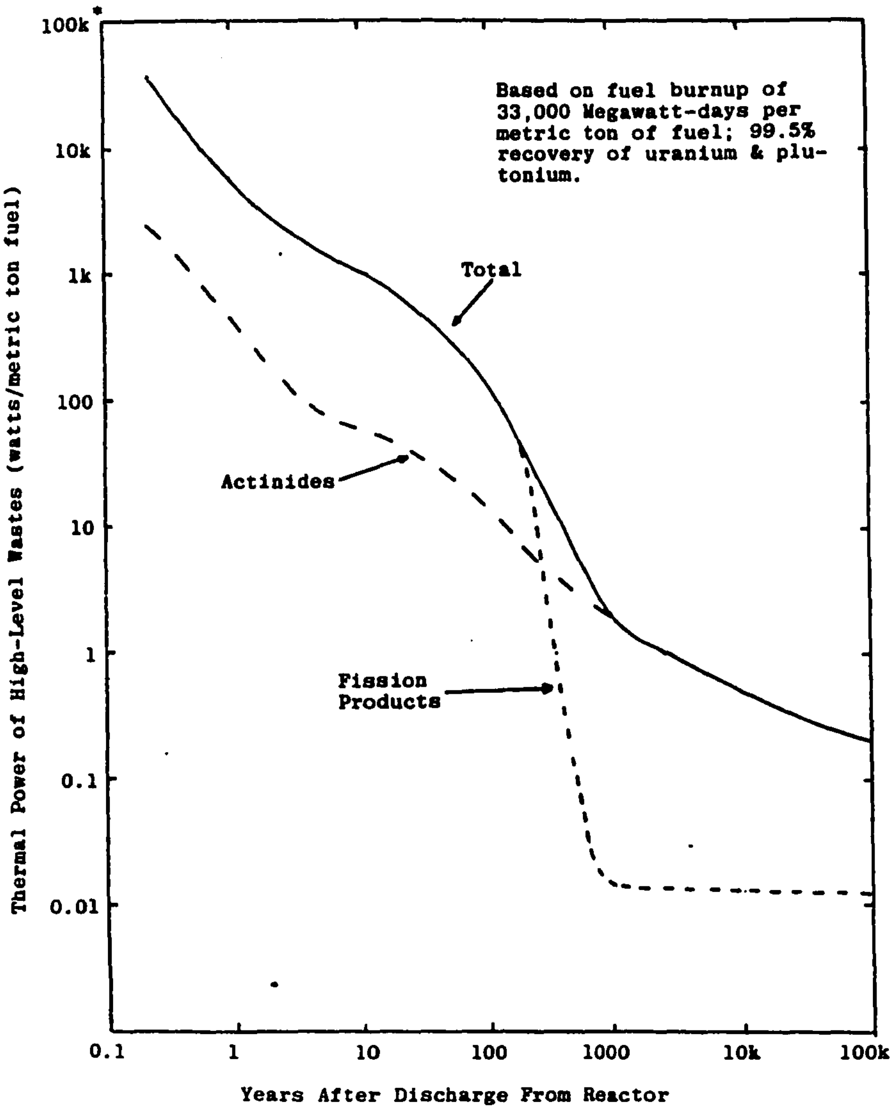


Figure 14

Thermal Power Released by the Radioactivity of High Level Waste from Reprocessing 1 Metric Ton of Irradiated Light Water Reactor Fuel.

Source: Lippschutz (1980)

Note: *k = thousand.

its toxicity is nearly meaningless (Smith, 1980).

The mill tailings problem also illustrates use of the time index. It has been stated that if the tailings are not isolated from the environment, after 100,000 years they will become the greatest source of radiological hazard (Lippschutz, 1980). This is because of the long half-life of uranium-238, the source of the radon emissions that are the chief concern in mill tailings hazard.

Although nuclear waste is hazardous for long periods, concern about risks of its entering the environment need not extend until the last radio-isotope has decayed into a stable atom. Of more concern, is the length of time needed until the hazard of the waste becomes acceptable. For this reason nuclear waste risks are often compared with background radiation sources as a "yardstick". i.e. how long it will be before the waste decays to a level equivalent to the background level, for example, natural uranium ore.

The time criterion is the reason for the debate over inter-generational equity. The question is often posed: Is it reasonable for the present generation to create radiological hazards that will last for periods of time longer than any human society has so far endured? On the other hand, is it futile to worry about the hazards of mill tailings 100,000 years into the future? These are philosophical questions that technology cannot answer.

Conclusion

The need for energy security in the Pacific region will make the decision to use more nuclear power for electricity generation politically hard to avoid for some countries. Large-scale use of nuclear power will significantly increase the levels of human-made radiation in the environment, through routine emissions, waste disposal, transport of radiaoctive materials, and possibly reactor accidents. The acceptability of these risks must be balanced against the benefits of nuclear power, that are unequally distributed within countries.

NOTES

2. A daughter product is an isotope that results from the decay of a radioactive "parent", and may itself be radioactive.

3. The rem, an abbreviation of Roentgen Equivalent Man, is a unit of measurement used to indicate the impact of radiation on human cells. The millirem (one thousandth of a rem) is also commonly used. The rad is a unit of absorbed dose of radiation.

4. The half-life is the time in which half the atoms of a particular radioactive substance disintegrates to another nuclear form (Lippshcutz,1980). This time may range from millionths of a second to billions of years. After a period of one half-life the radioactivity level of a radionuclide has decreased to 50 percent of its original value. The curve of exponential decay for cesium-137, a radionuclide found in nuclear waste, is shown in Figure 5.

5. An alpha particle is a helium atom consisting of two neutrons and two protons (Glasstone, 1958).

6. The Karnbranslesakerhet (Nuclear Fuel Safety Project) is the Swedish agency charged with responibility for research on nuclear waste disposal.

7. For a detailed discussion of these models see T.B. Johansson and P. Steen, Radioactive Waste From Nuclear Power Plants (1981), University of California Press, Berkeley.

8. Sometimes a fourth category, medium-level waste is also used. Medium-level wastes are included here in the discussion of high-level waste.

9. A curie (Ci) is a measure of radioactivity equal to that of one gram of radium per second, or approximately 37 billion disintegrations per second (Lippschutz, 1980). Other common units in radiation measurement are the millicurie (one-thousandth part of a curie), the microcurie (one-millionth part of a curie), the nanocurie (one-billionth part of a curie), the picocurie (one trillionth part of a curie), and the megacurie (one thousand curies). Under a new system of measurement, the unit Becquerel (Bq) will be used. One Becquerel is equal to $1/3.7x10^{10}$ curies.

10. The atomic number is the number of protons in the nucleus of an atom, and this determines the place of the chemical element in the periodic table.

11. Some TRUs commonly found in radioactive waste from power plants include plutonium, americium, neptunium, technetium, curium and iodine-129.

12. Thorium is another natural element that may be used as a nuclear fuel. Naturally-occurring thorium-232 may be converted to fissile thorium-233. World thorium resources are estimated to be three times as large as uranium resources, although the economically recoverable quantities of thorium may be less than that of uranium (Glasstone, 1958). There are large thorium deposits in Brazil, India, and China.

13. For a detailed description of waste products from the nuclear fuel cycle see Pigford, (1974), "Environmental Aspects of Nuclear Energy Production", Annual Review of Nuclear Science (24): 515-559; American Physical Society, (1978), Reviews of Modern Physics, 50(1, Part II), January, Report to the APS by the study group on nuclear fuel cycles and waste management, Appendix I.

14. In 1983 the largest uranium producers, in descending order of production, were the United States, Canada, South Africa, Namibia, Niger, France, Gabon, and Australia (OECD/NEA, 1982).

15. Cancer rates among uranium miners in the United States have been shown to be five times higher than the rate for the average population. See Gofman, (1981): 443-451.

16. Uranium is the only radio-isotope whose chemical toxicity (as a kidney poison) exceeds its radiotoxicity.

17. A fertile element is one that is capable of being transmuted into a fissile isotope through the process of neutron capture. A fissile isotope is a nuclide that undergoes fission on absorption of neutrons and can therefore be used as a nuclear fuel or for weapons production (Lippschutz, 1980).

18. Reactors are generally classified and named according to the coolants and moderators they employ. The light-water reactor (LWR), in widespread commercial use in the United States and Japan, is so named because ordinary water (light water, as opposed to heavy water, or deuterium) is used both as a coolant and a moderator. Other types of reactors include: the heavy-water reactor (HWR), which uses heavy water as a moderator and light water as a coolant; the gas-cooled reactor (GCR), which uses helium gas as a coolant and graphite as a moderator; the liquid-metal fast breeder reactor (LMFBR) which is cooled by liquid sodium and uses no moderator. For a detailed description of reactor types see American Physical Society, 1978.

19. Other methods of enrichment include high-speed centrifuge and laser separation.

20. In the United States the military has reprocessing for plutonium, and a plant at West Valley (NY) reprocessed commercial spent fuel from 1966-1972, but in April 1977 the Carter Administration issued a Presidential directive against reprocessing as a nonproliferation measure. The Reagan administration has overridden this directive, and has declared an intention to go ahead with reprocessing. Progress has

been slow because of uncertainty over demand, and marketing conditions (OECD, 1982).

21. Just after 4:00 am. on March 28, 1979, there was a minor pump failure in the nuclear power plant at Three Mile Island near Harrisburg in Pennsylvania. The ensuing combination of mechanical malfunction and human error turned a minor problem into a potentially very serious one. The core of the reactor was damaged and some gaseous fission products were released from the plant (Collier and Myrddin-Davies, 1980).

22. The financial plight of the owner of TMI-II, General Public Utilities, illustrates the inadequacy of simple property damage insurance in meeting the costs of a major nuclear accident. The insurance for TMI covers only $300 million of the $1 billion bill. The Reagan administration announced in December 1981 a plan to spend $123 million over the next three years in support of research and development aspects of the work at TMI (Nuclear Engineering International, 11/82: 9). The Edison Electric Institute are seeking $150 million from utilities as a clean-up fund because the experience at TMI-II will benefit all utilities. In October 1983 only $65 million had been pledged. The Utilities are waiting for a ruling from the Internal Revenue Service on whether contributions will be tax deductable (Nuclear Engineering International, 10/83:13).

23. Military nuclear wastes are generated from reprocessing operations at the Idaho National Laboratory (3 percent, mostly test and naval reactor fuels), Hanford, Washington (72 percent, weapons production fuels), and Savannah River, South Carolina (25 percent, weapons production fuels), (Majumdar et al., 1982).

24. This facility is now under construction and is scheduled to begin operating in 1988. Under the present schedule WIPP will be the first facility in the United States demonstrating geologic disposal of radioactive waste. WIPP will not initially handle high-level waste, except on a small research scale, and is not regarded as a precursor to a high-level waste repository (Nuclear Engineering International, 5/83: 22).

25. Queens is the largest hospital in the State of Hawaii, with 550 beds. This discussion is based on a convrsation with Don Tolbert, Ph.D., Radiation Safety Officer, Queens Medical Center, on November 7, 1983.

26. Queens Hospital is in the process of constructing a storage facility for shelf-decay of short-lived (less than 60 days) isotopes. The total amount of LLW shipped from the State of Hawaii each year is 228 cubic meters (USDOE, 1980).

27. The hospital disposes of one million gallons of wastewater per day. The amount of tritium included in this (less than 1 millicurie) is dilute and within Nuclear Regulatory Commission limits.

28. For example, see A.B. Turner, et al., "Earthquake Dating: An Application of Carbon-14 Atom Counting", Science (219), No.4590, 11 March, 1983: 1320.

29. For example, see Campbell, Loughran and Elliot (1982), "Caesium-137 as an indicator of geomorphic processes in a drainage basin system"; W.C. Graustein and R.L. Armstrong, "The Uses of Strontium-87/ strontium-86 ratios to measure Atomospheric Transport into Forested Watersheds", Science (219), No. 4582, 21 Jan. 1983:289.

30. New procedures for radiocarbon dating can date samples of up to 70,000 years. See Bennett, (1979), "Dating with Accelerators", American Scientist (67), July-August: 450-457.

31. This discussion is based on a conversation with Mr. Tom Bauer, Radiation Safety Officer, University of Hawaii, on November 10, 1983.

32. The authors further argue that the volume of an aspirin tablet is also erroneous, and that if all categories of waste from the fuel cycle are included, the volume would be between 3,300-3,600 aspirin tablets per person per year instead of one.

33. Mill tailings are not included as LLW, but are classified as a separate category in the United States (USDOE, 1980).

34. The ICRP, formed in 1928, makes periodic recommendations about the maximum dose of radiation to which various groups should be exposed. Most national regulatory bodies such as the National Council on Radiation Protection (US), the Australian Ionizing Radiation Advisory Council, and the Nuclear Safety Commission (Japan), follow ICRP recommendations.

35. For example see the discussion of low-level radiation effects by T. Mancuso, A. Stewart and G. Kneale, "Radiation Exposures of Hanford Workers Dying of Cancer and Other Causes", Health Physics (33), No. 5: 369; J. H. Fremlin, "How Dangerous is Low-level Radiation", Ambio (9) No.2: 58-65.

36. It has been suggested that these waste isotopes could provide a future resource for heat and thermally-produced electricity in areas such as the Arctic, in unmanned navigation stations, and in satellites used in space exploration (Nuclear Engineering International, 11/82: 26).

CHAPTER II. LITERATURE REVIEW AND METHODOLOGY FOR EVALUATING THE PERCEPTION OF HAZARDS

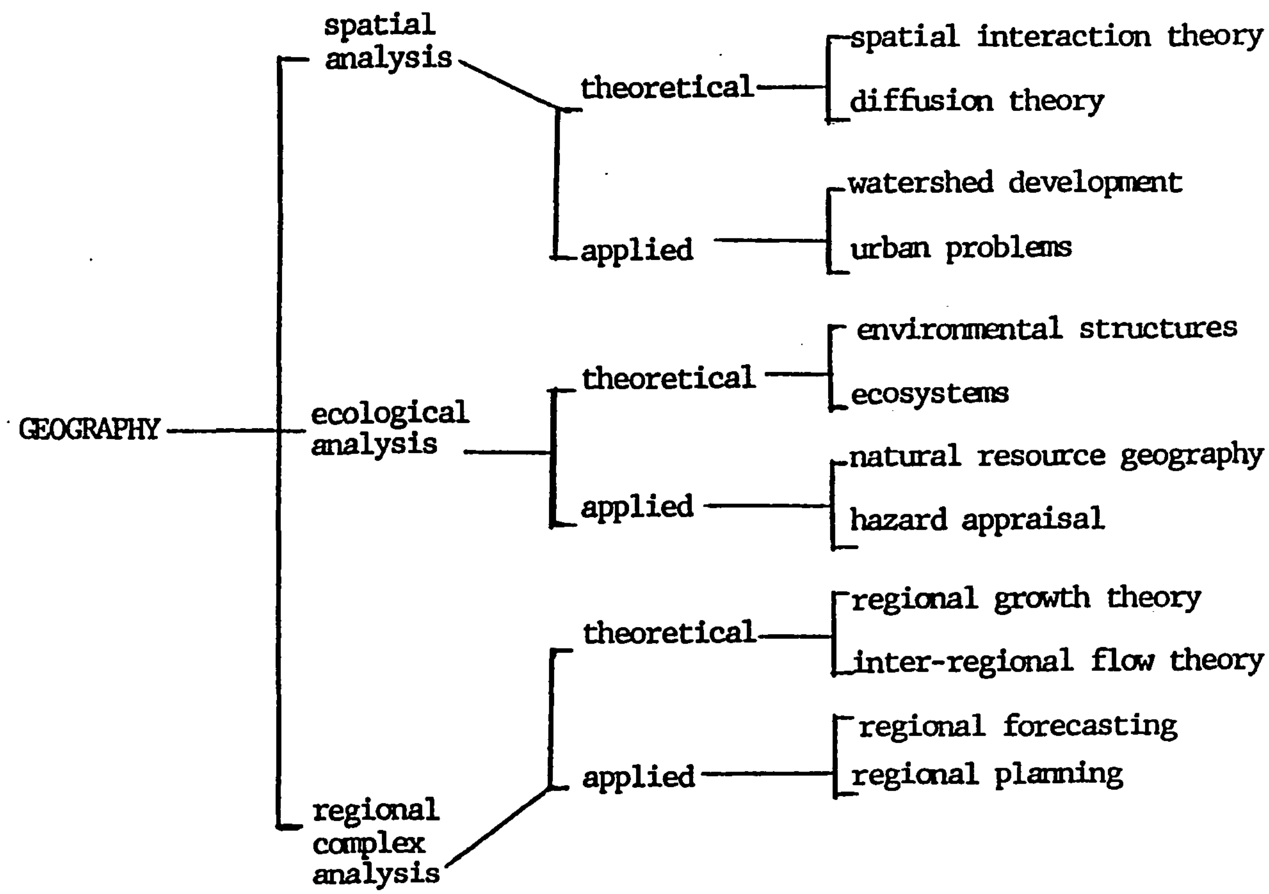
Natural hazards (earthquakes, floods, typhoons and drought), are still major causes of suffering of many of the world's people. In the industrialized countries it is an irony that as technology has progressed, and damage from diseases and geophysical events has been lessened, threats from human-made hazards seem to have increased, partly because of improved communication of information via modern news media. One branch of geography has examined the societal management of hazards in the context of environmental policy.

Public policy-makers in many societies are now grappling with the problem of hazardous waste disposal, of which radioactive waste is one class. The research question addressed here is whether or not the methodology that has been developed by geographers to analyze response to natural and human-made hazards is appropriate to a study of the hazard of radioactive waste disposal. Do the risks posed by radioactive waste require a unique set of research questions?

Natural Hazards

Hazards research is part of an integrative model of environmental management and is a branch of applied ecological analysis, (Fig.15). Early hazards research was set in the philosophical context of geography as the science of human ecology.

> ... the center of gravity within the geographic field has shifted steadily from the extreme physical side toward the human side, until geographers in increasing numbers define their



<u>Figure 15</u> <u>The Structure of Integrated Geographical Research</u>.

Source: Adapted from P. Haggett (1972). <u>Geography: A Modern Synthesis</u>, Harper & Row, New York.

> subject as dealing solely with the mutual relations between man and his natural environment. Thus defined, geography is the science of human ecology.
>
> (Barrows, 1923).

Gilbert F. White's work in the 1940s on urban flood plain management in the United States led to the development of a systematic framework for recognizing patterns of human adjustment to hazards in the environment. White and a team of researchers at the University of Chicago addressed the question, "How do people adjust to risk and uncertainty in natural systems, and what does an understanding of that process imply for public policy?" (White, 1964).

During the decade 1958-68 two lines of hazards research developed. One was followed by a National Academy of the Sciences (NAS)-sponsored group of physical and social scientists at the Disaster Research Center at Ohio State University. This group was primarily concerned with human reactions under the stress of emergency episodes. For example, "The Social and Psychological Consequences of a Natural Disaster: A Longtitudinal Study of a Hurricane", (Bates, et al., 1963).

The second line of research was pursued by a group of geographers at Toronto, Chicago and Clark Universities, whose work focused on the persistence of human settlement in hazard zones. This group broadened the work on flood plain management to include studies of various geophysical and meteorological hazards, (Burton and Kates, 1964), drought in Australia (Heathcote, 1969), drought on the Great Plains of the United States (Saarinen, 1966), urban snow hazards (Rooney, 1966), and tsunami in Hawaii (Havighurst, 1967). These studies advocated the social solution to hazard management (i.e. modification of human adjustment, such as controlled settlement), rather than the technological solution (i.e. modification of the hazard, such as the building of dams).

From its beginning the hazards model emphasized the role of human attitudes and behaviour. In this respect it was strongly related to the environmental perception approach by John K. Wright (1947; 1966) which was later pursued in studies of the cultural landscape by Lowenthal (1964), Tuan (1974), and others.

> Geography deals in large measure with human beings and the study of human affairs and motives has not yet reached a stage in which more than a small part of it can be developed as a science. Until it arrives at that stage, much geographical study will have to be considerably tinged with intuitive subjectivity.
>
> (Wright, 1947).

As geographers included a larger component of behaviour analysis in their studies, they added methods more highly developed in other social sciences. A variety of techniques for analyzing the perception of hazards was borrowed from psychology (projective tests)[37] and sociology (questionnaires and interviews)[38]. Models of decision-making and game theory used in business-managerial research were incorporated into the field, and optimizing procedures developed by economists such as cost-benefit analysis and probability theory were used where problems had well-defined risks and benefits. The economic models are less useful where uncertainty is a major factor, such as in the case of radioactive waste disposal.

At the 1968 International Geographical Union (IGU) congress held in New Delhi, geographers were encouraged to prepare national reviews of natural hazards. Some of these studies emphasized personality and culture in adjustment behaviour: Baumann and Sims on tornado threat in Illinois and Alabama, 1972; Murton and Shimabukuro on tsunami in Hawaii, 1974; Simpson-Housley on earthquakes in New Zealand, 1978. These were the first cross-cultural comparative studies in hazards research by geographers.

Although most of the early work on natural hazards was in the North American cultural setting, during the 1970s the scope broadened to become more international. As a consequence of the popular environmental movement that gained momentum in the early 1970s, concern for problems of the environment was institutionalized (e.g. Earth Day) and environmental protection agencies were set up by governments in many countries. Research on environmental pollution and adjustment to hazards was encouraged by international organizations. In 1972 the United Nations Conference on the Human Environment was held in Stockholm, and this led to the establishment of the Man and the Biosphere (MAB) program under the United Nations Education and Scientific Organization (UNESCO) the following year. In 1972, also, the International Geographical Union (IGU) established a Commission on Man and the Environment which stimulated and co-ordinated research in two directions within geography:

1. International studies

Since 1972 there has been a great increase in geographical literature on hazards in non-American cultural settings. e.g. volcanoes in Costa Rica (Lemieux, 1972), earthquake in Managua (Kates, 1973), famine in Bangladesh (Currey, 1979), flood in Sri Lanka (Hewapathirane, 1977). In 1974 White edited a book entitled Natural Hazards: Local, National and Global which included papers from such diverse areas of the world as Tanzania, Kenya, Japan, India, Mexico, Norway and New Zealand. Another milestone study of environmental hazards in the international context was published in 1978. This was The Environment as Hazard edited by Burton, Kates and White. In Australia, following Heathcote's early work on drought, further analysis was made of other natural hazards: bushfire (Wettenhall, 1975), natural hazards in Northern Australia (Pickup, 1978), natural hazards (Heathcote and Thom, 1979), disaster studies (Oliver, 1979), and flood (Forbes, 1980).

Most hazard studies in the Pacific Islands fall into two categories: (a) those concerned with traditional methods of coping with natural disasters, particularly typhoons (Schneider,1957, Kerr, 1976; Brookfield, 1977; McLean, 1976), and food supply relief through traditional methods and modern relief agencies (Waddell, 1975; Campbell, 1978; Currey, 1980). With the exception of the work by Murton and Shimabukuro (1974), and that of Sorenson (1980) on volcanic hazards, very little has been done on hazards in the Pacific using the perception approach. (b) geological-engineering risk studies by non-geographers particularly on volcanic activity in Papua New Guinea (Geological Survey of PNG) and the Solomons(USGS), and tsunami (Cox 1961, 1977), and landslides (De Silva, 1974) in Hawaii.

2. Technological hazards

The distinction between "natural" and "human-made" hazards may seem spurious, since a natural event does not become a hazard until human interaction with that event is involved. The distinction here is taken to be as follows: a natural hazard is one that results from human interaction with a natural event such as a typhoon or an earthquake. A human-made, or technological hazard is one that results from a human-made source, such as air pollution from automobiles. The focus of the early hazards research was on events of a geomorphic and meteorological nature. After 1972 this began to extend into an area of transition between natural and human-made hazards, that of air pollution.

Technological Hazards

In global perspective air pollution may still be very much a natural hazard. Suspended particulates from volcanic eruptions are much greater in volume than that from human-made sources (Burton,et al., 1978). In local perspective, however, air pollution hazards are the product of human activities. Early geographical studies of air pollution on a local scale initially followed the perception approach, and involved work in several countries: Auliciems and Burton in Canada (1971), Kirkby (1972) in the United Kingdom, Burton, Kates and White (1978) in Mexico. From these studies the hypothesis began to evolve that people show greater anxiety in dealing with technological hazards than toward natural hazards, and the question then arose as to why this should be so.

A basic difference between natural and technological hazards is that management for the natural hazard can often only be based on mitigation after the consequence of a disaster. It is almost impossible to prevent damage from a hurricane or a volcano. Technological hazard management can follow the preventive path to a greater degree. This implies a different role for public policy officials and presents the question: How do attitudes and decisions vary in relation to natural and technological hazards?

The landmark volume, Man's Role in Changing the Face of the Earth (1956) edited by William Thomas, provides a point of departure for discussion of geographical research on polluted environments. The volume is an impressive documentation of the contribution of geographers to the study of processes, initiated by man, that have resulted in environmental deterioration. The volume appeared more than a decade before public interest in environmental pollution really surged, and it even included an essay on fission materials in the environment (Bugher). For the most part the papers in the Thomas volume were descriptions of problems rather than analyses of adjustments to them.

Hewitt and Burton expanded the goal of hazard assessment in one place to include the contemporary concerns of the "environmental crisis" of the 1970s.

> A new and vivid image of mankind as the crew of spaceship earth has suddenly been impressed upon the popular imagination... The world is a spacecraft with fragile and troublesome life support systems and a rapidly expanding number of crew members who daily impose more strains on the system capacity.
>
> (1971, p.3)[39]

Environmental pollution is one of the greatest strains placed on the system, and this became a subject for study in many fields in the 1970s. The polluting side-effects of technology began to appear in the geographical literature as a new class of hazard.

In 1973, following the IGU Symposium, the United Nations Scientific Committee on Problems of the Environment (UNSCOPE) established a project to examine the state of the art with respect to coping with environmental risks. The project convened a workshop entitled "International Research on Societal Response to Scientific Information about Man-Made Hazards", which marked a recognition of the importance of public information on perception of technological hazards. From this 1973 SCOPE workshop Robert Kates was asked to undertake a study supported by the United Nations Environment Program (UNEP) on comparative risk assessment. The result was the book, Risk Assessment of Environmental Hazard (1978), in which Kates examined risk assessment methodology almost entirely in the context of technological hazards such as mercury poisoning in Japan, and the nuclear power industry in the United States. Kates has made the most substantive contribution as a geographer towards modelling the systems for dealing with technological hazards. His analysis is based on a three-stage assessment process:

(a) hazard identification
(b) risk estimation
(c) social evaluation

In the case of radioactive waste, the hazard has been largely identified by both the scientific and lay communities. One might add a stage between (a) and (b) called "risk accounting". Much of the controversy and confusion over technological hazards lies in a failure, systematically and consistently, to account for the entire system. For example, in discussing the risks of nuclear waste disposal there is often a myopic concentration on final disposal to the exclusion of the risks associated with transporting waste to the final site. Risk estimation is presently proceeding and is the topic of much debate. The social evaluation of the hazard is the subject of the present research.

Psychological Studies and Risk Assessment

The National Science Foundation (NSF) of the United States funded two years of research (1977-1979) into the management of technological hazards. The work was done by (a) Clark University's Center for Technology, Environment and Development and (b) Decision Research, Perceptronics in Eugene, Oregon. Those who worked on the research formed an interdisciplinary group of natural and behavioural scientists.

Kates' work draws heavily on psychological theories of the individual decision-making process and emphasizes the perception of risks and benefits of technological hazards. Kates joined forces with a group of cognitive psychologists led by Paul Slovic at Perceptronics, Eugene. Slovic has been mostly concerned with the characteristics of hazards and the question of why the risks of some technologies are perceived differently from those of others.

The characterization of hazards goes back to the work of engineer Chauncey Starr, who took an historical approach to devise "Laws of acceptable risk" that govern the acceptability of certain risks compared with others (1969). In his work on risk-benefit analysis, Starr calculated the estimates of risk of death in person/hours of exposure for a variety of activities compared to the benefits in dollars (Fig.16a). He called his method of detecting social preferences the revealed preference method. Otway and Cohen (1975) were critical of Starr's methodology and argued that a different risk-benefit relationship exists for voluntary and involuntary activities (Fig.16b). The absence of benefits attributed by Starr to natural disasters is also contrary to the findings of Burton, Kates and White (1978) regarding the relationship between beneficial location and natural hazard vulnerability.

The Slovic group expanded Starr's idea and developed a list of hazard characteristics that affect people's perception of risks associated with various technologies (1976), (Table 4). They found that risk meant much more to people than merely the number of expected fatalities, and that the perceived risk is far more important in the social evaluation of a hazard than are the quantified risks. This is particularly relevant to the hazards of nuclear power and radioactive waste disposal. Technical arguments and numbers do not convince people

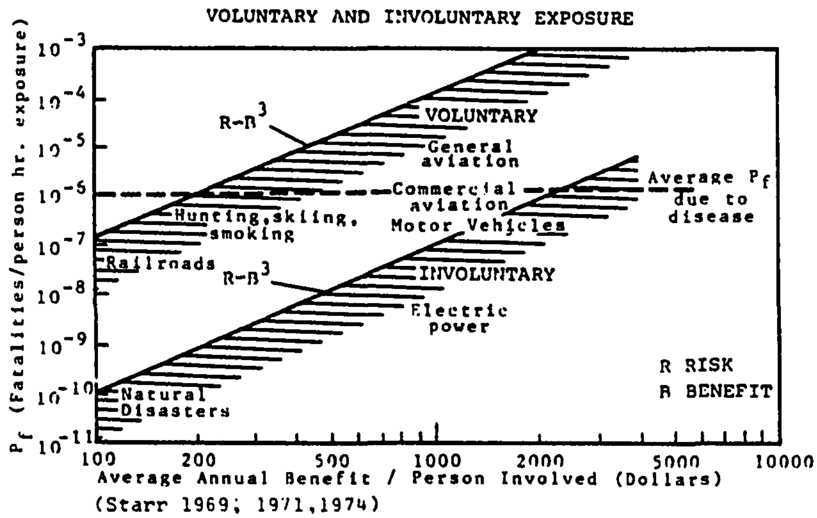


Figure 16a **Revealed Preferences**

Source: Starr (1969)

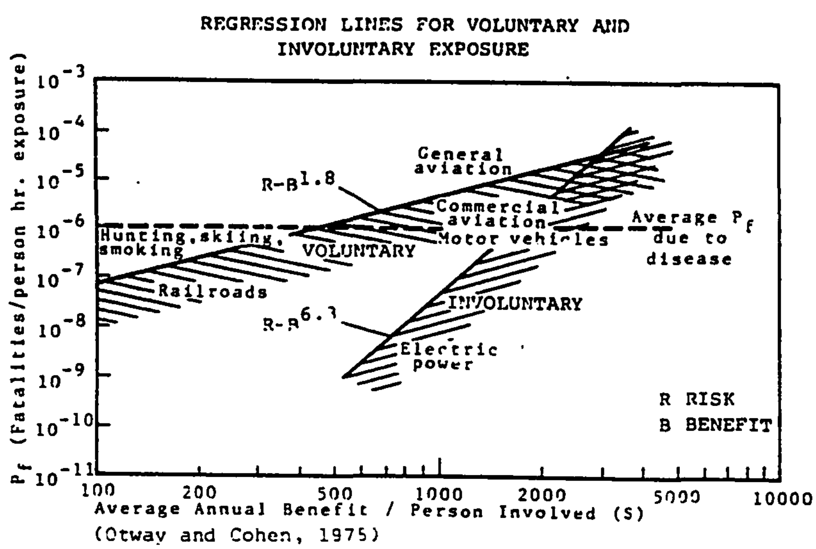


Figure 16b **Comments on the Starr Benefit-Risk Relationship.**

Source: Otway and Cohen (1975).

Table 4. Correlation between rating scales and measures of acceptable risk.
Source: Fischoff, Slovic, and Lichtenstein, (1976).

Scale	Risk Adjustment Factor	Level of Acceptable Risk [a]	Deviations from Perceived Benefit-Level of Acceptable Risk Regression Line
Voluntariness (1=voluntary)	.38*	-.47**	-.64***
Immediacy (1=immediate)	.28	-.64***	-.64***
Known to exposed (1=known precisely)	.21	-.68***	-.75***
Known to science (1=known precisely)	.29	-.57***	-.58***
Controllability (1=uncontrollable)	-.30	.40*	.48**
Newness (1=new)	-.34	.60***	.60***
Chronic (1=chronic)	.45*	.22	-.25
Common/dread (1=common)	.75***	-.29	-.24
Severity of Consequences (1=certain not to be fatal)	.54***	.17	.22

* $p < .05$
** $p < .01$
*** $p < .001$

[a]Perceived risk divided by risk adjustment factor

about the safety of nuclear power. Slovic, et al., found that nuclear power and radioactive waste scored high on all the characteristics that cause anxiety toward technological hazards as compared with other more familiar technologies such as electric power and X-rays (Figs.17a and 17b), and hence were consistently perceived as more dangerous than many other technologies and activites (Fig.18). This method of determining the perception of the safety of technologies is termed the "expressed preference" method, since people are asked to express their opinion by ranking the risks.

The studies of technological hazards have been set in a more rigorous mode than the early natural hazard work. The word "hazard" has gradually been supplanted by "risk", indicating a move away from qualitative environmental perception studies to the more quantitative, new science of risk assessment. There is currently an attempt to create a profession of "risk analysts", and a new international society published the first issue of its journal, Risk Analysis, in March 1981. From this point of view the work on technological hazards has moved out of the sphere of geographers and further into the fields of psychologists and mathematicians, although it is now common to find collaborative research on hazards by engineers, natural scientists, economists, psychologists, lawyers, and geographers. A series of articles on the perception and management of technological hazards published in the journal Environment beginning in 1978 exemplifies this interdisciplinary approach. The articles are by Kates and Kasperson (geography), Hohenemser (physics), Fischoff, Slovic and Lichtenstein

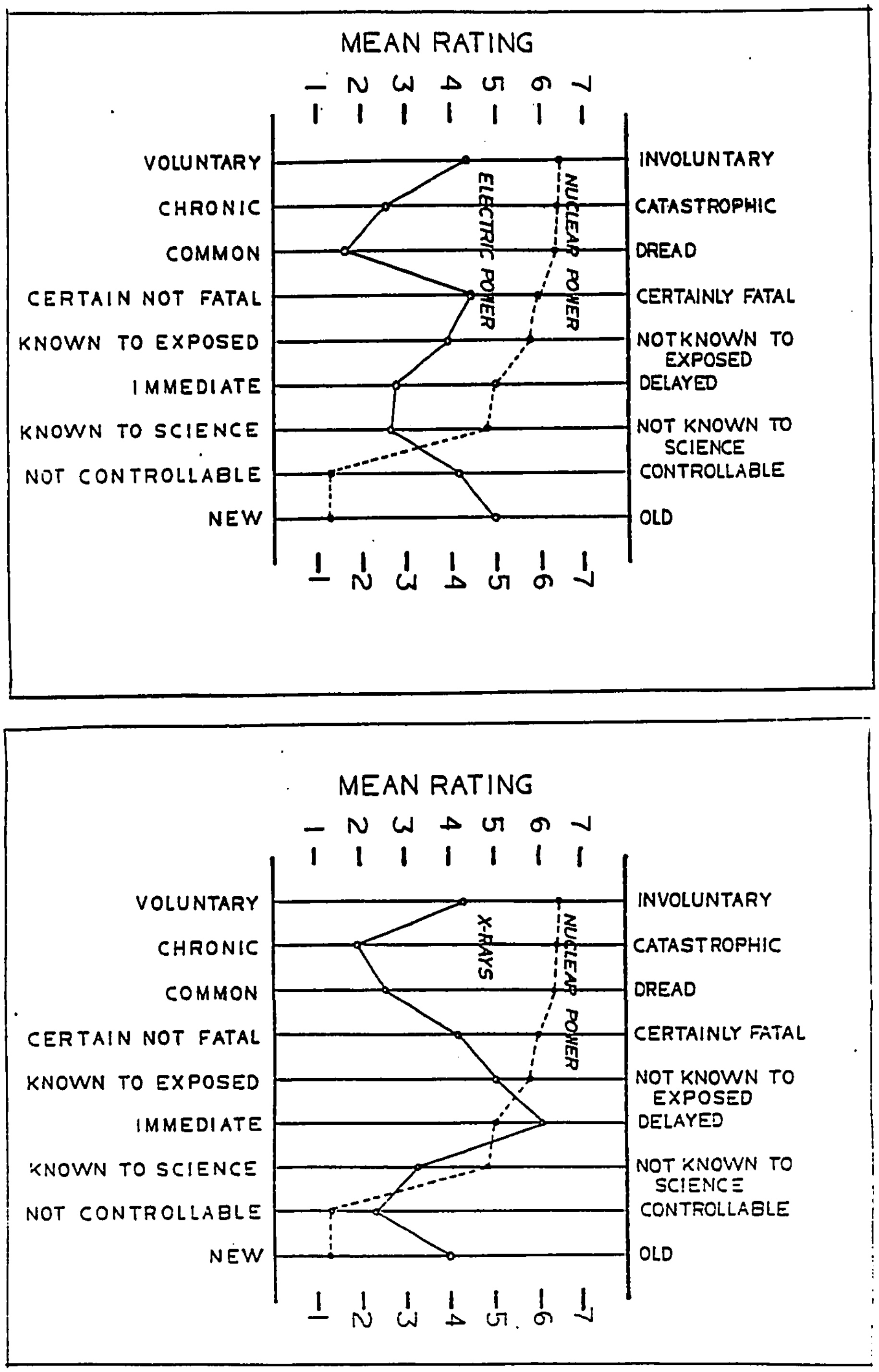


Figure 17. Comparison of risks of nuclear power and (a) electric power, and (b) X-rays.
Source: Fischoff, Lichtenstein, and Slovic (1981).

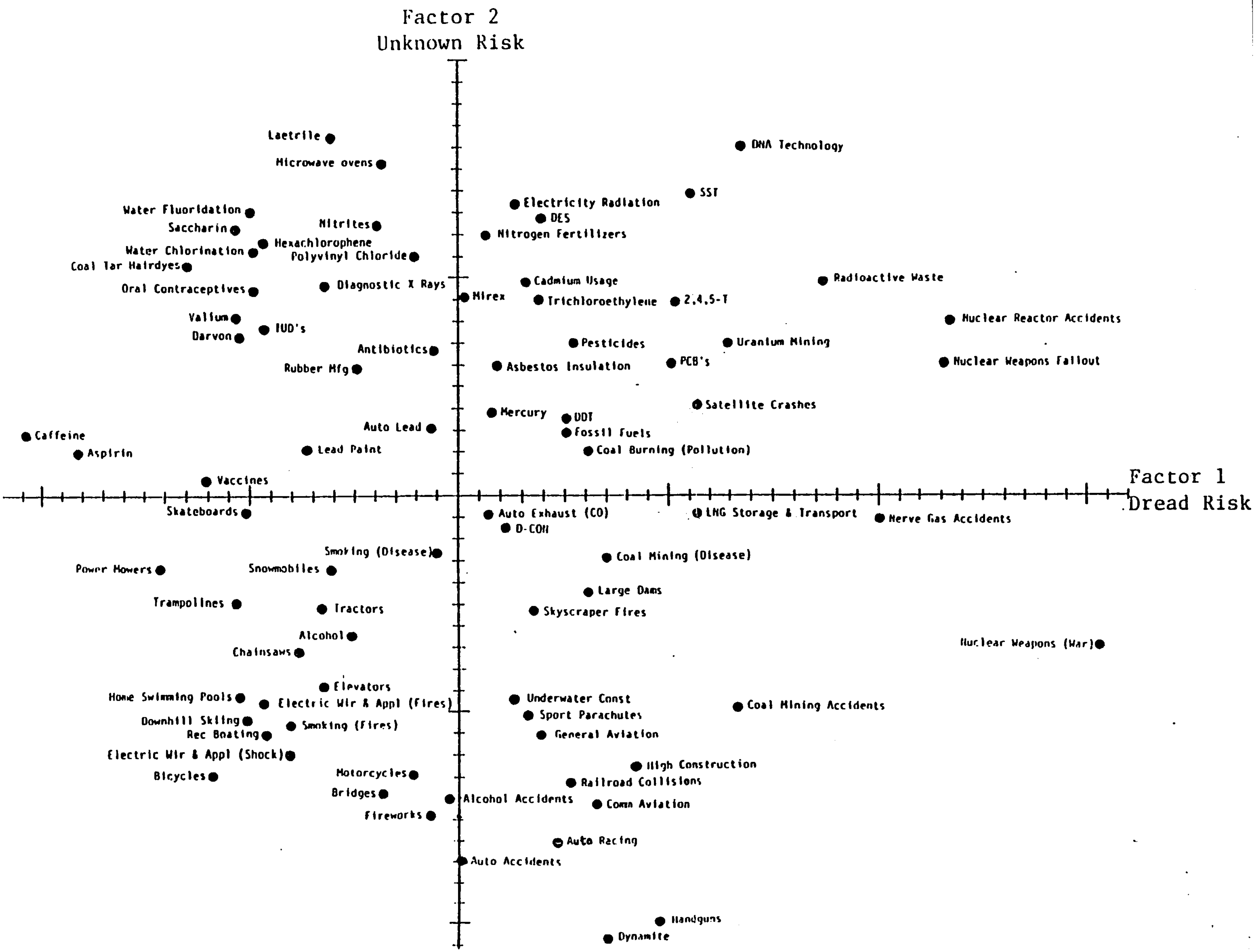


Figure 18. Perception of risks of technologies and activities.
Source: Fischoff, Licht[illegible] (1981)

(psychology). One of the most recent publications on natural hazards, Natural Hazard Risk Assessment and Public Policy by Petak and Atkisson (1982), incorporates risk assessment methodology.

The aim of risk assessment is to provide the information for policy-makers to be able to answer the question, "How safe is safe enough?" Recent studies cover the whole gambit of risks of contemporary life in an industrialized society. An assessment was even done of the potential risks from the fall of Skylab! (Kushnir, 1982). One of the most elaborate risk assessments done to date was the United States Nuclear Regulatory Commission's Report on nuclear reactor safety (the Rasmussen Report, 1975). It cost $3,000,000 and 50 person-years of professional effort. It subsequently underwent considerable review and criticism, but the report rapidly became a standard point of departure for discussion of risk assessment, although it contains no risk evaluation, as such. In practice, it is very difficult to separate risk estimation from risk evaluation, because of biases and value judgements, to which even experts are not immune[40].

Geographic Studies on Nuclear Hazards

The study of technological hazards lends itself to geographical analysis in two important ways. Firstly, there may be variation in dealing with technological hazards in different cultural settings. Outside the North American cultural setting, a recent study of the perception and management of technological risk in the European Community was published (Dierkes, et al., 1980). Little work has been done to examine the perception and handling of technological hazards in non-western societies such as the urban-industrial areas of East Asia, and exposure to technological hazards in Southeast and South Asia are largely unassessed. Secondly, hazards may result from the siting of noxious facitlities near populations, a problem that presents a new dimension for location theory. How will public opinion of nuclear waste hazards influence the siting of nuclear waste disposal facilities?

Work on nuclear-related topics by geographers falls into two main categories. Firstly, there have been papers on the perception of hazards of nuclear electric power (Hohenemser, Kasperson and Kates, 1976; Johnsrud, 1977). There has also been some interest in the social impact of the accident at Three Mile Island (Brunn, et al., 1979; O'Riordan, 1979; Sorenson, et al., 1983). A group of geographers at Oak Ridge National Laboratory have also been conducting research on the perception of nuclear power (Carnes, et al., 1983, J.H. Sorensen, 1983). Secondly, studies of the siting of controversial facilities that may have negative impacts on the population in their immediate vicinity such as airports (Mumphrey and Seeley, 1973) highways, toxic waste disposal facilities (Austin et al., 1970), and power plants (Worden and Gibson, 1980) have been examined in several papers whose findings are relevant to the siting of nuclear waste disposal facilties. Nuclear facilities have received some attention by geographers in the United States: nuclear power plants in California, (Mason, 1971), in North-West Indiana, (Hansis, 1980) and in the United States as a whole, (Semple and Richetto, 1976). Nuclear waste disposal problems in Illinois were examined by Kozak (1980) and in Michigan by Brunn, et al., (1980).

The Present Study

The regional scale of the present research does not allow for a detailed analysis of environmental and social impacts at a specific disposal site. Certain areas of the Pacific are under investigation as potential disposal sites (see chapters V, VI), but none has yet been positively chosen and no high-level waste has yet been buried.

The aim here is to state the present and possible future dimensions of the problem of radioactive waste disposal in the Pacific region, and to examine the differences in the perception of risks associated with radioactive waste between the "experts" and the "public", and in different cultural settings. One question addressed is: How do people view the risks of radioactive waste disposal compared with other natural and technological hazards?

The hypothesis is posed that the natural hazard methodology does not apply well to the hazards of toxic wastes. The time dimension of hazards such as toxic chemicals and radioactive waste, whose consequences are long-enduring, is the critical factor in discriminating between the perception of these risks and those of natural hazards. Uncertainty regarding future consequences is the chief cause of anxiety in the case of technological hazards. Scientific experts tend to deal more with stochastic probabilities, whereas the lay public is more concerned with consequences. For example, comparing the differences in perceiving the risks of fossil fuel power plants and nuclear power plants. In both cases the long-term consequencs of the hazards associated with the two kinds of power plant (the CO_2 problem, and the biological effects of ionizing radiation from a serious accident, respectively) are uncertain. With fossil fuels the probability of the occurrence of various pollutants being in the effluent is known, but not the conseqence of these pollutants. In the case of nuclear power plants, the consequence of a disastrous accident are known, but the probability of its occurrence is uncertain. The end result is the same - uncertainty concerning risks, but the nuclear power plant risks are feared more by than those of the fossil fuel plants.

Methodology

A field survey of public opinion on the nuclear waste issue in several Pacific Basin countries is beyond the constraints of the present research. The problems associated with deciding which "public" to survey, and in obtaining a representative sample across different cultural settings, have led the writer to concentrate on two limited, yet enlightening approaches through which preliminary conclusions concerning public opinion may be drawn in order to substantiate the thesis being presented.

(i) Expressed preference method. Public opinion polls on nuclear issues have been conducted by survey agencies and newspapers in some Pacific countries, and results of some of these are discussed. Slovic (1976) used the questionnaire method to survey perception of risks and benefits of various technologies in the United States (see above) including nuclear power and radioactive waste. The present research tested in Japan and Australia a questionnaire adapted from the Slovic model (see Appendix A), to examine how a sample of people in each cultural setting perceive the risks of nuclear waste compared to a selection of natural and technological hazards. Japan provides an example of a non-western population in a country with an already large nuclear-electric industry. The Australian group provides a sample in a non-American western country where, although there are no nuclear power plants, the public is aware of radiation hazards to some extent through the uranuium mining debate.

(ii) Deduced preference method. A substantial part of human experience is received indirectly, through exposure to various forms of communication media. This is particularly pertinent to the perception of risks from radioactive sources which are experienced directly by only a few, but indirectly by many through the news media. Television is unquestionably the most important public communication medium in North America, Australia, New Zealand and Japan, but it is difficult to survey information presented on television. Radio is the most important medium in the Pacific Islands but, again, it is almost impossible to survey broadcast news information. Lawless (1974) used the newspaper survey method to deduce levels of alarm over various technologies in the United States over a period of 28 years. He showed that press coverage of environmental hazards has increased exponentially since 1946.

It is meaningless to discuss the public perception of risks associated with radioactive waste without considering the events that have had such a profound effect on the public image of things nuclear. The present study examines the information available to the public of various Pacific countries concerning specific "nuclear events", that have influenced public perception of radiation risks, through newspaper accounts.

NOTES

37. For example, see M. Barker and I. Burton (1969), Differential Responses to Stress in Natural and Social Environments: An Application of a Modified Rosenzweig Picture-Frustration Test, Natural Hazard Research working Paper, No.5, University of Toronto, Toronto; S. Golant and I. Burton (1969), Avoidance-Response to the Risk Environment, Natural Hazard Research Working Paper, No. 6., University of Toronto, Toronto.

38. For example, see T.F. Saarinen (1971), "Research approaches and questionnaire design", in Perceptions and Attitudes in Resources Management, Resource Paper No. 2, Policy and Coordination Branch, Department of Energy, Ottawa; A. Whyte (1977), Guidelines for field studies in environmental perception, UNESCO, 1977.

39. The term "spaceship earth" was first used by economist Kenneth Boulding, in "The Economics of the Coming Spaceship Earth" (1966), in presenting the view, encouraged by the first satellite pictures, of earth as a closed and limited system.

40. See Fischoff, Slovic and Lichtenstein (1981), "Lay Foibles and Expert Fables in Judgments about Risk", in Progress in Resource Management and Environemtal Planning, T. O'Riordan and R.K. Turner (Eds.), Vol. 3. John Wiley, New York.

CHAPTER III. DISPOSAL METHODS: THE EXPERTS' VIEW

> Chemistry master to class: "Suppose I gave you all the money and all the facilities it would take and assigned you to produce an acid so powerful it would dissolve any substance - what would be your first step in going about it?"
>
> ...a number of responses from the class about setting up a series of distillation experiments, but the instructor shakes his head to them all.
>
> "Suppose you ever got such an acid, what could you keep it in? The first thing you have to determine in any experiment is, when you get whatever it is you're going after, what are you going to keep it in?"
>
> Bertram Cadbury,
> High School chemistry teacher, Friends Select School, Philadelphia, 1947[41].

This chapter examines current (1983) technological progress, the basis of the experts' confidence, in solving the problem of the disposal of nuclear waste, and gives a brief description of the past development and present status of disposal options that have been considered in various countries. Some of the broader problems underlying the failure, so far, to proceed to the actual disposal stage are discussed.

The belief that problems do have solutions before there is knowledge of how they are to be solved is a commonplace of modern technology (Galbraith,1967). Uncertainty, under the guise of "research and development", has become a recognized feature of the systematic application of scientific knowledge to practical problems. The progression that technology follows to eliminate such uncertainty is:

idea ⟶ laboratory experiment ⟶ pilot plant ⟶ commercial operation

These stages involve increasing scales of investment in time and money. This is particularly true in the case of the application of knowledge to the problem of radioactive waste disposal. Exhaustive research efforts have been elicited to ensure high safety standards for disposal extending far into the future, yet, even after twenty-five years, the progress of research on high-level radioactive waste disposal has barely reached the pilot plant stage in most countries that have nuclear power plants. It is stated by some scientific experts that there are areas of inherent technical uncertainty that will be extremely difficult, if not impossible to reduce. A monograph on geologic disposal states,

> The authors of this circular are confident that the steps outlined above can be carried out in such a way that the ultimate decision on the acceptability of a given site and waste handling procedure will have a strong scientific and technical foundation. However, some key geologic questions are unanswered and answers are needed before the risk associated with geologic containment can be confidently evaluated ... We consider a variety of possible interactions among the mined repository, the waste, the host rock and any water that the rock may contain. Many of these interactions are not well understood, and this lack of understanding contributes considerable uncertainty to evaluation of risk of geologic disposal.
>
> (Bredehoeft, 1978).

Despite the uncertainty of risks involved in disposal, it is the generally accepted belief in the scientific community, that ultimately disposal of high-level radioactive waste poses no significant technical problem (Nuclear News, 4/1982). The justification for this confidence lies in the research that has already been conducted on disposal methods.

Although figures of 250,000 years are often heard in public discussion of time required for waste isolation, the United States Nuclear Regulatory Commission (USNRC) has decided on a 1,000-year containment requirement for its waste management system (Dayal, et al., 1982). Other countries in the Pacific region are following the United States research efforts closely, particularly Japan, South Korea and Taiwan. The temporal dimension of the radioactive waste disposal problem is new to society. Long-term hazards are probably not confined to the nuclear fuel cycle, but it has been pointed out that research on the disposal of radioactive waste is providing a pathfinder role for assessing the difficulties of dealing with other long-term hazards such as toxic chemical wastes (Smith, 1980). The period of greatest hazard from high-level waste (HLW) is generally considered to be the thermal period[42] when activity from fission products is dominant. After a few score years, retrievability from a geologic repository may be an impossibility. Therefore, when the repository is abandoned, its long-term safety should be ensured by the intrinsic characteristics of the disposal system, in terms of containment by engineered or geologic barriers.

Most of the research conducted on disposal methods for HLW has assumed that spent fuel would be reprocessed and therefore that waste material would be in liquid form. The disposal method considered most promising is burial in a suitable rock formation deep below the earth's surface. This is usually referred to as deep geologic land-based disposal.

Deep Geologic Land-based Disposal: The Multi-barrier Approach

The deep geologic disposal method envisages a sophisticated multi-barrier system to concentrate and contain radionuclides present in HLW. Each stage of the waste disposal system -- the wasteform, the container, the backfill, and the repository site -- will act as an independent barrier to the migration of radionuclides from the site. There may be some differences in approach needed for various waste compositions, but the basic containment concept will still apply. The multi-barrier approach is shown diagrammatically in Fig. 19 and a description of the four components of the system is presented below.

Much detailed research has already gone into each of the barriers. The high-level liquid waste (HLLW) from the reprocessing stage (see Chapter I) first has to be solidified and converted into a more manageable wasteform, and then packaged in a container suitable for transport to the disposal site. Both the wasteform and the container have to be specially designed to withstand high levels of radioactivity and heat of decay from the waste.

1. Wasteform

The physical form of the HLW is an important aspect of the waste management system. Over the long term it may not be so critical but initially it is the main barrier holding the radioactivity in the waste.

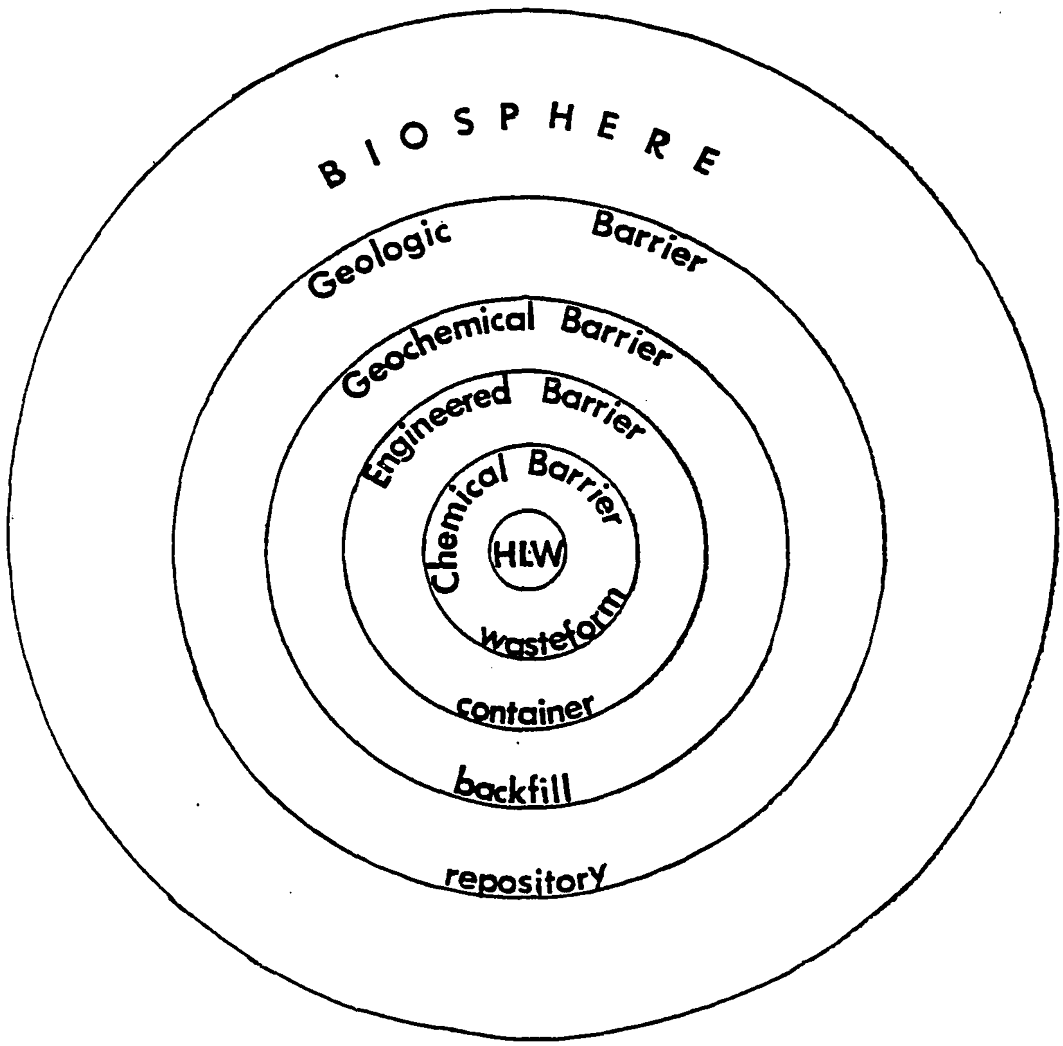


Figure 19. The multi-barrier system for the disposal of high-level nuclear waste.

Research on wasteforms is perhaps the most advanced component of the contemporary management system, with several processes already demonstrated at the pilot plant stage, and with one in commercial operation.

Important factors in evaluating wasteforms from the perspective of preventing leaching of radionuclides from the final disposal site are chemical durability, thermal insensitivity, radiation resistance, and mechanical strength[43]. Impact resistance is an important criterion for handling and transportation safety.

Leaching from the waste via groundwater is the most likely mechanism by which radionuclides might be returned to the biosphere. Thus, leach rate is the most important consideration in the design of a stable wasteform. Experiments have shown that materials are unlikely to remain unaltered in a typical repository for 1,000 years, but would crack and ultimately break down chemically. More recently a different philosophy has come to the fore which, allowing for decomposition of the wasteform, would then provide advantageous characteristics for radionuclide isolation in the decomposition products. Several methods of solidification have been investigated. A brief description of each follows.

(i) Calcines. Calcination is a process in which acidic liquid waste is sprayed through an atomizer and dried at high temperatures. The resulting granular product, a "calcine", can then be temporarily stored in bins to await further processing. The French developed a calcination process at Marcoule, and the United States at Idaho Falls uses a fluidized bed[44] to condense waste into a form suitable for further treatment. Calcination is a pre-requisite step in the vitrification process (see below). Alkaline waste from military programs (see Chapter I) such as those stored at Richland, Washington and Savannah River, Georgia in the United States, are first neutralized. At present, neutralized waste contains considerable amounts of water and cannot be calcined or put into glass form, except on a laboratory scale. Therefore, it is converted to salt cake by removing most of the water. Calcine form is preferable to salt cake because it allows for greater volume reduction, relative ease of handling, and because the technology exists for further immobilization in glass or ceramic form.

(ii) Glass forms. The greatest effort in wasteform research has been expended in the development of a suitable glass. One of the main reasons for considering glass is that, having no crystalline molecular structure, it is less likely to be structurally altered by radiation than would crystalline materials (Kaplan and Mendel, 1982). Vitrification involves the incorporation of calcined radioactive waste into a glassy matrix. The glasses are obtained by mixing waste oxides with additives such as oxides of silicon, boron, calcium, sodium and phosphorus. Borosilicate glass is the most thoroughly studied. This has been adopted as the reference wasteform in the United States, Europe, Canada and Japan. Although the first block of vitrified waste was produced at Battelle Pacific Northwest Laboratory (BPNL) in 1979, in the United States the process is still in the experimental stage, whereas in Europe the process has been under development for 25 years. In 1978 the plant at Marcoule was the first to begin commercial operation, and with this the French established a clear lead in vitrification technology. There is a vitrification plant under construction at Tarapur in India (Thomas, et al.,1979), and Japan plans to have a pilot plant operating by 1987 (Suzuki, 1980).

Laboratory experiments with borosilicate glass have shown that leach rates are low, although the only long-term study of leach rates from glass with realistic flow conditions was conducted at Chalk River, Ontario in Canada (Nuclear Engineering International, 3/1979)[45]. The extremely low rate of leaching recorded was surprising. Most of the leached material did not even migrate through the soil, but remained in place close to the glass block. The small percentage that did migrate moved through the water table about 100 times slower than the flowing ground water.

The major concern with glass is for chemical stability. It is not known how the glass ages under radiation and heat stress. Devitrification in brine under actual repository conditions may also be a problem. Experiments have shown that small samples of borosilicate glass containing synthetic waste placed in distilled water or brine, devitrified in weeks (McCarthy, 1978). Such uncertainty in the technical sphere, again, does little to assuage public fears concerning disposal safety, and in any case, a problem may exist with public credibility in the capacity of a material with such a fragile image as glass to perform the required long-term job. In this regard ancient glass may offer some proof of long-term durability. Although the composition of ancient glass is different from the nuclear waste glasses, there is some evidence for more than 3,000 year durability (Kaplan and Mendel, 1982). The ancient glasses were not subjected to radiation and heat as the waste glasses would be, but it seems that variations in decomposition rates of the ancient glasses is related to chemical composition that varies according to geographical location and historical period. Thus, archaeology can point out compositions to be avoided in nuclear waste glasses.

(iii) Ceramics. The concept behind ceramic wasteform is the incorporation of radioactive waste elements in the atomic structure of synthetic crystalline minerals that are analogues of natural minerals known to have been stable under varying geologic conditions for long periods. Even if the ceramic breaks down, it is expected that the crystalline structure will retain the radioactive materials. Two examples of ceramic wasteform are (a) supercalcine and (b) synroc.

(a) Supercalcine: This has been developed in the United States. It is formed by mixing HLW with inert chemical additives such as oxides of silicon, calcium, aluminium and zirconium. The mixture is then calcined, heated and compressed. During this process, specific minerals with low solubility are formed. Under severe temperature and pressure conditions supercalcine shows very low leach rates in distilled water, but like borosilicate glass, when placed in brine, the ceramic releases large amounts of waste into solution (Kerr, 1979). A problem in the use of supercalcine is its susceptability to structural damage by radiation, and to chemical instability by transmutational daughter products (see Chapter I) which may have different chemical properties from the parent sources.

(b) Synroc: This is a synthetic rock comprising a mixture of titanium, aluminium, zirconium, calcium and barium oxides. At high temperatures (1200-1300°C) the mixture recrystallizes to form a solid consisting of three minerals: hollandite ($BaAl_2Ti_6O_{16}$), perovskite ($CaTiO_3$), and zirconolite ($CaZrTi_2O_7$). These minerals have been found to occur naturally in rock up to 2,000 million years old and have survived in environments far more severe than are likely to be encountered in a waste repository (Ringwood, 1982). The waste is mixed with the synroc mixture and the atoms of radionuclides bind themselves to specific synroc mineral atoms. In the synroc process wastes must be chemically separated into groups of elements (partitioned) in order to attain maximum geochemical stability. This is a major disadvantage as the partitioning requirement is likely to be expensive. The main advantage of synroc is that leach rates have been shown to be 2-3 orders of magnitude lower than for borosilicate glass. Another consideration is that the public is much more likely to accept a rock, compared to glass, as a suitable wasteform.

The original synroc research was done at the Australian National University in Canberra, and development is continuing both there, and at the Australian Atomic Energy Commission in Sydney, where a demonstration plant is soon to be built (1984). There are also several synroc projects in laboratories in the United States.

(iv) Composite wasteforms. Composite wasteforms that give double protection against leaching have also been investigated.

(a) Metal matrix: "Cermet" (combination of ceramic and metal) is a wasteform produced by embedding vitrified or crystalline pellets of waste in a molten metal matrix such as lead, lead alloy, or ferro-nickel alloy. Cermet has good thermal conductivity which would permit a high waste loading, and also has good impact and corrosion resistance. The production process has been demonstrated in Belgium (Geel and Eshrich, 1975). Cermet has been considered the prime candidate for a wasteform in the space disposal option (see below).

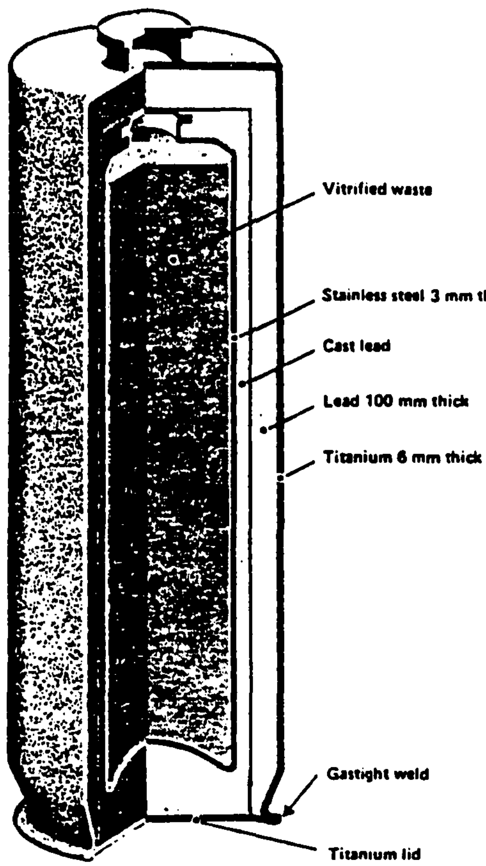
(b) Coated Particles: A core containing radionuclides is coated with single multiple layers of one or more inert chemical materials. The inner core can be a glassy or crystalline wasteform. The individual waste particles can be coated with ceramic, carbonaceous or metal materials. These coated particles can be further protected but embedding them in a metal matrix. The resultant wasteform provides improved leach and oxidation resistance and mechanical strength compared to the single-layer wasteforms.

2. The container

The container provides an engineered and second barrier to radionuclide movement in the waste disposal system. The USNRC anticipates that the container itself will be the principal means for meeting the 1,000-year isolation criterion (Dayal, et al., 1982). Corrosion resistance is the most important factor to be considered in selecting a container material. Because of their strength and ease of fabrication, metallic materials are emphasized more than ceramic or polymeric materials for HLW containers. Several metals have been tested, including carbon steels, stainless steels, and alloys of nickel, copper, zirconium, titanium, and cobalt.

Lead and titanium are the chief materials in the Swedish design, which has been largely adopted by other countries. The envisaged container is composed of three layers. Reprocessed and vitrifed waste will be placed in stainless steel (3mm.), a layer of lead (100mm.) will surround this, and finally a layer of titanium (6mm.) will encapsulate the whole container, which would be 1.5 meters long, 0.6 meters in diameter, and fully loaded would weigh 450kg. (Ahlstrom, et al., 1980) (Fig. 20).

Groundwater chemistry in various host-rock types will vary and will interact differently with the container metal. Water chemistry will also vary with the depth and geographical location of the repository. Some research has been conducted into host rock-container metal interactions. Tests were performed on candidate metals in Belgium for interactions with clay. Heated clay releases chlorides which are



The encapsulated waste. The waste cylinder is provided with a canister of titanium and lead. The canister is 1.8 metres long and has a diameter of 0.6 metres.

Figure 20 The container for high-level radioactive waste (Swedish design)
Source: Ahlstrom (1980)

thought to be an important factor in pitting corrosion. In the United States various metals have been tested for corrosion resistance in Salton Sea brines. All metals except titanium showed pitting corrosion, and thus, titanium was the only material recommended for meeting the 1,000-year containment criterion in a salt environment. Salt represents a much more aggressive environment than granite, basalt, or shale. Hence, from the standpoint of container corrosion, hard rock repositories are preferable. In Sweden corrosion of titanium has been tested in a granitic environment and also in Baltic Sea water, and the metal was found to be satisfactorily resistant.

Laboratory tests cannot simulate the time frame of 1,000 years stipulated by the USNRC for radionuclide isolation, and there are problems in extrapolation of short-term results to the long-term. One way in which future corrosion can be estimated is, again, through the examination of archaeological artifacts. From the point of view of public acceptability of corrosion rates these archaeological studies may be more convincing than detailed engineering studies. Some metals that have been exposed to atmospheric and subterranean environments for millenia have remained intact (Johnson and Francis, 1980). Gold and silver coins have been recovered from Spanish galleons that have been on the ocean floor for hundreds of years. Lead and copper, also, have survived in seawater for periods of longer than 1,000 years without destruction. Roman coins, buried in the moist soils of Europe for about 2,000 years have been preserved. Even iron nails, buried about 70 AD in Scotland in clean beaten earth under oxygen-free conditions, were recently recovered unrusted after 1870 years (Evans, 1971). These archaeological findings are encouraging signs that a high-integrity container can be designed for the geologic isolation of HLW. The USNRC seems to be confident that a suitable container can be produced.

> ... a 1,000 year container appears to be clearly achievable.
> (Dayal, et al., 1982).

Some research has been done on non-metallic container materials in order to avoid corrosion problems, but there is the danger that fracture could easily occur from rock overburdens or seismic activity. Lack of impact resistance may also be a problem during transportation.

3. Backfill

The purpose of the backfill is to surround the container and provide a third independent barrier to radionuclide migration. The temperature rise from heat of radiaoctive decay (see Chapter I) will occur across the backfill between the canister and the host rock medium. Therefore the thickness and thermal conductivity of the backfill material is important. The backfill will also aid in controlling inward groundwater flow, and modify groundwater chemsitry so as to reduce the likelihood of container corrosion. The backfill design incorporates a blend of two or more materials, each of which performs a particular function. Candidate materials are:

(i) Expandable clays. Chosen for low permeability, swelling properties, ability to seal fissures, and high ion-exchange capacity. Such clays will retard the movement of radioactive substances away from the container. Bentonite clay has been the principal choice.

(ii) Quartz sand (or crushed host rock). Chosen for thermal conductivity and mechanical strength.

The Swedish program is the only one to include a detailed backfill component so far (12/1983). The design is for a mixture of quartz sand (80-90 percent) and bentonite to surround the container in a single layer (Fig. 21). Other countries will probably follow this design.

4. The repository host rock

In the envisaged disposal system, the waste package, (i.e. wasteform, container and backfill), will be placed in a mined cavity in an area of suitable host rock. The rock will act as a geological and fourth independent barrier to provide long-term isolation. Wastes from a repository could be exposed to the biosphere in three principal ways:

(a) by some geologic process such as tectonism, diapirism, or erosion that directly exposes the waste. Seismicity, glaciation and climate change may alter the initial repository conditions,

(b) by groundwater transporting the radionuclides,

(c) by human intrusion.

The objective of the geologic isolation concept for radioactive waste is to preclude radioactive materials from reaching the biosphere by any of these three routes until they have decayed to a point at which their concentrations no longer constitute a hazard.

The geological repository itself will be similar to a conventional

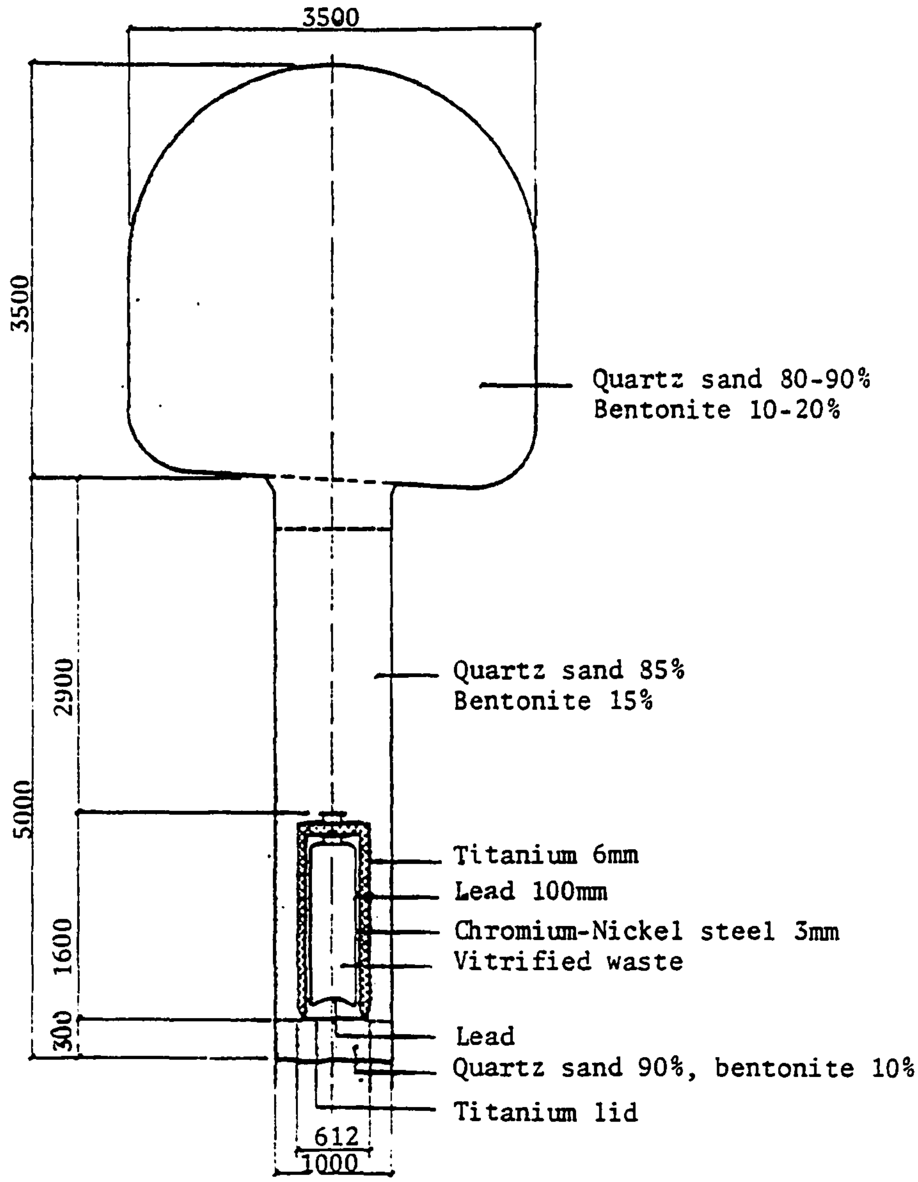


Figure 21 The Backfill (Swedish design)

Source: Ahlstrom (1980)

mine. Under current (1983) design this would be about 600-900 meters below the surface and access would be via shafts from surface structures. Corridors and rooms would be excavated for waste emplacement operations. Each repository will allow for the handling and emplacement of a few hundred canisters of wastes and for continuous monitoring and retrieval of waste containers for a specified period. The size of the repositories being considered, covering several square kilometers, would involve considerable perturbation of the geologic medium, and one difficulty with designing such facilities lies in over-simplification based on small experimental repositories. The temperature and pressure conditions that could be encountered by waste emplaced in a geologic repository at a depth of 600 meters will be severe, and it is generally assumed by geologists that no rock medium will be completely impermeable over geologic periods of time. The presence of water at some time in the life of the repository is a vital factor to be overcome.

Suitability criteria. While each prospective repository location must be carefully studied and evaluated to identify the unique geologic features of the specific site, there are some general requirements for the host rock which are applicable to any region or site, and which, if met, will provide a geological barrier to radionuclide migration.

The host rock will be mechanically, thermally, and chemically disturbed for substantial periods of time by excavation of the repository, and by the waste itself. Even if the wasteform has a very low leach rate, some radionuclides will eventually be released. The rate of leaching may change significantly with time as the waste undergoes radioactive decay, interacts with the enclosing rock, or comes into contact with groundwater. Characteristics of the host rock that could retard the transport of radionuclides to the biosphere include the following:

(a) Location - in the sub-surface 300-1,000 meters below.

(b) Homogeneity - a high degree in both vertical and lateral dimensions.

(c) Lateral continuity - over an area of several square kilometers in order to accomodate both the actual repository and a buffer zone.

(d) Resource potential - for discovery of commercially valuable mineral resources in the host rock must be low, since this may result in future use conflict and extraction would endanger the integrity of the repository. Because several of the candidate rock-types are sedimentary, and found primarily within geological basins that also contain petroleum, gas, potash and other mineral resources, another consideration is the density of exploration bore holes that may have been drilled previously.

(e) Physical-chemical properties - these control the response of the rock itself and of its contained fluids to the repository, to the wasteform and to the container; the effect of pore-water movement on radionuclide migration; and mineralogic changes which might alter rock-mechanical properties or pore-water chemistry. The host rock should have low permeability, low porosity, and high sorptive capacity.

The uncertainties of how radioactive wastes will interact chemically with rock and fluid systems seem to be large (Bredehoeft, 1978).

(f) Faulting - no faulting or large-scale fractures, no steep inclinations, dips or other structural distortions such as intrusive igneous rocks, solution caverns and related solution-collapse features should be present.

Planning a waste repository requires a full understanding of the sub-surface geology of an area. Many critical features in the geological medium are subtle. Small faults can be extremely difficult to detect and date. The fracture system, which could act as a conduit system for groundwater, might be revealed from regional structural features clearly evident only at the scale of a Landsat image (Bredehoeft, 1978). Techniques for remotely sensing a volume of rock are in preliminary stages of development. For example, high-resolution seismic and accoustic techniques, which can detect fine-scale structural and lithographic variations, electromagnetic methods, which are sensitive to the distribution of water, and short-pulse radar. These techniques can provide a non-destructive way of characterizing the site in detail.

(g) Groundwater - should not be circulating within the chosen rock formation proper, and the repository should be effectively isolated from aquifers above and below. There should be a low hydraulic gradient, and a long flow path to the biosphere.

Techniques for determining past rates of groundwater flow in rock of potential repository areas include tracing and dating with radioactive elements such as carbon-14, uranium-1234, and thorium-230. A major engineering task in any repository will be to prevent water from entering the workings through fractures caused by the mining process. The groundwater system, as mentioned above, has the potential to provide the most plausible vehicle for transport of radionuclides to the surface. Modelling groundwater systems for any specific area is a highly complex task, but it has been argued that the groundwater flow system, under favorable conditions, could work as an active barrier to assure long, slow migration paths (Bredehoeft, 1982). This approach bases disposal on the long-term stability of the flow pattern. It is difficult to predict flow on a local scale in granite, for instance, because of the complex fracture system associated with this rock type, but on a large scale, flow within buried crystalline rocks is controlled by that in overlying sediments. The inland areas of many continents are covered by a blanket of sedimentary rocks that often contain salt, shale and other geologic deposits that could further isolate flow from the deeper crystalline rocks. This also has the advantage that in many of these areas the groundwater is non-potable (salty), and therefore is not a potentially attractive resource.

(h) Seismicity - the host rock should be located in a non-seismic zone because of the possibility for earthquake-induced damage, both to the burial cavity and to surface facilities and access shafts. A long history of tectonic stability is a pre-requisite but the future stability of any site cannot be guaranteed.

Geology is basically a retrospective rather than a predictive science (Kitts, 1976). To try to predict future tectonic and seismic activity in a specific area even one thousand years from the present is a formidable task. Past geologic events such as faulting, seismicity, and climatic change, probably have not been random (Bredehoeft, 1981). Some geologists have even suggested that information from studies of long-term events in the solar-climate-geodynamic cycle can be useful to the question of the isolation of radioactive waste.

> The relative safety of radioactive waste storage will always be an actuarial estimation. A totally stable region of the earth's surface is a geological impossibility. Because of plate tectonics both continental and oceanic crusts are in constant motion. The planet earth must be recognized as a member of the dynamic complexity of the universe, all parts of which are in orbital motion and develop interacting gravitational fields... cyclic events of both internal and external origin may be predicted for the earth's crust.
>
> (Fairbridge, 1979).

Such a grand-scale planetary model inspires an awesome respect for the science of geology, but going to the opposite extreme, the smallest fault in a repository could result in an intrusion of groundwater.

The first serious discussion of geologic waste disposal was in 1955 and was organized by the National Academy of Sciences (NAS) at Princeton, New Jersey, to consider the physical, chemical and geologic aspects of waste containment. During the 1950s and 1960s investigations examined the feasibility of disposal of HLW in deep geologic basins and in salt mines. Three nations, Sweden, the Federal Republic of Germany, and the United States, are relatively advanced in their studies on the geologic aspects of the waste disposal system. Of these three, only the United States has pursued research simultaneously on several possible host rock types. Sweden has already selected granite, and Germany has chosen rock salt. In each of these cases the medium chosen was the only one considered.

So far the question of radioactive waste disposal has remained a matter for national governments, because of the political difficulties involved in establishing an international repository, and each country has been primarily concerned with investigating rock types within its own territorial boundaries. In many countries one single rock candidate has assumed the dominant role due to its wide occurrence. Rock types which have been studied for possible repository siting include bedded and domal salt, granite, shale, basalt, and volcanic tuff. A brief description of the research conducted on each is presented below.

(i) Salt formations. Embedded or domal salt formations have been studied more extensively than any other rock type. The existence of dry salt deposits that are known to be hundreds of millions of years old testifies to their isolation from water and their stability. Salt is a highly plastic medium that displays viscous flow (creep) under earth pressures. This tends to seal fissures, but the property is also a disadvantage in that it is difficult to stabilize tunnel openings in a salt formation.

Investigations of rock salt for waste disposal date back to the late 1950s in the United States where thick, geographically widespread deposits of bedded salt occur at suitable depths (300-1,000m). Project Salt Vault, which involved the evaluation of an abandoned salt mine at Lyons, Kansas, in the mid-1960s, failed because of petroleum exploration drill holes found at the site, although salt was seen as a favorable choice and was the focus of research for another decade. The current attention to salt in the United States is chiefly as a medium for defense wastes, and centers on the Waste Isolation Pilot Plant (WIPP) project (see Chapter I).

Two of the most serious problems with salt formations as a disposal medium are water content and resource potential. The apparent dryness of salt seemed at first to be a major advantage, but further investigation revealed that the crystals contain significant amounts of water. The heat from the waste container would tend to draw this water toward it, creating a corrosion problem. Secondly, salt is not only a resource itself, but salt deposits are often interbedded with petroleum-bearing sedimentary layers which could result in conflict over resource use.

Despite these difficulties, in West Germany, the abandoned Asse salt mine in Lower Saxony has been used as a test repository and this area of salt domes in Gorbelen has been chosen as a final repository for Germany's wastes (Kuhn, et al., 1979). Poland also expects to use salt formations in the Baltic Seashore region when its first nuclear power plant begins operation in 1984 (Kunstman, et al., 1979). France, Canada, and the United Kingdom are considering the use of salt only as a back-up solution. Japan has no suitable salt deposits.

(ii) Granite. Granites are generally homogeneous and are composed of a dense matrix of hard, durable minerals such as silica and mica, which are almost chemically inactive under ambient temperatures and pressure conditions. The United States, Canada, France, Sweden, the United Kingdom, and Japan have conducted research on granitic rock. Canada has selected areas of the Canadian shield in Ontario for a final repository (Hatcher, 1979). Sweden has no salt deposits and has focussed on granite. Access to a granitic rock mass in the Stripa iron mine in Sweden provided a unique opportunity for underground experiments related to the geologic disposal of radioactive waste. Joint investigations were begun in 1978 by Sweden, the United states, Japan and Finland. Canada and France were associate members on the project, which was to cost $10 million and is due to end in 1984. The tests include full-scale heating experiments that simulate thermal conditions expected to arise from nuclear wastes in a repository. In the United States, testing of granitic bedrock has been conducted at the Nevada test site and also at an experimental mine in Idaho Springs, Colorado. In the United Kingdom test drilling has been conducted in an area of Caledonian granite in the north of Scotland (Feates, 1979). India is concentrating on granite and gneiss formations in the Bundelkind area of northern India, and in the southern state of Andhra Pradesh (Thomas, et al., 1979). Japan has been conducting experiments in granite formations at Shimokawa, in northern Hokkaido.

(iii) Shale. Shale is the product of the lithification of mud, predominantly composed of clay or silt-sized particles, and often occurs in thick impermeable and homogenous beds. Shale has a thermal conductivity as high as salt. Italy, Belgium, and Japan have been active in investigating clay sediments for a waste disposal medium. In the United States relatively thick marine shales occur in the mid-continent region. The concern with shale is for mechanical stability when deep excavations are made in clay-rich rocks, especially in the young (Tertiary), highly plastic clays that are being studied in Japan and Europe.

(iv) Basalt. Basalt is a very dense and strong extrusive rock with high magnesium and silica content. Because of difficulties involved in the public acceptance of disposal sites, many countries have begun to investigate the geological formations that lie beneath their national nuclear laboratories. Although these have other appropriate geological characteristics, certain areas of basalt and volcanic tuff in the United States are mostly political choices. There are large basaltic flows of the Columbia River plateau in the vicinity of the Hanford reservation in the state of Washington. This area is already federally controlled and excluded from future productive use because of contamination from existing nuclear facilities. Investigations of the Hanford basalt was begun in 1977.

(v) Volcanic tuff. There are two kinds of tuff: welded tuff, which is a volcanic ash flow fused at the time of formation; and zeolitic tuff, which is generally formed by the alteration of silicic volcanic glass and other minerals rich in silicon and aluminum. Both kinds are comparable to basalt in terms of rock strength and thermal conductivity. Because of their high sorptive capacity, natural zeolites have been used to filter out radionuclides from contaminated effluents at nuclear facilites.

The Sedan Crater at Yucca Flat, Nevada, has been proposed as a site for disposal of HLW (Winograd, 1981). This crater was formed by a weapons test in 1962 and is 98 meters deep and 370 meters in diameter and is now the site of a major military installation. The volume of the crater may be several times that of the projected volume of United States' radioactive waste to the year 2,000, and disposal there could be accomplished with substantial financial savings compared with schemes for mined repositories (Ibid.). Waste would be mixed with zeolitic tuff and buried at a shallow depth (15-100m) above the water table, which at Sedan Crater occurs at a depth of 580 meters. The crater scheme relies both on the host rock characteristics and on the hydrologic system to isolate radioactive materials. Maintaining control over the repository would be facilitated by the presence of military installations at the site.

Summary of deep geological, land-based disposal

The major problems with the wasteform components lie in uncertainties related to long-term chemical stability. The integrity of the container is primarily related to the susceptibility of metals to corrosion. The most serious deficiencies in technical knowledge appear to be in the geological aspects of waste containment. In the technical sense, none of the geologic formations described above has all the advantages. Salt rocks have good thermal and permeability properties, but often contain potentially valuable minerals, and it is difficult to make long-term estimates as to their possible future use. Crystalline rocks are easily mined and are not of great economic interest, but fissures create groundwater problems. Clay rocks have important ion-excange properties, but they make mining operations difficult, and often occur in an unfavorable hydrological context.

After a few hundred years have passed, and repository markers have disappeared the risk of accidental intrusion by humans may be greater than the risk of transport of radionuclides from a mined repository to the biosphere by groundwater. The choice is then between geological formations where the risk of human intrusion is lower, but containment is less satisfactory, and formations that could ensure highly satisfactory containment of radionuclides in the technical sense, but may involve a greater risk of human intrusion in the future. Alternative waste disposal methods may offer a lesser risk of human intrusion.

Alternatives to Land-based Geological Disposal

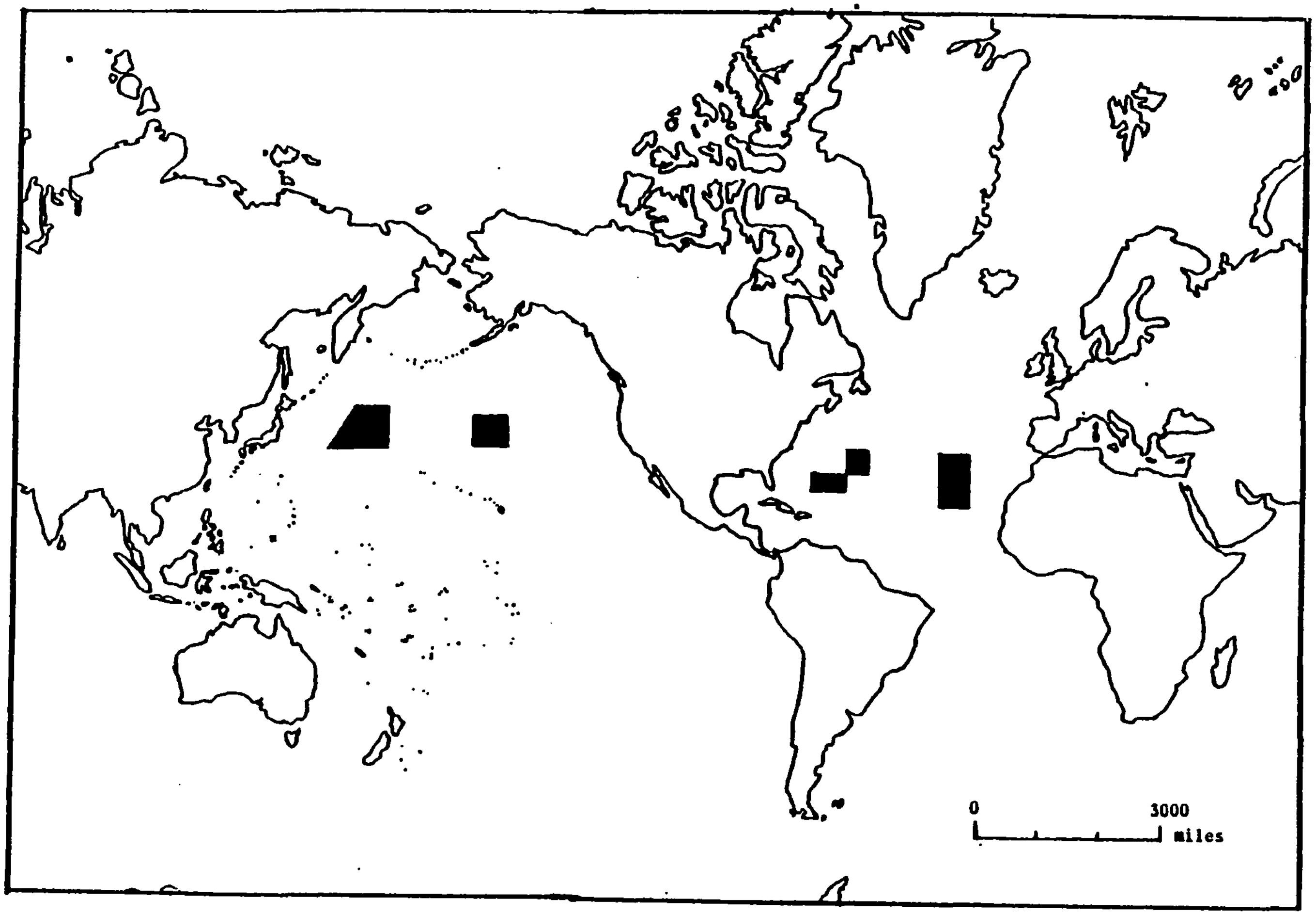
International options have been proposed that would avoid some of the political problems of siting a repository on land (see Chapter V), even though these options involve a greater degree of technical uncertainty than the deep land-based geologic disposal concept. Countries, such as Japan, that have few land areas with suitable geology for HLW disposal are interested in international disposal. The most feasible plan is the seabed clays option.

1. The subseabed option

This method has been under investigation since the mid-1970s. The primary candidate site is an area of abyssal clays in the midplate-midgyre (MPG) area of the ocean floor, in the center of sub-oceanic tectonic plates, at ocean depths of 2-3 miles, is an area of gentle topography covered by 150-300 feet of red clay sediment. Disposal in these clays would involve emplacing canisters of HLW by means of a penetrometer which would free-fall to the ocean floor from a ship and bore a hole in the sediments sinking the canister with it to a depth of between 30-100 meters below the sea floor (Hinga, et al., 1982). Alternatively, a canister could be lowered into a hole bored by a drilling rig. Areas of seabed presently under investigation are in the north Atlantic and north Pacific (Map 1).

From the geological perspective, the clay sediments have many advantages as a disposal medium. They are composed of particles that have been settling to the ocean bottom and accumulating evenly for some 70 million years (Kerr, 1979), and have important ionic retention properties for retarding the migration of radionuclides. Another advantage is that the MPG areas are geologically stable and their future is fairly predictable. They are away from plate boundaries and are less susceptible to catastrophic geologic events than any other parts of the globe (Hinga, 1982). The sediments appear to be composed of homogeneous material over wide areas. The plasticity of the clays seems to ensure that holes would seal after canister emplacement. An important non-technical advantage of the seabed option is that the sites are unlikely to be breached by humans, either intentionally or accidentally. The seabed may the the least economically valuable portion of earth's crust, apart from a few areas in the Pacific and Indian Oceans where thick deposits of manganese nodules rich in copper and nickel exist.

There are still serious technical uncertainties concerning the seabed option. Despite assurances by marine scientists to the contrary[46], the retrievability capability of this option is still in question. Retrievability can be regarded as both an advantage, from the



Map 1. Regions in the northern oceans under consideration for subseabed disposal of high-level nuclear waste.
Source: K.R. Hinga, G.R. Heath, D.R. Anderson, and C.D. Hollister (1982).

point of view of terrorist attack and non-proliferation, and a disadvantage from the point of view of future potential use of the waste, and in halting leakage. Secondly, the response of the clay sediments to heat and radiation is unclear, although experiments are underway to investigate this. The point of the subseabed option is that no leaking should take place, but should the waste actually reach the sediment surface through heating effects on the clay, radioactive materials might enter the aquatic food chain. Ion retention for elements such a plutonium may no longer be significant. Even in the calmer seabed sites, currents have been measured that could carry radioactive materials across the oceans within periods of several hundred to 1,000 years (Kerr, 1979). Recent research has shown that biota on or near the deep sea floor is not only plentiful, but may be part of the overlapping food chain that reaches all the way to the surface.

At present the subseabed option is regarded by most countries only as a long-term alternative to land-based disposal. For the United States the Atlantic possibly offers a more economic prospect than the Pacific Ocean site, since the former is close to the major east coast nuclear power plants. Considerable expense would be involved in transporting waste from east coast reactors to a disposal site in the Pacific Ocean. On the other hand, Japan would be fairly close to the Pacific site presently being investigated .

2. Deep Ocean Trenches

Another marine option that has been suggested is use of deep ocean trenches. This concept involves the depositing of waste canisters in the trenches so that these would evenutally be drawn into the earth's crust during the subduction process. The idea was soon abandoned by the scientific community when calculations revealed that the subduction process is too slow for the purpose, and that waste would be exposed to bottom currents during the dangerous thermal period (Lippschutz, 1980). Many cite the trench disposal method when ocean disposal of radioactive waste is mentioned, although few have ever heard of the more feasible MPG concept. This is an indication of how important the diffusion of specific pieces of information can be in the formation of public attitudes.

3. Extra-terrestrial disposal

Extra-terrestrial disposal of radioactive wastes has also been proposed. Although the technical uncertainties of rocketing waste into the sun, or even into solar orbit, seem high, the notion of permanently eliminating radioactive wastes from the earth is an attractive one. There is a possibility that some of the longer-lived isotopes in the waste could be separated out and delivered into an orbit by the space shuttle. Given the outstanding questions involving the development of an infallible ejection system and waste container, and the prohibitive financial cost, it seems doubtful whether this option will be seriously considered in the foreseeable future.

4. Ice-cap disposal

Disposal of wastes in the ice-caps of Greenland or Antarctica has also been proposed. This concept relies on the heat of radioactive decay from the container to melt its way gradually through the ice to the bedrock beneath. It is not known how permanent the ice-sheets are and whether the isolation period would be sufficient for the transuranics contained in the waste (Kubo and Rose, 1973). Transportation and working conditions in arctic regions would present problems and in addition, political difficulties exist. The Antarctic is kept free of nuclear materials by the international treaty of 1959, and Greenland is soon to become an independent nation.

Spent Fuel Disposal

There is a possibility that today's wastes may become tomorrow's resources, and this is particularly true of spent nuclear fuel. The disposal methods mentioned above all concern wastes from the reprocessing stage of the nuclear fuel cycle. At present few countries have reprocessing facilities (see chapter I). Therefore, the immediate problem for many countries with nuclear power plants is that of handling, storing, and perhaps ultimately disposing of spent fuel assemblies.

The present (1983) practice is for spent fuel to be stored for an indefinite period in on-site cooling pools, but many reactors are running out of space temporarily to store their entire inventory of fuel in the event of an emergency or extensive repairs requiring core removal. Away-from-reactor (AFR) storage sites have been selected as a stop-gap solution but there is a danger that these could become permanent "temporary repositories", relieving reactor operaters of the responsibility for spent fuel, but not solving the waste disposal problem. A new design for on-site dry vault storage of spent fuel that uses natural air convection for cooling has been proposed in the United Kingdom (Nuclear Engineering International, 8/81). Some research has gone into containers for unreprocessed spent fuel. The Swedish design is specifically for a granite repository, and consists of a pure copper container with spaces between fuel rods and the canister being filled with lead (Ahlstrom, 1980). Temporary storage of spent fuel has a different set of problems from those of the permannt disposal of reprocessed wastes, but after the announcement of the findings of the International Nuclear Fuel Cycle Evaluation (INFCE) in 1980, more countries may proceed with the building of reprocessing facilities. Thus, future disposal research will probably continue to focus on wastes from reprocessing operations.

Conclusion

No matter how reliable the technical aspects of disposal methods, political exigencies may dictate that no country will accept waste from another. The crux of the problem is that few or no benefits are perceived in being near a radioactive waste disposal facility. As one delegate to the 1979 International Atomic Energy Authority symposium on the geologic disposal of waste said,

> No matter how small the risk, if the public perceives that the benefit of the waste disposal is zero, then we don't have a very favorable risk/benefit ratio.
>
> (Hatcher, 1979).

NOTES

41. Cited by Fred C. Shapiro in Radwaste (1981).

42. The thermal period is the approximately 600 years after discharge from the reactor, when the thermal power from spent fuel or reprocessing waste is dominated by fission products, particularly strontium-90 and cesium-137 (see Chapter I, Fig. 18).

43. These are termed collectively "loading".

44. In the fluidized bed process the waste is suspended in a rapidly moving stream of gas to enhance condensation.

45. In August 1958 25 glass blocks were buried in wet, sandy soil at the Chalk River Nuclear Laboratory. The purpose was to determine the rate at which radioactive material might leach out of the glass and be carried through the wet, sandy soil by water.

46. Charles Hollister of the Woods Hole Oceanographic Institute, has stated that with present technology a hole 3 inches in diameter can be found anywhere on the ocean floor (Conference on Nuclear Energy in the Asia-Pacific, East-West Center, Resource-Systems Institute, Honolulu, January 23-28, 1983).

CHAPTER IV. THE PUBLIC VIEW OF THE RISKS

> As I compare the issues we perceived during the infancy of nuclear energy with those that emerged during its maturity, the public perception and acceptance of nuclear energy appears to be the question that we missed rather badly.
> (Alvin Weinberg, 1976)

While most research on the disposal of nuclear waste has concentrated on technical aspects, until recently little emphasis has been placed on the political and social issues involved. Political pressure on power companies and governments to find a solution to waste disposal was not strong enough in the past. Poor waste management strategies have made the public extremely wary of disposal schemes, and public opposition arises as soon as any hint of investigation of potential sites is heard.

How does the public view the risks associated with the disposal of nuclear waste? This chapter discusses the popular perception of the hazard. As was mentioned in Chapter II, both direct and indirect methods of gaining insights into public perception of the risks have been employed in this study: a questionnare survey, and newspaper accounts of events related to radiation hazards. The results of these surveys are presented below.

The Questionnaire Results

The sample populations surveyed in this study comprised university students, and the usefulness of the results for extrapolation to the "general public" in Japan and Australia is limited. The samples do, however, provide a comparison with the American student population surveyed by Slovic (see Chapter II).

Sample populations

The Japanese survey sample was a group of 103 students between the ages of 19 and 23, majoring in geography or economics at universities in three different parts of Japan, (Keio University in Tokyo, Bunkyo University in Saitama Prefecture, and Setsunan University in Osaka)[47]. A separate group of ten students from the nuclear engineering department of the University of Tokyo, a sample of the next generation of Japan's nuclear experts, also completed the same questionnaire. The Australian survey sample comprised 42 students majoring in environmental studies at Griffith University and in geography at the University of Queensland in Brisbane[48]. These students were mostly in the age range 19 to 28 years[49].

Part I: Risks

Part I of the questionnaire (see Appendix A) asked people to compare the risks of 17 items. Omitting the Japanese nuclear engineering students, the two sample groups shared similar perceptions of the risks associated with the hazards listed in the questionnaire. The nuclear engineering students tended to rate all risks lower than the social science students. A comparison of the risk ratings by the three groups is shown in Figure 22.

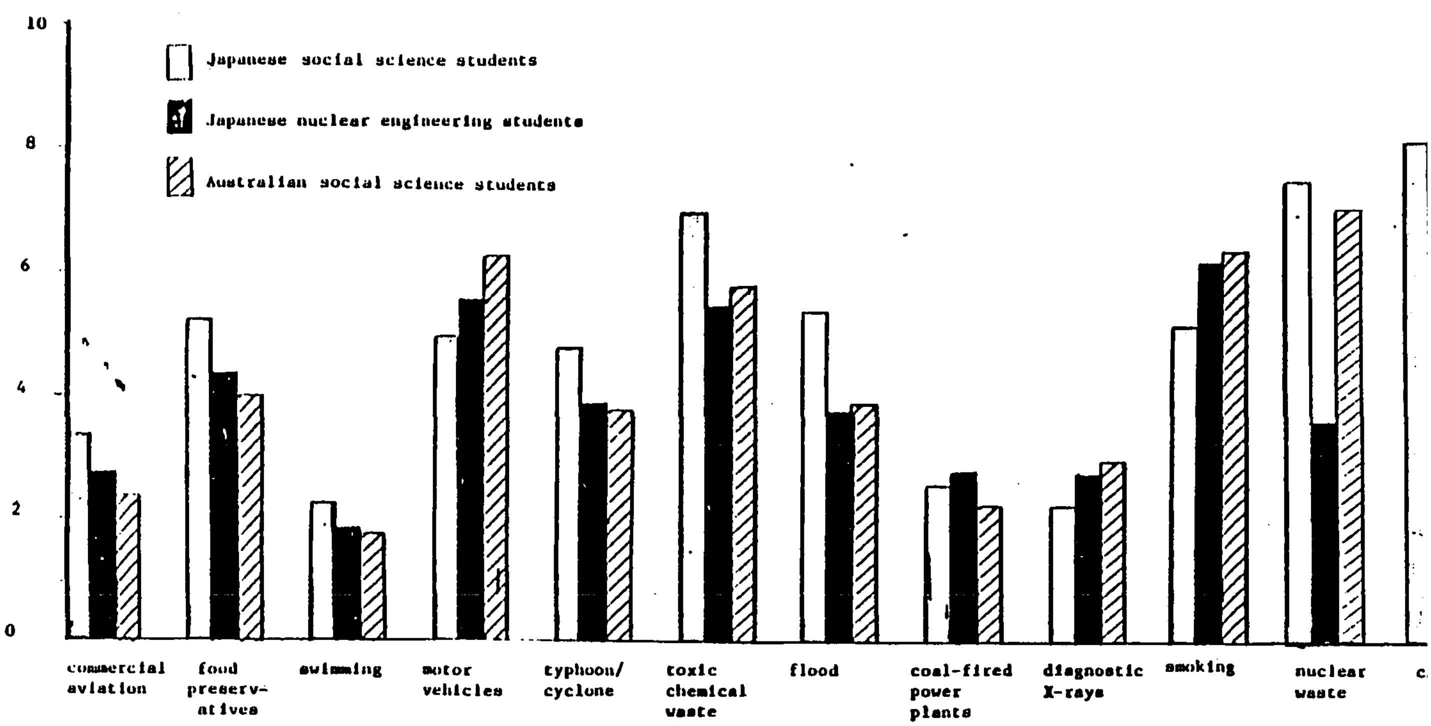
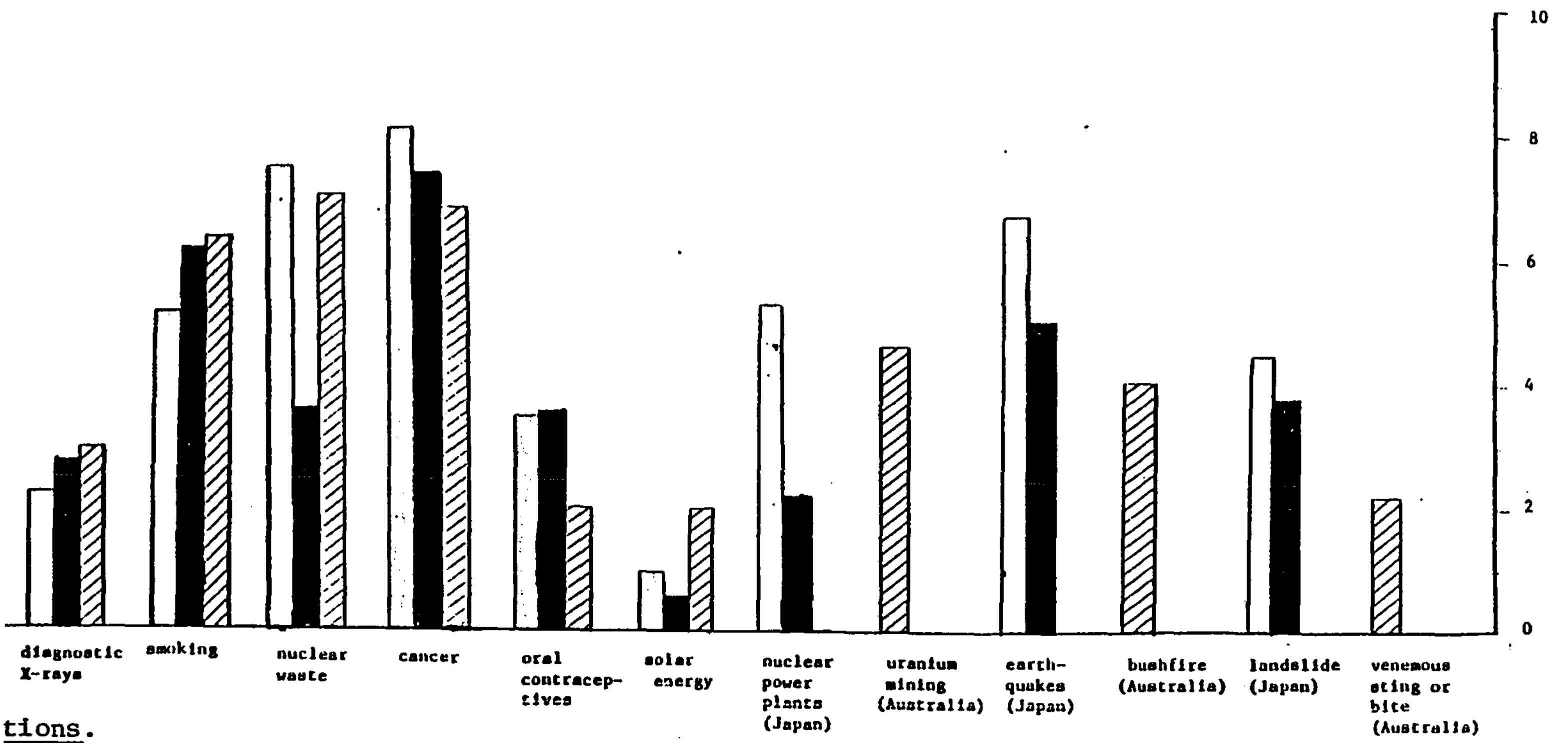


Figure 22 Comparison of risk ratings by three sample populations.

Figure 22. Comparison of risk ratings by sample populations.


10
8
6
4
2
0
diagnostic X-rays
smoking
nuclear waste
cancer
oral contraceptives
solar energy
nuclear power plants (Japan)
uranium mining (Australia)
earthquakes (Japan)
bushfire (Australia)
landslide (Japan)
venemous sting or bite (Australia)

tions.

The hypothesis that familiarity with risk leads to a decrease in anxiety seems to be supported by the survey. Natural hazards that are fairly familiar, such as typhoon (cyclone in Australia), flood, and bushfire, were rated at medium risk. The earthquake risk was rated higher by the Japanese than were the other natural hazards. This may be related to the character of the earthquake risk. There is a seasonal predictability related to the landslide and typhoon hazards, but no one knows when, and often where, an earthquake is going to strike. Similarly, technological hazards and activities which are familiar were rated as comparatively low by all three groups. This includes commercial aviation, diagnostic X-rays, oral contraceptives, coal-fired power plants, and swimming. The risks of solar energy, although a nascent technology, were also rated low by all groups. This is a reflection of the image of solar power as being a clean, safe source of energy.

Both groups recognized the high risk potential of smoking and motor vehicles, although these are familiar sources of risk. This may indicate that the student samples are a fairly well-informed population. The higher score of motor vehicles in the Australian sample over the Japanese probably reflects the greater use of the private motor car in Australia. A much greater percentage of the Japanese population travels by public transport on a regular basis. Cancer was ranked highest by all students, with nuclear waste coming second by the social science students. The greatest difference in the perception of risk between social science students and nuclear engineering students was shown with the nuclear waste case.

Some of the listed items were examples of risks that are still in the stage of hazard identification, i.e., the risks are still being estimated by the scientific community. Nuclear waste and toxic chemical waste fall into this category and were rated high on the risk scale. These hazards score low on public information and high on media exposure. The Japanese view of the risks of toxic chemical waste, perhaps reflects the legacy of pollution-related diseases from industrial and agricultural chemical waste in Japan in the 1970s[50]. The Australian students also rated the toxic chemical waste hazard highly, perhaps reflecting recent, highly-publicized problems with chemical waste disposal both overseas (e.g. Love Canal) and in Brisbane[51].

The radiation-related hazards in the list were uranium mining (Australia), nuclear power plants (Japan), diagnostic X-rays, and nuclear waste (common to both groups). The Australian group ranked the risks of uranium mining as fairly high compared with natural hazards, and other more familiar technological hazards, even though Brisbane is at least 1,000 miles from the nearest uranium mine (see Chapter V). The Japanese group, surprisingly, ranked the risks of nuclear power plants as lower than toxic chemicals, and about the same as food preservatives, flood and smoking. One could postulate that the Japanese are becoming more familiar with, and therefore less anxious about, nuclear power plants. Perhaps more importantly, this result reflects a recognition of Japan's need to develop energy sources as alternatives to imported oil.

Part II: Risk characteristics

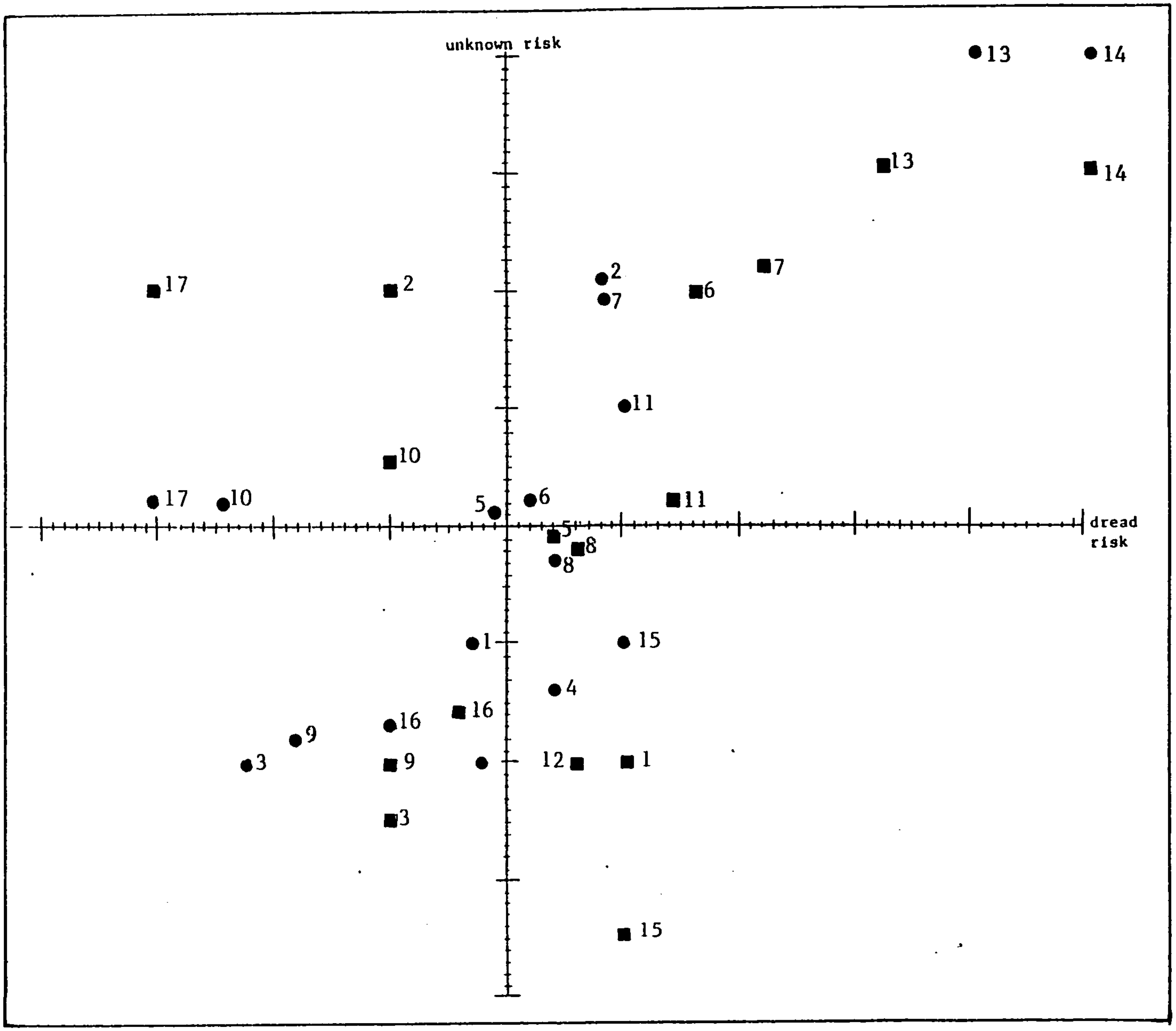
Part II of the questionnaire asked people to evaluate the same risk items according to nine different characteristics in order to test the hypothesis that certain characteristics of risk cause more alarm than others. The results of the rankings by the social science students of the common-dread characteristic, and the known to science-unknown to science factor are presented in Figure 23. There were no major differences between the Japanese and Australian groups. Both groups feared cancer and nuclear waste most. The latter correlates with the position of radioactive waste in the American sample surveyed by Slovic (see Chapter II, Fig.18). Bushfire and earthquake were the natural hazards most feared. Although nuclear power is in the unknown-dreaded quadrant, it is fairly low on both factors. In the American survey "nuclear accidents" scored high on the dread scale.

Part III: Benefits

Part III of the survey asked people to compare benefits of eleven of the risk items. Perceived benefits of some items, such as commercial aviation, appear to balance the perceived risks.

Part IV: Open-ended questions on nuclear power and nuclear waste

Part IV of the questionnaire, a set of open-ended questions relating to nuclear power and nuclear waste disposal, was designed to clarify the risk-benefit rankings that people gave in parts I and III. In general, the answers to Part IV were consistent with the rankings. For example, the answers to Q.IV(1) and IV(2) substantiate the differing views in



KEY

1. Commercial aviation
2. Food preservatives
3. Swimming
4. Motor vehicles
5. Typhoon/cyclone
6. Uranium mining/nuclear power plants
7. Toxic chemical waste
8. Flood
9. Coal-fired power plants
10. Diagnostic x-rays
11. Bushfire/earthquake
12. Smoking
13. Nuclear waste
14. Cancer
15. Landslide/venomous sting or bite
16. Oral contraceptives
17. Solar energy

■ Australia

● Japan

Figure 23. Characteristics of risks: known-unknown to science; common dread. Australian and Japanese respondents.

Japan and Australia on the risks and benefits of nuclear power.

> Q.IV(1). Taking into account all you have heard, or read, how do you feel about nuclear-electric power in general?

In answer to this question, the words most people used denoted a practical understanding of the energy resources in the two countries rather than an emotional or fearful response. In Japan the word most frequently used was "necessary". In striking contrast to this, the word most frequently used by the Australians was "unnecessary"[52]. The difference in the importance of nuclear power as an energy source for the two countries is illustrated again by the results of Q.IV(2).

> Q.IV(2) In order to meet the future power needs of the nation, how important do you feel it is to have nuclear power plants?

Answer choice	Japanese social science students	Australian social science students
extremely important	62%	0%
somewhat important	32%	19%
not very important	3%	24%
not important at all	-	57%

This illustrates the fact that cultural differences in perception of risk may be less relevant than basic geographical conditions or resource use patterns within a country.

The high ranking of nuclear waste by social science students in both countries is re-emphasized by the answers to Q.IV(3).

> What is your biggest worry about nuclear power?

Nuclear waste disposal was the most frequent answer given by the the Australians (90%) and the Japanese (65%), with power plant accidents coming second in Japan (41%), and weapons proliferation coming second in Australia (36%).

A majority in both social science samples (62% in Japan, 86% in Australia) said that they had no confidence in either the government or the nuclear power companies to solve the problem of nuclear waste disposal in an acceptably safe manner (Q.IV(5)). The nuclear engineering students showed more confidence in the electric utilities than did the social science students. The Japanese students overall showed significantly more confidence in the government's ability to solve the problem than the Australians, perhaps reflecting Japan's traditional pattern of respect for a central authority. A majority of social science students in both samples thought that safe nuclear waste disposal was "impossible to achieve" Q.IV(7).

Do you think that safe nuclear waste disposal is:

(a) No problem, and that disposal is now being dealt with satisfactorily,
(b) Technically demonstrated but so far not financially supported,
(c) Theoretically proven feasible, but so far not technically demonstrated,
(d) Not theoretically solved, but a solution is close,
(e) Impossible to achieve.

The popularity of choice (e) reflects the image of nuclear waste as an intractable, high-risk problem. The result also illustrates a gap between the public view and that of experts. A group of 28 experts in the nuclear field from different countries of the Asia-Pacific region[53] answered the same question Q.IV(7) by choosing (b) or (c). Similarly, in choice of disposal method, Q.IV(8), a gap between public and expert views is is evident[54].

answer choice	Australian students*	Japanese students*	Nuclear experts
(a) deep geologic land burial	35%	13%	72%
(b) seabed clays	0	19	25
(c) ice-cap	5	3	1
(d) ocean trenches	5	2	0
(e) outer space	27	37	0
(f) "nowhere"	23	21	0

*social science

The popularity of choice (e) by the social science students, reflects the public ignorance of the technological risks of space disposal, and also the popularity of the image of ridding earth of nuclear waste entirely. Choice (f) was, in fact, "other", but many people put "nowhere" as an answer here. This response is an indication of the public desire to avoid the disposal question altogether, (the "NIMB" syndrome). Many social science students added to choice (f) the opinion that nuclear waste should not be produced, a common reaction that fails to consider the fact, that even if all nuclear power plants were shut down tomorrow, there would still remain the problem of disposal of the present inventory of waste.

Public Opinion Polls

Published results of public opinion polls conducted by survey organizations and national newspapers generally support the findings of the questionnaire survey discussed above. By the late 1970s the nuclear waste issue had captured widespread public attention, and now the problems of the disposal of nuclear waste are often cited by respondents as the major objection to the further growth of nuclear power.

Melber (1977) reported that by 1975-76, Harris surveys in the United States had found that nuclear waste was considered a serious enough issue to be volunteered by respondents in open-ended questions. Similar results are reported by Japan's leading daily newspapers, the Asahi Shimbun and the Mainichi Shimbun, and by the McNair Anderson national public opinion survey organization in Australia.

The Newspaper Survey

News material provides part of the historical background to the current impasse in nuclear waste disposal in the Pacific region. By tracing the history of the "nuclear Pacific" and changes, revealed by the reporting, in attitudes towards radiation risks, some idea of public opinion on the radioactive waste disposal issue may be deduced.

Hazards compete with one another for attention in the media. Those which can command the attention and support of various interest groups appear in society's agenda and engage society's "worry beads."

> Individuals and societies have a small, relatively fixed stock of worry beads to dispense on the myriad threats of the world.
>
> (Kates, 1978)

Radioactive waste has become one of the most worrisome threats concerning society in the 1980s.

The experts' role is one of identifying risks and originating assessment of risks. It is one role of the news media to disseminate different experts. Lawless (1974) concluded that because of the role of headlines and the nature of the media, distortion is inevitable. The media tends to overemphasize the bizarre aspects of news. This is eminently true of the reporting of nuclear-related stories. Cartoons depicting nuclear issues have captured well some of the characteristics of the risks, as they are popularly perceived, associated with nuclear activities. Particularly since 1979, cartoons on the subject of nuclear waste, usually portraying nuclear waste disposal as a bizarre problem, sometimes close to science-fiction, have proliferated in newspapers. People make jokes about nuclear waste. The cartoons are included here, not flippantly, but to provide insight into public images of the nuclear issues.

A summary of the history of nuclear activities in the Pacific is presented in Table 5. The events and news sources surveyed are shown in Table 6 and a list of abbreviations for newspaper quotations is given in Table 7. The Los Angeles Times was the first choice as a representative Amercian newspaper because of its Pacific orientation, but it was not available for most of the events surveyed, so the New York Times was substituted.

The sparsely populated areas of the Pacific, the islands, central Australia, and the Pacific Ocean itself, have often been regarded as an immense backyard that could be used for nuclear experimentation and waste disposal. The Pacific region has been inextricably involved in the history of nuclear energy. Facilities for the first large-scale

Table 5. Chronology of nuclear and political events in the Pacific 1945 to 1983.

TABLE 5

CHRONOLOGY OF NUCLEAR AND POLITICAL EVENTS IN THE PACIFIC (1945-PRESENT).

DATE	MICRONESIA	FRENCH POLYNESIA	OTHER PLACES
1945			HIROSHIMA AND NAGASAKI
1946	BIKINI - 1ST TEST		
1947	U.S. ACQUIRES TRUST TERRITORIES OF MICRONESIA	POUVANAA BEGINS CAMPAIGN FOR POLITICAL REPRESENTATION FOR POLYNESIANS	SOUTH PACIFIC COMMISION FORMED
1948		FIRST DEMAND FOR SELF-GOVERNMENT	
1949			
1950			SOUTH PACIFIC CONFERENCE (ISLANDER REPRESENTATIVES) FORMED
1951			
1952	1ST H-BOMB - BIKINI		AUSTRALIA - MONTE BELLO IS. TESTS
1953			AUSTRALIA - MARALINGA TESTS
1954	EXPOSED TO FALLOUT FROM TEST BRAVO: RONGELAP, AILINGINAE, RONGERIK, UTIRIK, AND JAPANESE FISHING VESSEL "LUCKY DRAGON".		UN - MICRONESIAN LEADERS PETITION FOR HALT TO TESTS; SHUNKOTSU MARU - JAPANESE RADIOLOGICAL SURVEY OF THE NORTH PACIFIC
1955			
1956			
1957			
1958	END US TESTING; TOTAL ENEWETOK 43; BIKINI 23	POUVANAA ARRESTED ON BOGUS CHARGE - HELD POLITICAL PRISONER IN FRANCE FOR 11 YEARS	JOHNSTON IS. TEST (US) - 2 UPPER ATMOSPHERE
1959			
1960			FIRST FRENCH TEST IN ALGERIA
1961	KWAJALEIN BECOMES BASE FOR ICBM TESTS		
1962			CHRISTMAS IS. TESTS (UK) TOTAL 24; JOHNSTON IS. TOTAL 12; W. SAMOA INDEPENDENCE
1963			US-USSR TEST BAN TREATY
1964			
1965	FIRST SESSION OF CONGRESS OF MICRONESIA (COM)		
1966		FIRST FRENCH TEST MUROROA (ATMOSPHERIC)	
1967	COM ESTABLISHES POLITICAL STATUS COMMISSION		

1961	KWAJALEIN BECOMES BASE FOR ICBM TESTS		
1962			CHRISTMAS IS. TESTS (UK) TOTAL 24; JOHNSTON IS. TOTAL 12; W. SAMOA INDEPENDENCE
1963			US-USSR TEST BAN TREATY
1964			
1965	FIRST SESSION OF CONGRESS OF MICRONESIA (COM)		
1966		FIRST FRENCH TEST MUROROA (ATMOSPHERIC)	
1967	COM ESTABLISHES POLITICAL STATUS COMMISSION		
1968			NAURU INDEPENDENCE
1969	BIKINI CLEAN-UP BEGINS	POUVANAA RETURNS HOME	
1970		ATOM (AGAINST TESTING ON MURUROA) FORUMS AT UNIVERSITY OF THE SOUTH PACIFIC, SUVA, FIJI.	FIJI INDEPENDENCE; TONGA INDEPENDENCE
1971	MARIANAS SECEDES FROM MICRONESIA TO JOIN US AS COMMONWEALTH OF NORTHERN MARIANAS		SOUTH PACIFIC FORUM ESTABLISHED; FIJI REPRESENTS PACIFIC IS. VIEWS AT THE UN
1972	SOME BIKINIANS RETURN HOME DESPITE CONTAMINATION WARNINGS BY AEC		
1973		AUSTRALIA, NEW ZEALAND, AND FIJI CHALLENGE FRENCH TESTING IN THE INTERNATIONAL COURT OF JUSTICE	PAPUA NEW GUINEA INDEPENDENCE
1974		ATMOSPHERIC TESTS CEASE	
1975	BIKINIANS FILE SUIT AGAINST US	UNDERGROUND TESTS BEGIN	UN GENERAL ASSEMBLY SUPPORTS IDEA OF NUCLEAR FREE ZONE FOR SOUTH PACIFIC; FIRST NUCLEAR FREE PACIFIC CONFERENCE, SUVA, FIJI
1976			SOLOMON IS. INDEPENDENCE; BANABA (OCEAN IS.) VS. UK LANDMARK COURT CASE; BOUGAINVILLE SEPARATIST MOVEMENT
1977	ENEWETOK CLEAN-UP BEGINS		
1978	BIKINIANS EVACUATED AGAIN BECAUSE OF HIGH RADIATION LEVELS		TUVALU (ELLICE IS.) INDEPENDENCE; SECOND NUCLEAR FREE PACIFIC CONFERENCE, PONAPE.
1979	RUNIT DOME COMPLETED	ACCIDENT AT MURUROA - BOMB EXPLODES IN SHAFT	KIRIBATI (LINE IS.) INDEPENDENCE
1980		DOCK WORKERS REFUSE TO LOAD CONTAMINATED WASTE WITHOUT EXTRA PAY; FRENCH GOVT. ADMITS TESTING NEUTRON BOMB	VANUATU (NEW HEBRIDES) INDEPENDENCE; THIRD NUCLEAR FREE PACIFIC CONFERENCE, KAILUA, HAWAII; PACIFIC CONCERNS RESOURCES CENTER ESTABLISHED IN HONOLULU
1981	BIKINIANS FILE SUIT FOR $450 MILLION AGAINST US GOVT.; MARSHALL IS. APPROACHED BY JAPAN RE NUCLEAR WASTE STORAGE ON BIKINI		CHINESE MISSILE TESTS, WESTERN PACIFIC. FIJI GOVERNMENT REGISTERS COMPLAINT.
1982	ENEWETOK RESIDENTS SUE US GOVT FOR $500 MILLION	MOVEMENT FOR INDEPENDENCE CONTINUES	FIRST SPREP (SOUTH PACIFIC REGIONAL ENVIRONMENT PROGRAMME) CONFERENCE IN COOK IS. TAKES STRONG ANTI-NUCLEAR STAND
1983			DISCUSSION OF REGIONAL ANTI-NUCLEAR TREATY AT SPC IN NOUMEA

		ASAHI SHIMBUN	FIJI TIMES	HONOLULU ADVERTISER	JAPAN TIMES	LA DEPECHE	LOS ANGELES TIMES	NEW YORK TIMES	NEW ZEALAND HERALD	PACIFIC ISLANDS MONTHLY	PNG POST-COURIER	SYDNEY MORNING HERALD
1946	July 1. Bikini test	✓	✓	✓	✓	NA	NA	✓	NA	NO REPORT	NA	✓
1952	October 3. Monte Bello test	✓	✓	✓	✓	NA	NA	✓	NA	✓	NA	✓
1954	March 1. Bikini accident	✓	✓	✓	✓	NA	NA	✓	NA	✓	NA	✓
1966	July 2. Moruroa test	✓	✓	✓	✓	✓	NA	✓	✓	✓	NA	✓
1974	May 19. Indian test	✓	✓	✓	✓	NA	NA	✓	NA	NO REPORT	✓	✓
1979	March 28 Three Mile Island	✓	✓	✓	✓	✓	✓	✓	✓	NO REPORT	✓	✓
1979	August Palmyra plan	✓	✓	✓	✓	NO REPORT	✓	✓	✓	✓	✓	✓
1980	June 9 Pacific Fisher docks in Hawaii	NO REPORT	✓	✓	✓	NO REPORT	✓	✓	✓	NO REPORT	✓	✓
1980	October 5. Japanese dumping plan.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

NA. Not available in Hamilton Library.

The newspaper survey was possible because of the extensive collection of microfilms of Asian and Pacific newspapers in the Hamilton Library of the University of Hawaii. The New Zealand Herald was obtained on inter-library loan from the Duke University library through the Resource Materials Collection at the East-West Center.

The Papua New Guinea Post Courier before 1974 was a government gazette, not a regular newspaper.

The Asahi Shimbun was available only in shukusatsuban (reduced-size) editions.

Table 7 Abbreviations for newspapers.

Newspaper	Country	Abbreviation
Asahi shimbun	Japan	AS
Fiji Times	Fiji	FT
Honolulu Advertiser	Hawaii, USA	HA
Japan Times	Japan	JT
La Depeche	Tahiti	LD
Los Angeles Times	USA	LAT
New York Times	USA	NYT
New Zealand Herald	New Zealand	NZH
Pacific Islands Monthly		PIM
Papua New Guinea Post Courier	Papua New Guinea	PC
Sydney Morning Herald	Australia	SMH

NB. Dates given in text are in American style.
i.e. 2/1/83 signifies February 1st, 1983.

manufacture of plutonium were located in the state of Washington, on the Pacific coast of the United States. Australian uranium was used in the development of the British nuclear energy program. Hiroshima and Nagasaki are the only cities to have experienced attack by nuclear weapons. Since the 1940s the Pacific Ocean has been used at various times for disposal of low-level radioactive waste by the United States, Japan, Australia, and probably South Korea. Nuclear weapons and missile tests have been conducted in the region by Britain, China, France, the United States, and the USSR (see Table 5).

It is this history that has shaped public attitudes toward nuclear activities. Even though the percentage of the population actively engaged in anti-nuclear demonstrations is small, there is a strong undercurrent of public feeling that is antagonistic toward, and even fearful of, anything labelled "nuclear". Newspaper reporting of nuclear issues since World War Two has been influential in creating such attitudes, since the press is largely responsible for the information available to the general public. Does the reporting exhibit emphasis on certain characteristics of radiation risks, thereby encouraging people to perceive them as uniquely dangerous?

In the 1940s and early 1950s reporting of nuclear events was sensational and pervaded by a kind of mystique surrounding nuclear energy. In the late 1950s and during the 1960s, a clearer recognition of the risks of radiation and of the global extent of radioactive fallout was apparent. The nuclear mystique had turned into the nuclear menace, and negative feelings toward nuclear energy in all forms became more widespread. The environmental movement of the late 1960s and early 1970s gave much impetus to the anti-nuclear movement, which became increasingly visible in the news. By the late 1970s the increasing gap between the "expert" and "public" perception of risks associated with nuclear power was obvious. Nuclear power became the focus of wide-ranging social, moral and political debate, and the rhetoric of anti-nuclear lobbies became increasingly sophisticated, especially in the United States in the use of "expert opinions". In the 1980s nuclear issues have become the rallying point for political causes in the Pacific. A dichotomy with a North-South flavor has developed between the rim countries of the North Pacific (United States, Canada, Japan, South Korea, Taiwan), that have large nuclear power programs, and the small island nations of the South Pacific that would like to make the Pacific free of all nuclear activities. Australia and New Zealand vacillate between the two camps.

1. The first Bikini test - 1946

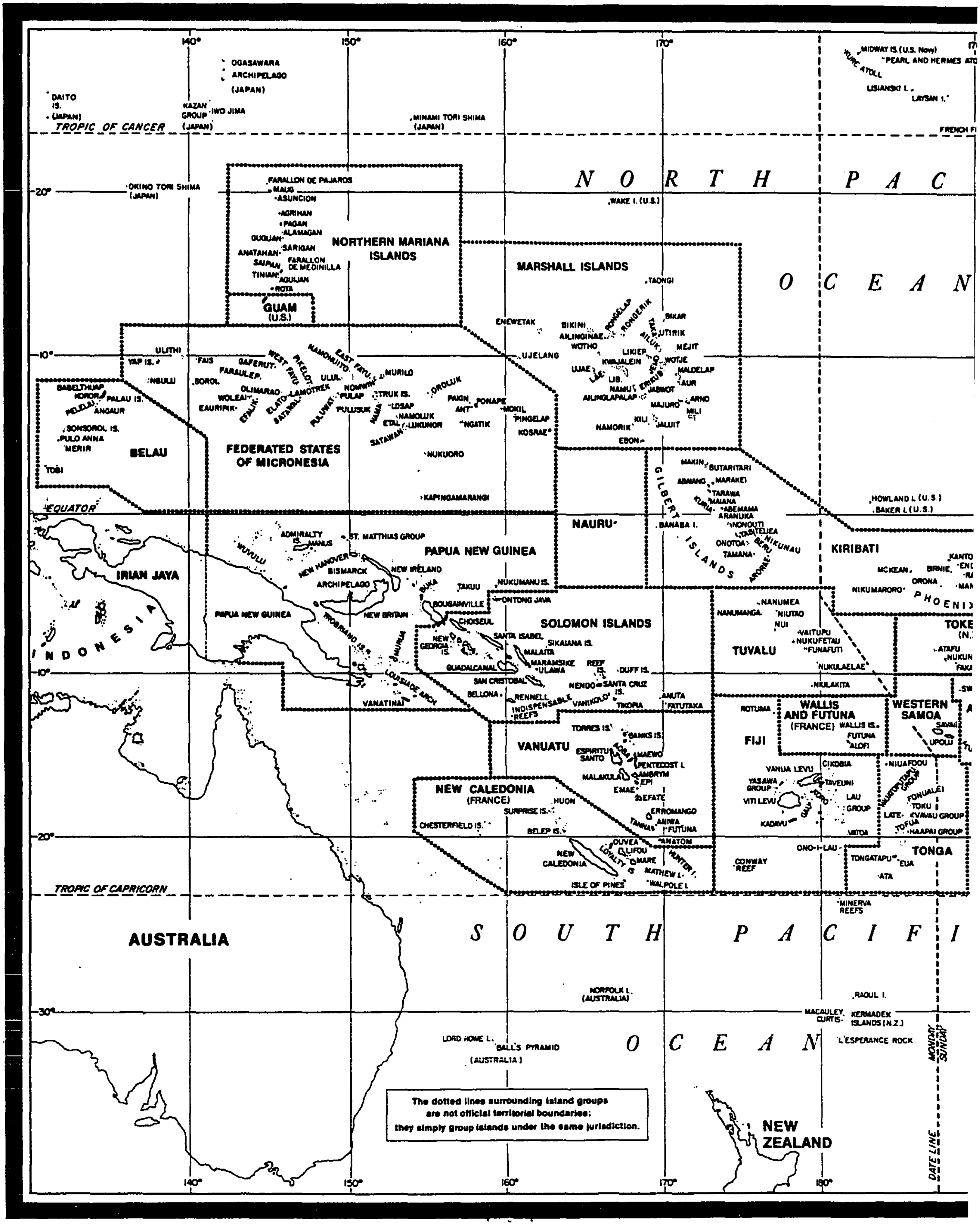
> The atoll is a product of the ocean: alive, growing, its shape and character adjusted to the movement and circulation of the ocean waters and regulated by tropical light and heat.
> (Hines, 1962: 28)

In July 1946 Operation Crossroads, a United States military exercise to test atomic weapons took place at Bikini Atoll in the Marshall Islands. The first nuclear weapons test in the Pacific was built up into a spectacular media event, even though it took place less than one year after the bombing of Hiroshima and Nagasaki. The search for a test site had begun in late 1945 with specifications calling for:

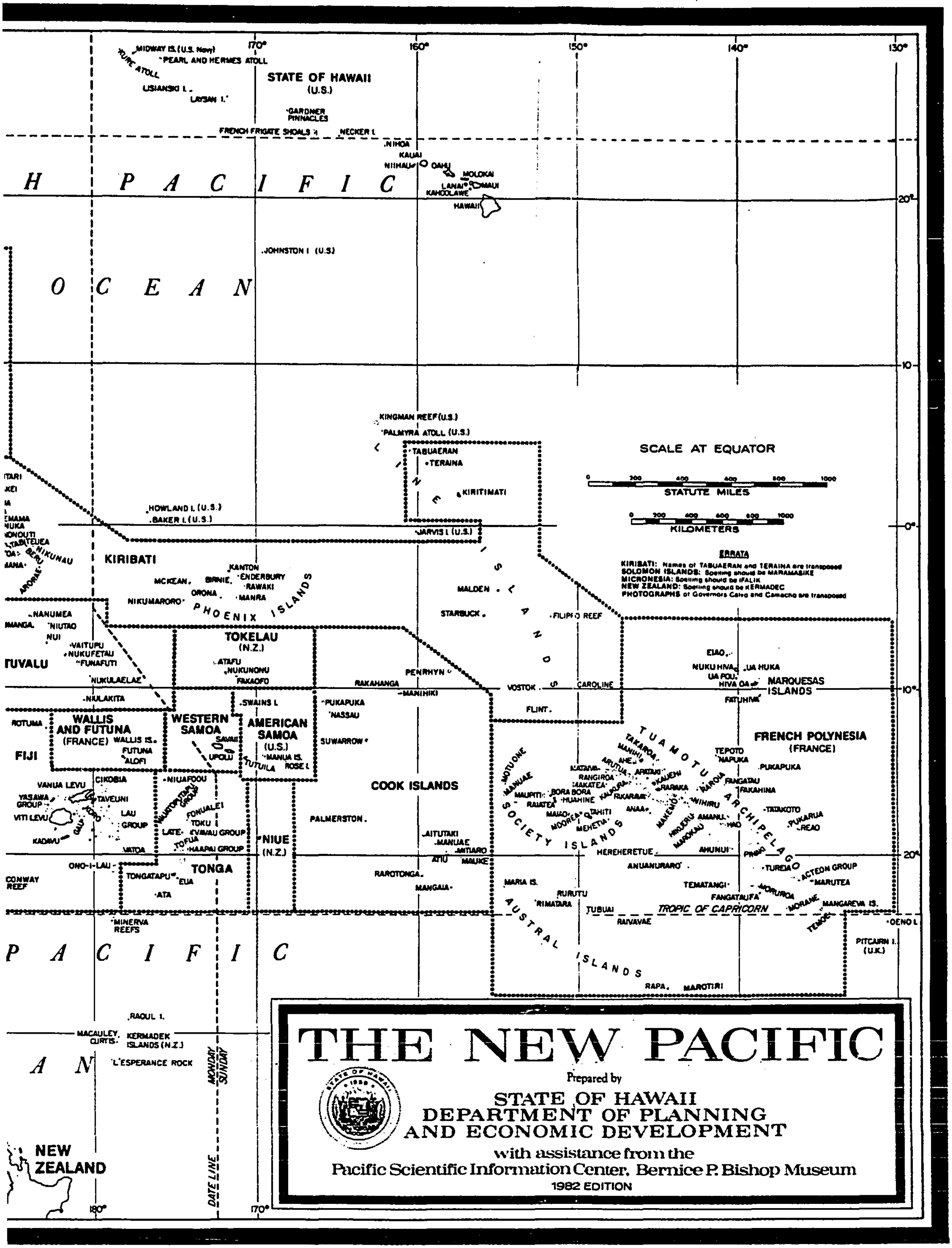
> a site within the control of the US, uninhabited or subject to evacuation without imposing unnecessary hardship on large numbers of inhabitants, within 1,000 miles of the nearest B-29 aircraft base (in expectation that one atomic device would be delivered by air), free from storms and extreme cold and offering a protected anchorage at least 6 miles in diameter and, thus, large enough to accomodate the large fleet of target vessels and the additional vessels that would have to be used in support of the operation. Also required were distance from cities or concentrations of population, winds predictably uniform from sea level to 60,000 feet and predictable water currents not adjacent to inhabited shorelines, shipping lanes or fishing areas.
>
> (Hines, 1962: 22)

Sites in the Atlantic, Caribbean, and Pacific were reviewed, but the Marshall Islands, so recently captured from the Japanese and set in the mid-Pacific Ocean (Map 2) were situated in the trade-wind zone and fulfilled the required conditions of climate, isolation, and small population.

The geographical area of the Marshall Island group is approximately 180,000 square miles (Map 3), yet the 1,150 separate islands of the group comprise a total of less than 70 square miles of dry land. This ratio between water and land is a critical factor in Pacific Island cultures and social structure (Kiste, 1974), particularly on the low coral atolls with meager land resources. For example, Kwajalein, perhaps the largest atoll in the world, comprises 97 islands distributed around a lagoon that is 840 square miles in area, yet the total land surface of Kwajalein is only 6 square miles. Bikini atoll (Map 4),



140°
150°
160°
170°
180°
OGASAWARA ARCHIPELAGO (JAPAN)
DAITO IS. (JAPAN)
KAZAN GROUP (JAPAN)
IWO JIMA
MINAMI TORI SHIMA (JAPAN)
TROPIC OF CANCER
MIDWAY IS. (U.S. Navy)
PEARL AND HERMES ATOLL
KURE ATOLL
LISIANSKI I.
LAYSAN I.
OKINO TORI SHIMA (JAPAN)
20°
FARALLON DE PAJAROS
MAUG
ASUNCION
AGRIHAN
PAGAN
ALAMAGAN
GUGUAN
SARIGAN
ANATAHAN
SAIPAN
FARALLON DE MEDINILLA
TINIAN
AGUIJAN
ROTA
NORTHERN MARIANA ISLANDS
GUAM (U.S.)
N O R T H P A C
WAKE I. (U.S.)
MARSHALL ISLANDS
TAONGI
O C E A N
ENEWETAK
BIKINI
AILINGINAE
RONGELAP
RONGERIK
TAKA
BIKAR
UTIRIK
AILUK
WOTHO
UJELANG
LIKIEP
MEJIT
UJAE
KWAJALEIN
WOTJE
LAE
LIB
MALOELAP
NAMU
ERIKUB
AUR
AILINGLAPALAP
JABWOT
MAJURO
ARNO
MILI
KILI
NAMORIK
JALUIT
EBON
10°
ULITHI
YAP IS.
FAIS
GAFERUT
WEST FAYU
NAMONUITO
EAST FAYU
MURILO
NGULU
SOROL
FARAULEP
PIKELOT
ULUL
NOMWIN
OROLUK
BABELTHUAP
KOROR
PALAU IS.
PELELIU
ANGAUR
OLIMARAO
WOLEAI
EAURIPIK
IFALIK
ELATO
LAMOTREK
SATAWAL
PULUWAT
PULAP
PULUSUK
TRUK IS.
LOSAP
NAMA
NAMOLUK
ETAL
LUKUNOR
SATAWAN
PAKIN
ANT
PONAPE
MOKIL
PINGELAP
NGATIK
KOSRAE
SONSOROL IS.
PULO ANNA
MERIR
BELAU
FEDERATED STATES OF MICRONESIA
NUKUORO
TOBI
KAPINGAMARANGI
EQUATOR
GILBERT ISLANDS
MAKIN
BUTARITARI
ABAIANG
MARAKEI
TARAWA
MAIANA
KURIA
ABEMAMA
ARANUKA
NONOUTI
TABITEUEA
BERU
NIKUNAU
ONOTOA
TAMANA
ARORAE
HOWLAND I. (U.S.)
BAKER I. (U.S.)
NAURU
BANABA I.
KIRIBATI
ADMIRALTY IS.
MANUS
ST. MATTHIAS GROUP
WUVULU
NEW HANOVER
BISMARCK ARCHIPELAGO
NEW IRELAND
PAPUA NEW GUINEA
IRIAN JAYA
BUKA
TAKUU
NUKUMANU IS.
ONTONG JAVA
BOUGAINVILLE
NEW BRITAIN
TROBRIAND IS.
WOODLARK
CHOISEUL
SOLOMON ISLANDS
NEW GEORGIA IS.
SANTA ISABEL
SIKAIANA IS.
MALAITA
GUADALCANAL
MARAMSIKE
ULAWA
REEF IS.
DUFF IS.
SAN CRISTOBAL
NENDO
SANTA CRUZ IS.
BELLONA
RENNELL
INDISPENSABLE REEFS
VANIKOLO
TIKOPIA
ANUTA
FATUTAKA
LOUISIADE ARCH.
VANATINAI
INDONESIA
MCKEAN
BIRNIE
ORONA
NIKUMARORO
PHOENIX
KANTO
NANUMEA
NANUMANGA
NIUTAO
NUI
VAITUPU
NUKUFETAU
FUNAFUTI
NUKULAELAE
NIULAKITA
TUVALU
TOKE
ATAFU
NUKUN
FAKA
ROTUMA
WALLIS AND FUTUNA (FRANCE)
WALLIS IS.
FUTUNA
ALOFI
WESTERN SAMOA
SAVAII
UPOLU
FIJI
TORRES IS.
BANKS IS.
VANUATU
ESPIRITU SANTO
AOBA
MAEWO
PENTECOST I.
MALAKULA
AMBRYM
EPI
EMAE
EFATE
ERROMANGO
TANNA
ANIWA
FUTUNA
ANATOM
NEW CALEDONIA (FRANCE)
HUON
SURPRISE IS.
CHESTERFIELD IS.
BELEP IS.
OUVEA
LIFOU
LOYALTY IS.
MARE
HUNTER I.
MATHEW I.
NEW CALEDONIA
ISLE OF PINES
WALPOLE I.
VANUA LEVU
CIKOBIA
NIUAFOOU
YASAWA GROUP
TAVEUNI
VITI LEVU
KORO
LAU GROUP
KADAVU
GAU
VATOA
NIUATOPUTAPU GROUP
FONUALEI
TOKU
LATE
VAVAU GROUP
TOFUA
HAAPAI GROUP
ONO-I-LAU
TONGATAPU
EUA
ATA
TONGA
CONWAY REEF
TROPIC OF CAPRICORN
MINERVA REEFS
AUSTRALIA
S O U T H P A C I F I
NORFOLK I. (AUSTRALIA)
RAOUL I.
30°
MACAULEY, CURTIS
KERMADEK ISLANDS (N.Z.)
LORD HOWE I.
BALL'S PYRAMID (AUSTRALIA)
O C E A N
L'ESPERANCE ROCK
MONDAY SUNDAY
The dotted lines surrounding island groups are not official territorial boundaries: they simply group islands under the same jurisdiction.
NEW ZEALAND
DATE LINE



THE NEW PACIFIC
Prepared by
STATE OF HAWAII
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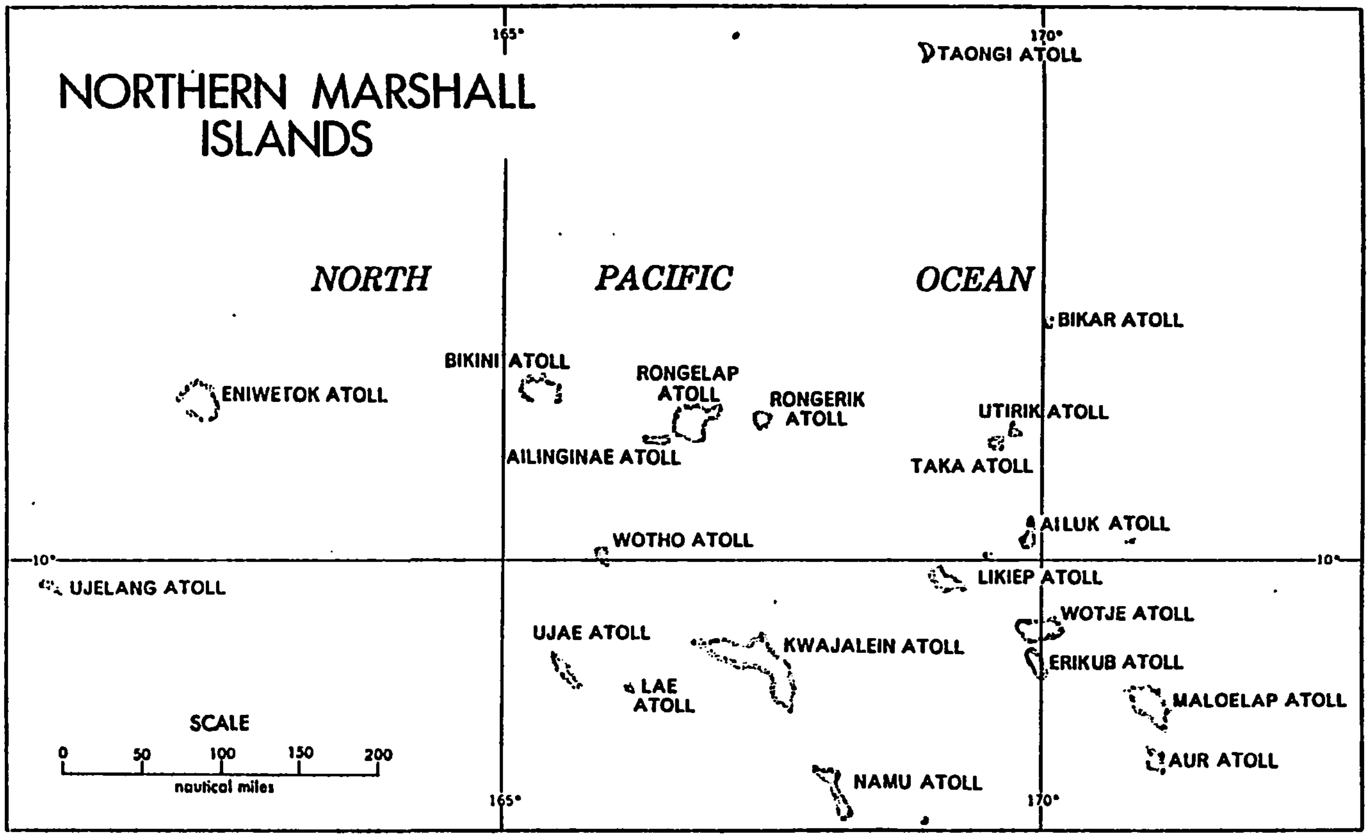
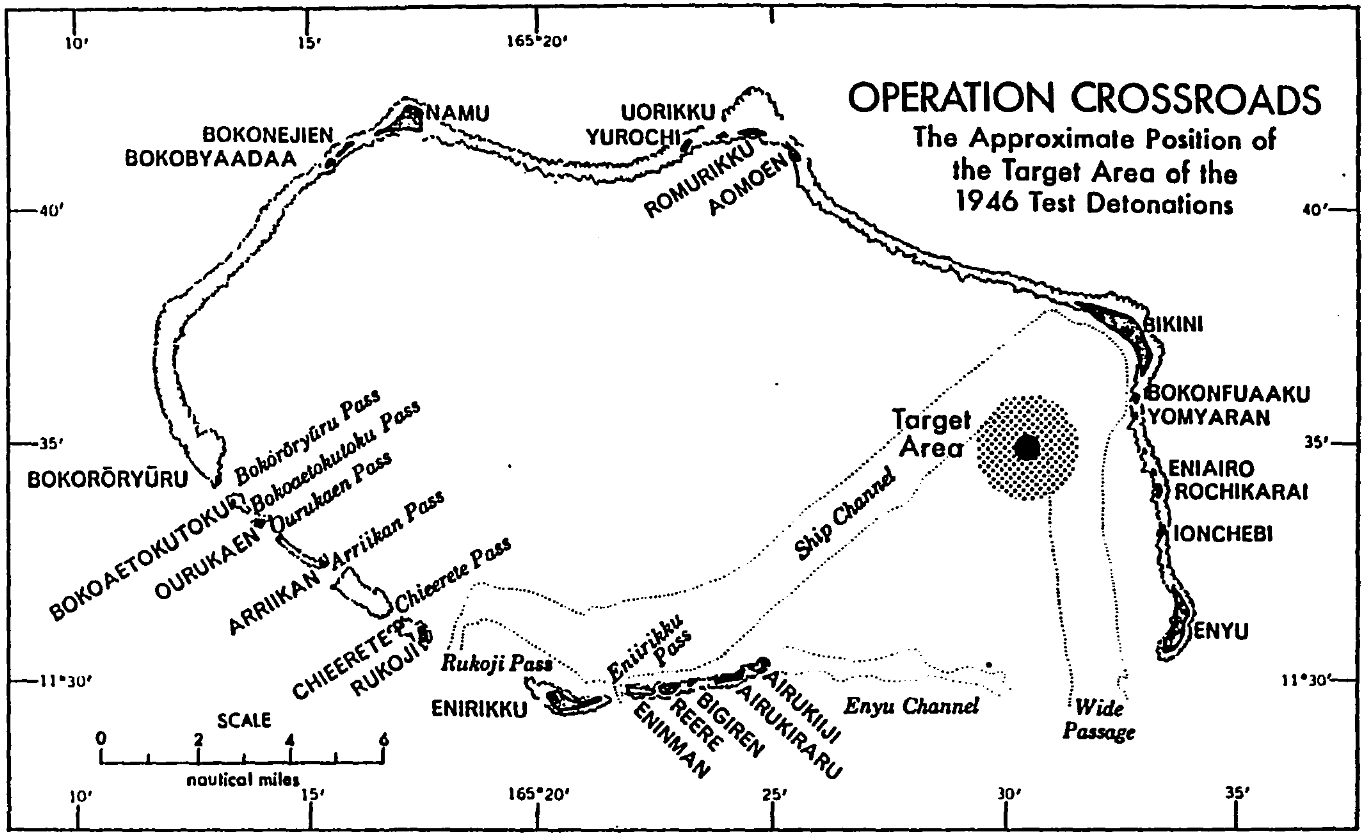
1982 EDITION
SCALE AT EQUATOR
STATUTE MILES
KILOMETERS
ERRATA
KIRIBATI: Names of TABUAERAN and TERAINA are transposed
SOLOMON ISLANDS: Spelling should be MARAMASIKE
MICRONESIA: Spelling should be IFALIK
NEW ZEALAND: Spelling should be KERMADEC
PHOTOGRAPHS of Governors Calvo and Camacho are transposed
P A C I F I C
O C E A N
STATE OF HAWAII
(U.S.)
MIDWAY IS. (U.S. Navy)
PEARL AND HERMES ATOLL
LISIANSKI I.
LAYSAN I.
GARDNER PINNACLES
FRENCH FRIGATE SHOALS
NECKER I.
NIHOA
KAUAI
NIIHAU
OAHU
MOLOKAI
LANAI
MAUI
KAHOOLAWE
HAWAII
JOHNSTON I. (U.S.)
KINGMAN REEF (U.S.)
PALMYRA ATOLL (U.S.)
TABUAERAN
TERAINA
KIRITIMATI
HOWLAND I. (U.S.)
BAKER I. (U.S.)
JARVIS I. (U.S.)
KIRIBATI
KANTON
ENDERBURY
MCKEAN
BIRNIE
RAWAKI
ORONA
MANRA
NIKUMARORO
PHOENIX ISLANDS
MALDEN
STARBUCK
FILIPPO REEF
TOKELAU
(N.Z.)
ATAFU
NUKUNONU
FAKAOFO
TUVALU
NANUMEA
NIUTAO
NUI
VAITUPU
NUKUFETAU
FUNAFUTI
NUKULAELAE
NIULAKITA
PENRHYN
RAKAHANGA
MANIHIKI
VOSTOK
CAROLINE
FLINT
PUKAPUKA
NASSAU
SUWARROW
SWAINS I.
WALLIS AND FUTUNA
(FRANCE)
WALLIS IS.
FUTUNA
ALOFI
ROTUMA
WESTERN SAMOA
SAVAII
UPOLU
AMERICAN SAMOA
(U.S.)
TUTUILA
MANUA IS.
ROSE I.
FIJI
VANUA LEVU
CIKOBIA
TAVEUNI
YASAWA GROUP
VITI LEVU
LAU GROUP
KADAVU
VATOA
ONO-I-LAU
CONWAY REEF
NIUAFOOU
TOKU
LATE
VAVAU GROUP
HAAPAI GROUP
TONGA
TONGATAPU
EUA
ATA
NIUE
(N.Z.)
COOK ISLANDS
PALMERSTON
AITUTAKI
MANUAE
MITIARO
ATIU
MAUKE
RAROTONGA
MANGAIA
MARQUESAS ISLANDS
EIAO
NUKU HIVA
UA HUKA
UA POU
HIVA OA
FATU HIVA
FRENCH POLYNESIA
(FRANCE)
TUAMOTU ARCHIPELAGO
SOCIETY ISLANDS
TEPOTO
NAPUKA
PUKAPUKA
TAKAROA
MANIHI
AHE
ARUTUA
RANGIROA
MAKATEA
BORA BORA
HUAHINE
RAIATEA
TAHITI
MOOREA
MEHETIA
ANAA
HAO
AMANU
HEREHERETUE
ANUANURARO
TEMATANGI
FANGATAUFA
MURUROA
ACTEON GROUP
MARUTEA
MORANE
MANGAREVA IS.
TEMOE
TUREIA
TATAKOTO
PUKARUA
REAO
MARIA IS.
RURUTU
RIMATARA
TUBUAI
RAIVAVAE
AUSTRAL ISLANDS
RAPA
MAROTIRI
TROPIC OF CAPRICORN
OENO I.
PITCAIRN I.
(U.K.)
MINERVA REEFS
RAOUL I.
MACAULEY
CURTIS
KERMADEK ISLANDS (N.Z.)
L'ESPERANCE ROCK
MONDAY
SUNDAY
DATE LINE
NEW ZEALAND
170°
160°
150°
140°
130°
180°



Map 3. The Northern Marshall Islands

Source: Hines (1962)



Map 4. Bikini Atoll and Operation Crossroads.

Source: Hines (1962)

similarly, has a central lagoon of 243 square miles in area, of 180 feet in average depth, and passages and outflows on the protected leeward side. Twenty-six low sandy islets surround the lagoon, supporting vegetation that varies from windswept scrub to stands of coconut palms and other tropical plants. Bikini is the largest island in the atoll, being two and a half miles long, half a mile wide, and having a maximum elevation of 16 feet above sea level. Bikini is 2,500 miles south-west of Honolulu, but within easy access of the American military base on Kwajalein.

In July 1946 the inhabitants of Bikini numbered one hundred and sixty two. Agreement for the use of the atoll was made between the United States Navy and the Bikini people through a council led by Juda, the iroiji (headman) of the community (Kiste 1974). The Bikinians were at first evacuated to Rongerik atoll, 130 miles to the east, an unwise choice that resulted in severe food shortages and near starvation for the Bikinians because of the island's low carrying capacity. The subsequent forced migration of the Bikinians to Kwajalein and to Kili Island has been documented by Kiste (1974, 1975).

Few geographical details of the Bikini environment or the way of life of the Bikinians were included in the 1946 press reports describing the atomic weapons tests. The image of Bikini was of a "remote Pacific island with swaying palm trees" (NYT, 7/25/46:1).

Crossroads was a military and scientific experiment on an unprecedented scale involving 42,000 personnel. It was probably the most thoroughly documented, reported and publicized peacetime military exercise in history. A whole shipload of reporters were brought along to observe the explosion. In 1945 and 1946 there was a general curiosity among political leaders and the public about the magnitude and meaning of the new atomic force that had been used against Japan. This sentiment is reflected in the epochal importance given to the tests in the world press.

The military implications of the test were emphasized in press reports which gave detailed descriptions of damage to ships and were extrapolated to possible effects on cities. Two reports, one American and one British, on the casualties from the Hiroshima and Nagasaki bombings were released on the eve of the Bikini tests. An editorial in the Sydney Morning Herald (7/2/46) called the 120,000 death toll "a dreadful, appalling figure", but these reports did not seem to dampen the excitement that pervaded the articles describing the Bikini experiment.

Descriptions of the blast's immediate effects were, almost without exception, sensational exaggerations rather than scientifically substantiated descriptions.

> ...with the heat of 10,000 suns, the pressure of billions of atmospheres, winds of 5-10 times a hurricane...
>
> (NYT, 7/1/46:5).

The nuclear mystique was nurtured in the language of the newspapers.

> It was an awesome, spine-chilling spectacle. A boiling, super-volcano struggling toward the sky, belching enormous masses of irridescent flames and smoke and giant rings of a rainbow, at times giving the appearance of a monster tugging at the earth in an effort to lift it into space.
> (Lawrence, NYT, 7/2/1946)
>
> The lagoon water seethed and boiled and deadly vapours and steam curled round the ships, hiding them from view, as though to claim their victims.
> (FT, 7/2/1946).

Several newspaper articles expressed disappointment that there was not more damage done to the fleet of target ships. Headlines such as "World still intact" and "At least the Pacific did not disintegrate" (FT, 7/1/1946) appeared, indicating the extent to which the first test had been built up in the media prior to the explosion. Fears that seismic convulsions and tidal waves would be precipitated around the Pacific by the explosion at Bikini were a measure of the popular horror that the atomic bomb inspired in 1946. It was as though an awesome genie had been unleashed (Fig. 24).

There were few voices of dissent raised in the press. The New York Times reported that a group of 35 demonstrators in New York City demanded a halt to the testing and to production of atomic weapons in the United States. This was probably the world's first anti-nuclear rally. A letter to the editor of the Sydney Morning Herald (7/23/1946) protested that the rights of the Bikinians had been "brazenly violated" and that the Australian Aboriginals were soon to be treated in the same way in preparation for British missile and bomb tests in central Australia.

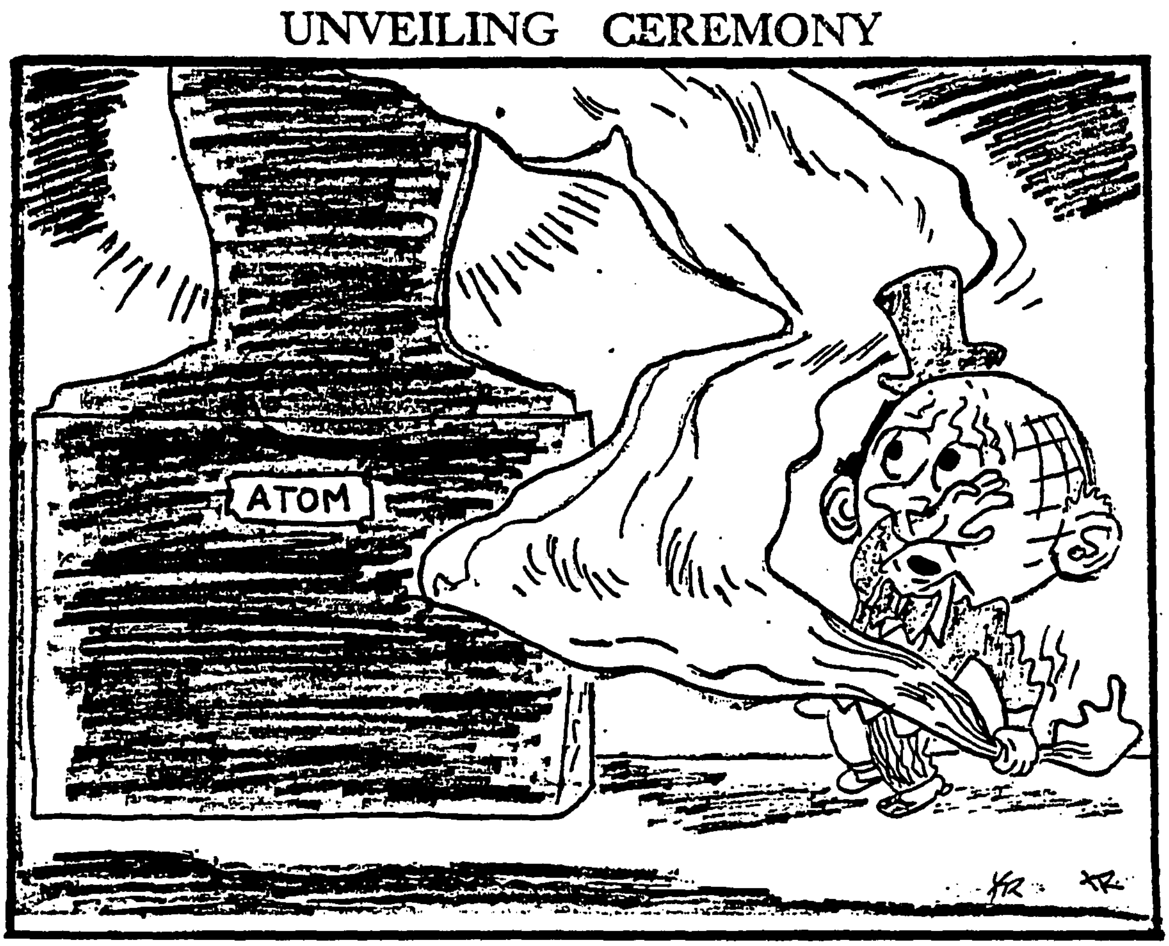


Figure 24 The Awesome Genie

(SMH, 7/1/46:1)

There is little variation in the press coverage of the tests in the different countries because most followed the United Press International (UPI) reports. In July 1946 Japan had not yet been permitted to maintain correspondents abroad, and, thus, the Japanese press relied for reports on UPI, Associated Press (AP), and the New York Times for reports. The Asahi Shimbun carried a front page story on the American test. The Japan Times was the only newspaper examined that reported radioactivity recorded in Tulsa, Oklahoma, four days after the July 1 test. The Fiji press was very colonial at the time, obtaining most of its reports directly from British sources, and, like the Japanese press, was not autonomous in its overseas reporting.

Although there was a recognition of the need to extract from the tests all possible information concerning radiation, (25,000 counters, badges, and measuring devices were brought to Bikini), there seems to have been little inkling that the tests would begin long-term research in radiobiology. The concept of radionuclide circulation in the food-chain was not new, but its relevance to the Bikini experiment seems not the have been realised (Hines, 1962: 35).

Stories concerning later damage counts of the target fleet and the fate of test animals on the ships continued to appear in the press throughout the month of July, showing the beginnings of an awareness of the latent effects of radioactivity.

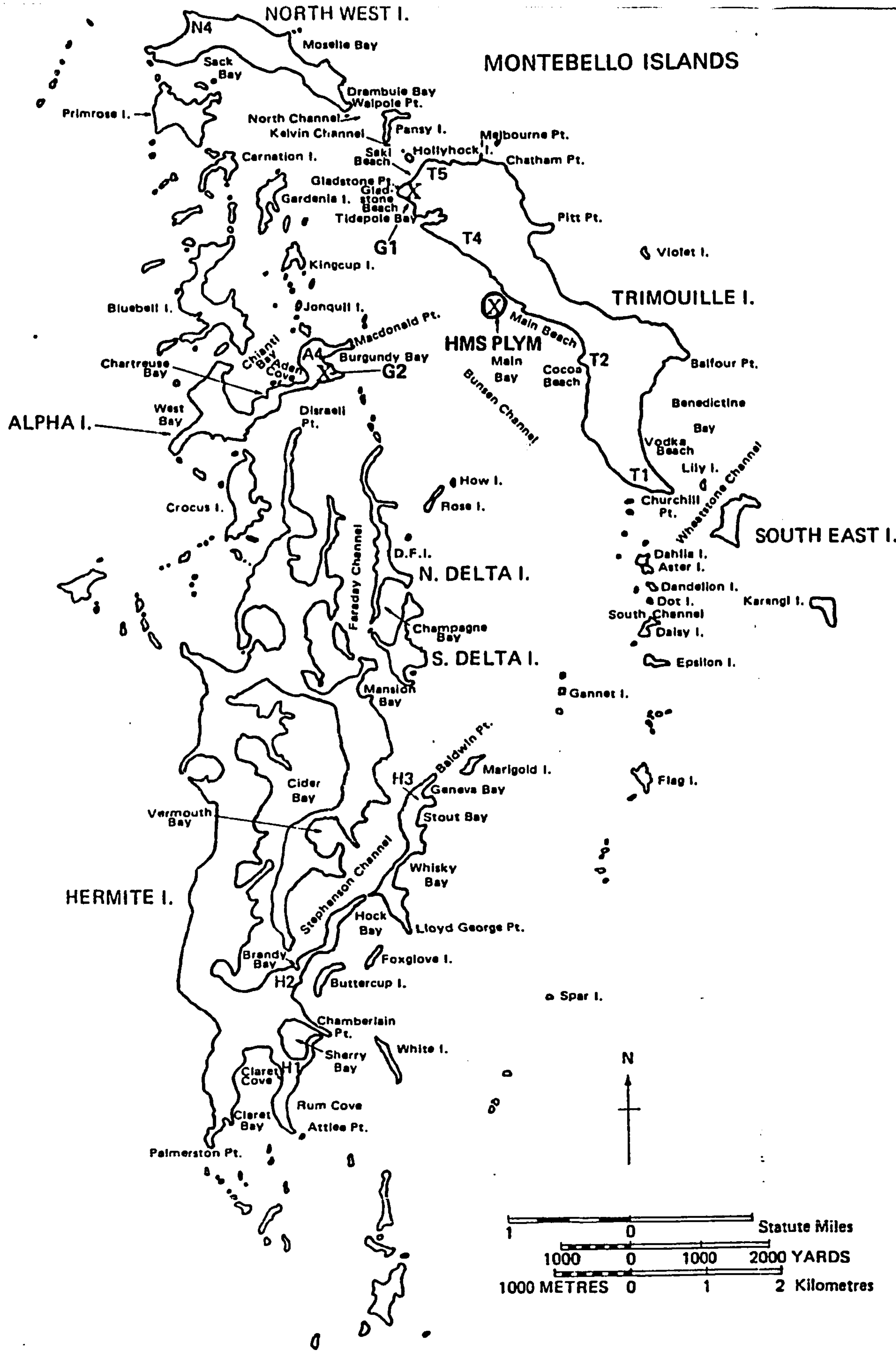
> At the indicated rate of animals dying, it seems fairly certain that the radioactivity at Bikini was far deadlier than many thought.
>
> (SMH, 7/16/46:3).

The press coverage of the 1946 test at Bikini probably encouraged public awe of atomic weapons, and, perhaps, a concomitant suspicion of all nuclear activities. The "common dread", to use Slovic's term, of things nuclear is rooted in their connection with nuclear weapons.

2. The Monte Bello test - 1952

An atomic weapons test named "Operation Hurricane" was conducted by Britain at the Monte Bello Islands off the coast of Western Australia in 1952. Two further tests were later conducted at the same site in 1956. Australian reporting of the Monte Bello tests had the same sensationalism as the 1946 Bikini test, and illustrate again the awesome quality of nuclear energy in the popular image.

The Monte Bello islands were selected for the test because they were uninhabited, remote from populated areas, and were regarded as barren with no productive potential. The Monte Bello group (Map 5) consists of approximately one hundred islands of sizes varying from small rocky outcrops to Hermite Island which is 3.6 square miles in area. The islands enclose a series of lagoons and channels, navigation of which is impeded by submerged reefs and rocky outcrops. All the islands are fairly low, the highest points being about 130 feet above sea level. The islands are composed of coastal limestone and sandstone, and vegetation consists of grass and low shrubs, presenting an exposed, windswept terrain. The group is subject to cyclonic weather during summer (November to April) when many of the smaller islands may become awash and most become inaccessible. Native marsupials appear to have



Map . The Monte Bello Islands, Western Australia.

Source: The Australian Ionizing Radiation Council (1979) been displaced from the islands by feral cats and rats long before the atomic tests took place (Australian Ionizing Radiation Advisory Council, 1979), and feral animals still live on the islands. Recently, the discovery of oil at Barrow Island to the south and the development of the iron ore industry in Western Australia have brought more people to the region and it can no longer be considered isolated.

The first British test at Monte Bello, naturally, was reported with far less enthusiasm in the Amercian press than the first Bikini test had been, but was hailed as a great success by the papers in Australia and Fiji. The overriding emphasis in all reports was political, in keeping with the climate of the times: the cold war (Russia had exploded its first atomic bomb in 1949), spy intrigues involving British agents selling atomic secrets to Russia, and the growing momentum of the nuclear arms race. The extent of the secrecy surrounding the British test is indicated by the fact that no American observers or Australian officials were permitted to witness the Monte Bello tests, although three Australian scientists had been involved in the preparations. It is also an indication of the colonial attitudes in Britain and Australia in 1952 that the British were permitted to use Australian territory for the test while not allowing any Australian observers, and that the Sydney Morning Herald praised the British research effort. An editorial (SMH 10/4/1952: 2), however, questioned the need for an arms race between allies (Fig. 25).

"Yes, I can do it too!"

Figure 25 An arms race between allies.
(SMH, 10/4/52:2)

The general tone of articles describing the British test shows that there was still a good deal of positive excitement generated by the explosion of an atomic weapon in 1952. In the township of Onslow on the Western Australian coast, 87 miles from the test site, one can imagine that the test was the most exciting event to take place in many years.

> People ran from their homes to the beach. There on the horizon was the atomic cloud, shooting skywards and drifting to the north ... breathless pressmen raced down the street to the post-office. They had seen the tell-tale cloud.
>
> The schoolmaster, Rex Bandy, took the whole school of thirty-six children down to a vantage point on the beach. There he explained to them what had happened.
>
> With the town in a mood for celebrating after the long wait, drinkers were faced with the dismal news that there were only three crates of beer in the Beadon Hotel - the only one in town.
>
> (SMH, 10/4/1952: 1)

There seems to have been little concern in the Australian press for the dangers of radioactive fallout. Public information on radiation hazards was still fairly sketchy at the time, so when, four days after the blast, radioactive hail and rain fell in Adelaide and Melbourne, no protest was reported in the Sydney Morning Herald, an unbelievable situation in 1983.

> Radioactive rain fell in Melbourne today, but it was harmless.
>
> (SMH, 10/4/52:1)

A research chemist at Adelaide University asserted that the hail, which had double the normal reading of radioactivity, was probably the result of cosmic rays, not the Monte Bello tests. Meanwhile a researcher at the Kodak Company in Adelaide stated that there was no doubt that the tests caused the abnormal precipitation. Thus, the disagreement between "experts", that has fostered public skepticism regarding the ability of authorities to manage radiation hazards safely, began to appear.

Interestingly, in Japan at this time, four leading Japanese physicists had urged the establishment of a Japan Atomic Energy Commission (JAEC), but the Japan Council of Sciences, the most respected academic body in Japan, opposed this on the grounds that "the government cannot be trusted in regard to the peaceful use of atomic energy" (JT, 10/25/1952:3).

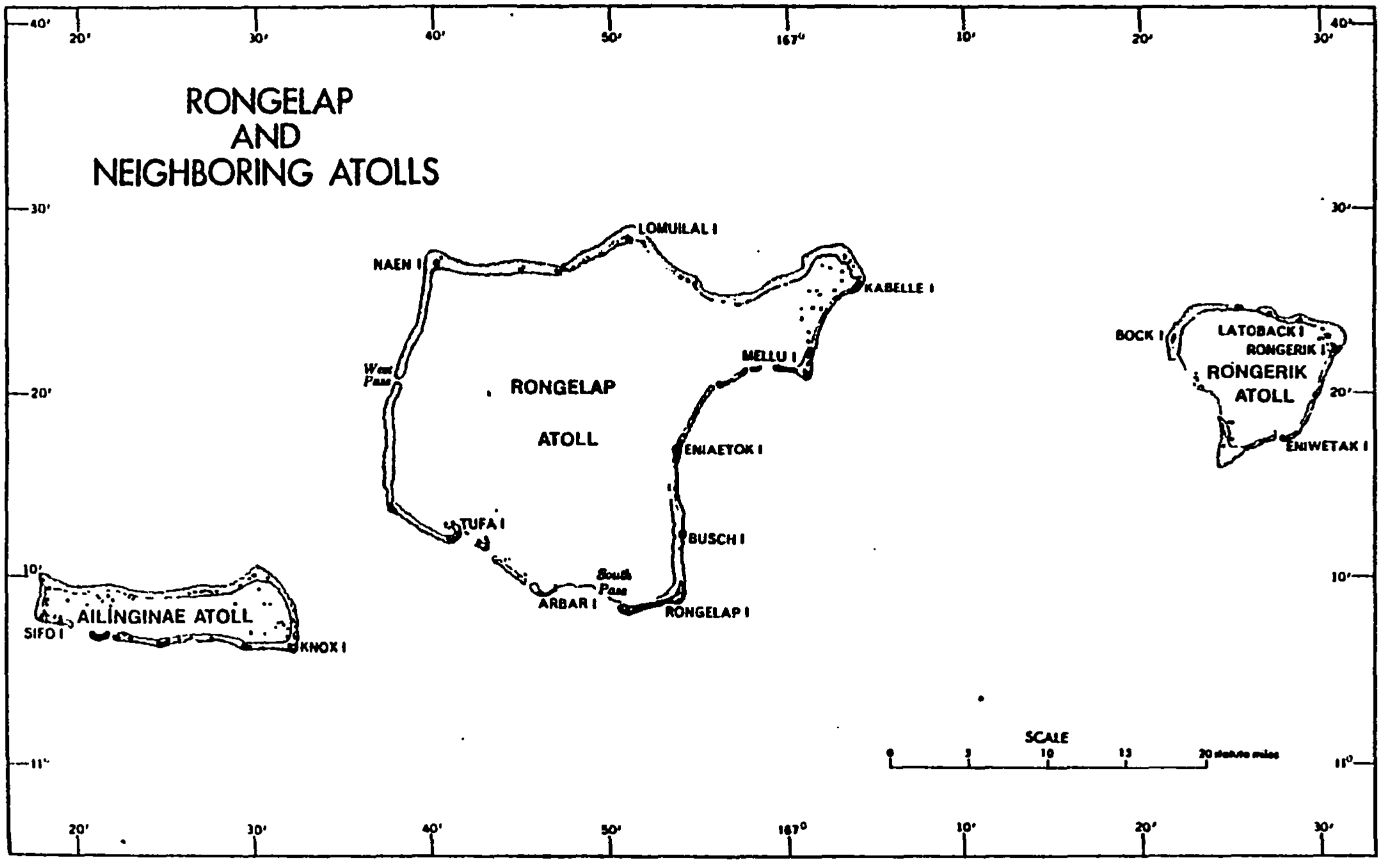
The Australian and Fijian press reported the activities of the growing anti-nuclear movement in Britain led by several Labour Members of Parliament, the National Committee of Science and Peace, and the Quaker organization. These groups had begun to use the word "fallout". The Fiji Times (10/1/1952) noted that the West Australian townships of Onslow and Rockbourne, 87 and 103 miles, respectively, from the test center, would be safer from possible atomic ill-effects than places much farther away because a vast cloud of radioactive material would be thrown into the stratosphere and pass over nearby areas. Fallout in areas further away, would be a greater danger.

The New York Times (10/3/1952:1) reported the British test in a small but factual front-page article with a map. The Honolulu Advertiser (10/3/1952:1) included only a one-sentence report on the British test in its "World at a Glance" column. The Pacific Islands Monthly had no article specifically on the test, but made reference to it at the conclusion of an editorial essay on the arms race, where the test was seen as an essential part of the western world's strategy to halt the expansion of communism. In the 1950s colonial shackles precluded the voicing of opposition, if any existed, to the use of the Pacific for nuclear activities by the big powers.

3. The Bikini accident - 1954

On March 1 1954 the United States exploded a thermonuclear (hydrogen) bomb[55] in Test Bravo at Bikini Atoll. The blast occurred at a time when circumstances were combining to produce a mishap that was to have tremendous repercussions in the Pacific region.

Public announcement of the decision to resume testing at Bikini, after a period of eight years, was made by the United States Atomic Energy Commission (USAEC) in April 1953. The explosion on March 1 created a cloud that reached an altitude of 100,000 feet and contained a great volume of radioactive particles (Hines, 1962). On the morning of the detonation an upper air wind was blowing across the Pacific that carried radioactive fallout not to the north, as had been expected, but east toward the inhabited atolls of Rongelap, Ailinginae, and Rongerik (Map 6). In the area of the eastward fallout, about 80 miles from Bikini, there was a Japanese long-line tuna fishing boat, the Fukuryu-maru (Lucky Dragon) with 23 crewmen aboard. Its presence was unsuspected by the military officials conducting the test. The Fukuryu-maru had been fishing in the vicinity of Midway Island but, having had only limited success, had worked its way toward the Marshall Islands. On the day of the test it was drifting north of Rongelap. The



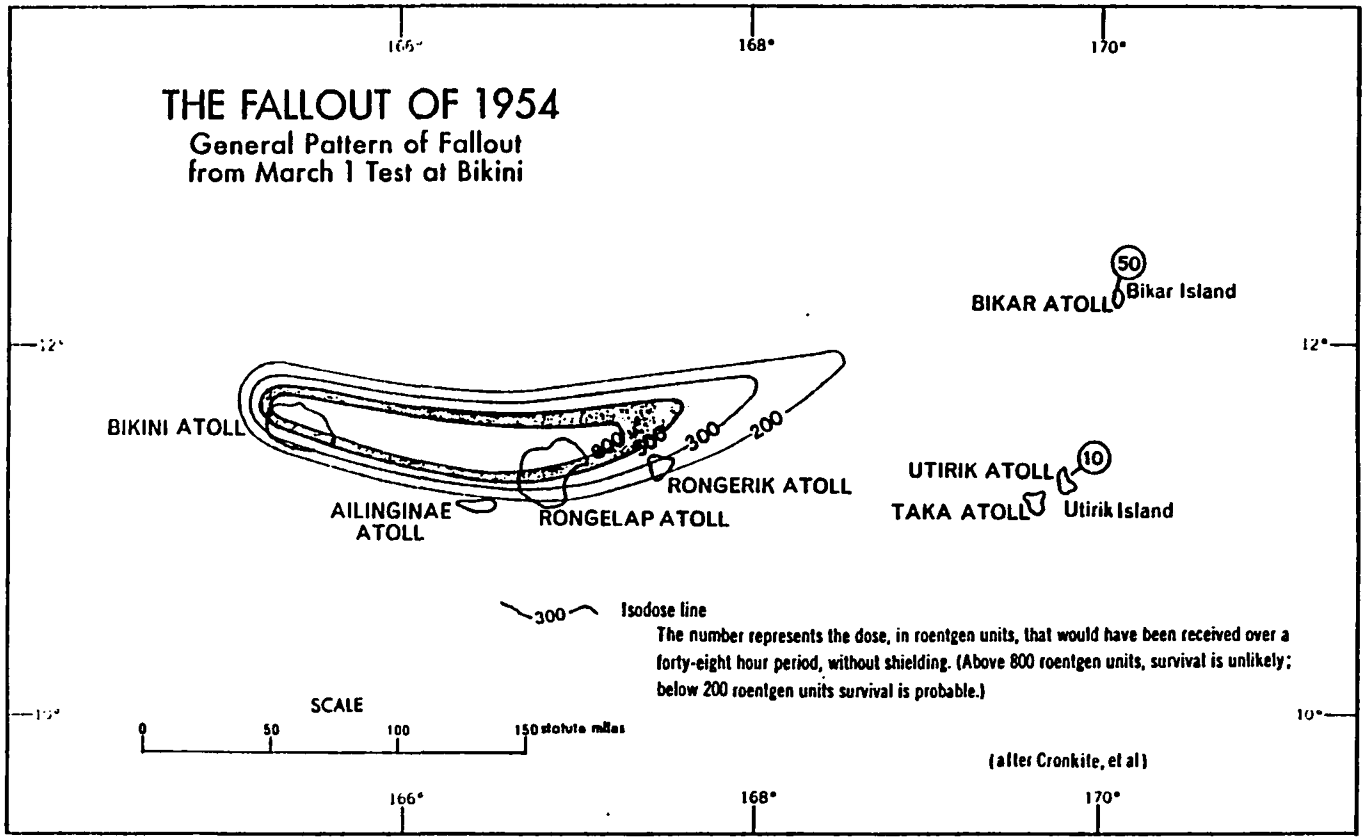
Map 6. Rongerik, Rongelap, and Ailinginae.

Source: Hines (1962)

captain of the boat later said that he knew of the existence of the American proving ground but that he was not aware of the warning of renewed testing at Bikini (Hines, 1962). The most recent explosion at Eniwetak, 200 miles from the place where they were fishing, had been two years previously.

Soon after the Bravo blast, radiological safety officers on board the naval task force vessel, thirty miles east of the test area, realized that the atomic cloud's behavior was erratic, and within one hour Geiger counters on the ship began to record an increase in radioactivity. The plume of radioactive particles in the 28-mile high cloud reached beyond the margin of the prescribed danger zone and fell across the ocean and atolls in a long ovule pattern extending more than 200 miles, its southern fringe touching Rongelap and Rongerik, a streak of heavy contamination bisecting Rongelap and extending out into the ocean toward Utirik (Hines, 1962) (Map 7). Two hundred and thirty-six Marshallese on the three islands, and twenty-eight American servicemen stationed on Rongerik, received considerable whole-body doses of radiation before they were evacuated to Kwajalein.

Those on Rongelap and Rongerik described the fallout as "snow-like". Meanwhile, ninety minutes after the Japanese fishermen saw the cloud and heard the blast, white ash began falling around the Fukuryu-maru. Some of the fishermen suggested that the cloud and light they had seen on the horizon perhaps meant that the Americans had resumed their testing, but none apparently connected the ash-like substance falling around them



Map 7. Pattern of fallout after Test Bravo, March 1, 1954.

Source: Hines (1962)

with the test (Hines, 1962). Some even tasted the material in an attempt to try to identify it. They made their way back across the 2,000 miles of Pacific Ocean to their home port of Yaezu in Japan. Their arrival there on March 14 created panic. While the Marshallese and the Americans had been under medical supervision since the day of the accident, the Japanese fishermen had been living for two weeks in a contaminated vessel at sea without medical care. They ended their voyage frightened and with severe radiation burns, loss of hair and other symptoms of radiation sickness. One fisherman died on September 23, seven weeks after being exposed to the fallout.

The first official word from the United States Atomic Energy Commission (USAEC) in Washington regarding the accident came in a laconic announcement on March 11.

> During the course of a routine atomic test in the Marshall Islands, 28 US personnel and 236 residents were transported from neighbouring atolls to Kwajalein Island according to plans as a precautionary measure. The individuals were unexpectedly exposed to some radiation. There were no burns. All are reported well.
> (NYT, 3/12/1954:1)

This statement was published unchanged in many other Pacific newspapers (SMH, FT, HA). As the days went by in March and the story became clearer the press continued to play down the severity of the radiation exposures with statements concerning the harmlessness of small doses of radiation.

> Exposure to mild radiation is not necessarily dangerous. Reporters last spring were within two miles of an atomic explosion at the Nevada proving grounds and later walked to "Ground Zero". Instruments showed that they were subjected to some radiation, but no ill effects have shown up.
> (NYT, 3/12/1954:1)

Even with eye-witness reports from Kwajalein of the Marshallese suffering from burns, the New York Times continued to pay little attention to the accident, and to emphasize the technical achievement of producing such a powerful weapon.

> We are highly pleased with the bangs. The test (of a thermonuclear bomb) in 1952 obliterated a whole island and ripped a crater in the floor of the Pacific big enough to hold 140 buildings the size of the U.S. capitol.
> (Republican senator from New York State, Chairman of the Joint Atomic Energy Committee, NYT, 3/14/54:38).

The same was true of the Australian press. The Sydney Morning Herald (3/13/1954:3) gave more prominence to articles on British and United States plans to develop atomic power stations, and to the new Australian nuclear research efforts, than to the plight of those exposed on Rongelap.

The exposure of the Marshallese and Americans was, in general, reported rather indifferently by the press, but the news of the exposure of the Japanese fishermen brought forth more concern. The New York Times gave details of American efforts to send medical experts to Japan, but continued to emphasize military and scientific achievements in the nuclear field. One article (NYT, 3/17/1954:1) was entitled, "Atom smasher sets record: Japan gets radioactive fish". Meanwhile the San Francisco Chronicle (3/20/54:1) reported concern on the Pacific side of the United States for contamination of fish. Checks were made on incoming Pacific tuna in Seattle, San Francisco and Los Angeles. From the perspective of a mid-Pacific American territory the Honolulu Advertiser emphasized the dangers of contaminated fish and raised the possibility of fallout reaching Hawaii. Hawaiian officials played down the danger.

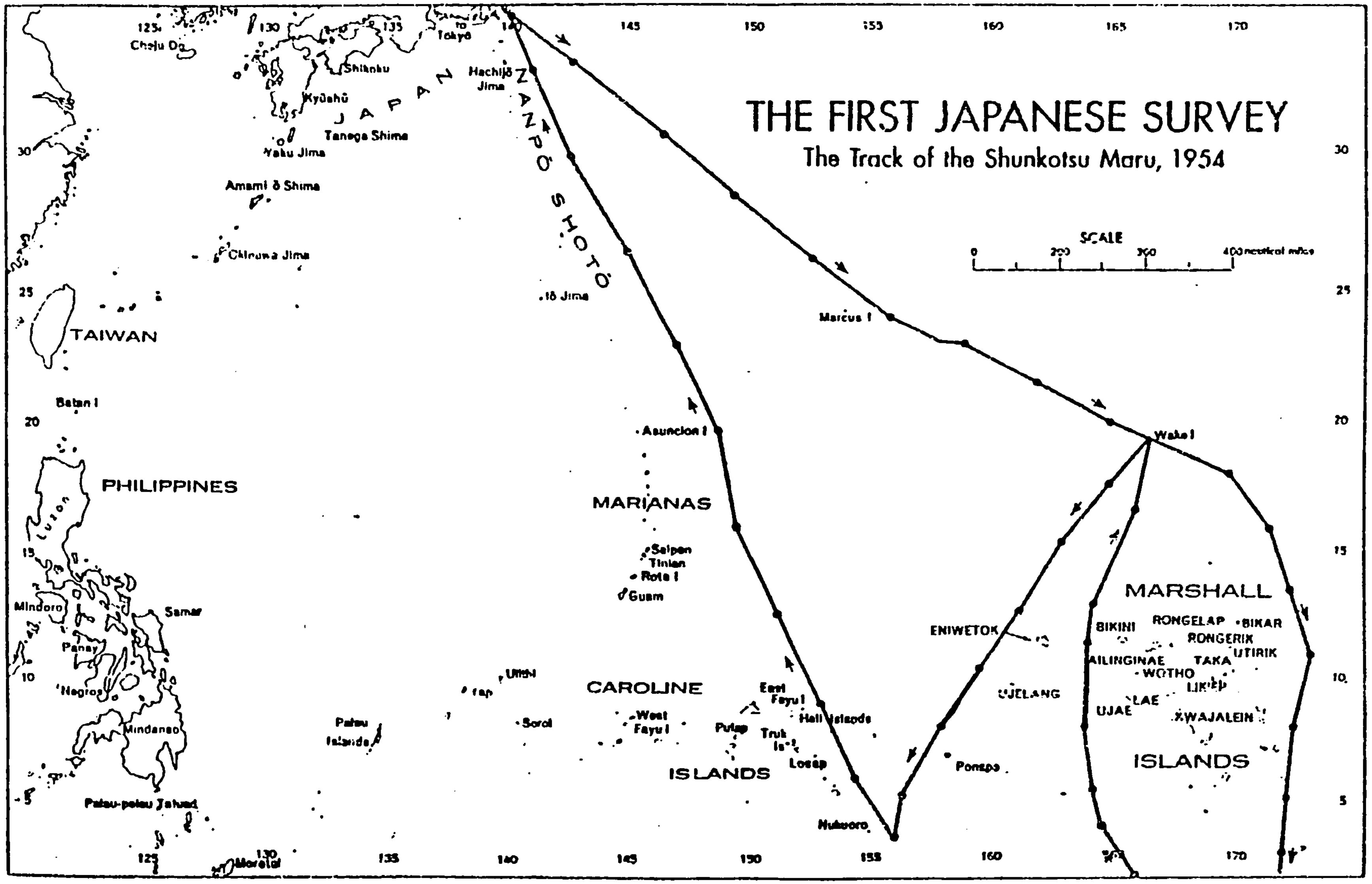
> The possibility of radiological contamination in either the atmosphere or imported marine life as a result of the tests in the Pacific, is extremely remote.
>
> (HA, 3/20/54:1)

Not surprisingly because of the large Japanese population of the islands, there was more sympathy voiced in Hawaii for the plight of the Japanese fishermen. On the whole, however, the American papers conveyed neither the depth of the emotional response, nor the scope of public panic in Japan over the incident.

The Japanese Reaction. The Fukuryu-maru story produced immediate reactions of shock and indignation in Japan. The topic was debated in the Japanese Diet and the United States was asked to pay compensation to the fishermen. The occasion was seized by left-wing groups to stir up anti-American sentiment. Articles in the Asahi Shimbun (March, April, 1954) not only conveyed feelings of dismay from a public still haunted by the horrors of Hiroshima and Nagasaki, but also emphasized how the incident touched a vulnerable spot in Japanese economy and way of life: the fishing industry. When it became known that the Fukuryu-maru's catch had been sold into the fish markets of Yokohama and Tokyo, there began a frantic search for contaminated fish. Thousands of pounds of fish were buried and the price of tuna fish dropped by 50 percent (AS, 3/17/1954). Fish markets were unable to sell many other marine products commonly used in the Japanese diet such as shark-fin, sashimi (raw fish) and kamaboko (fish meal).

The "great worry of the Japanese", as radiation was called, was fed daily in the Japanese press by reports and editorials on the "Ashes of Death" (shi no hai). The Asahi Shimbun gives the impression that at this time the fear had arisen in Japan that the United States was pouring incalculable quantities of radioactivity into the ocean that would present an insidious and cumulative danger. As apprehension grew it came to encompass not only fish brought home by the Japanese fishing fleet, but also the westward moving waters of the ocean. Parents would not allow children to visit Japan's Pacific coast beaches that summer (AS, 4/28/54), and with increasing frequency reports of town assemblies protesting the H-bomb appeared. By April fish dealers in Tokyo had organized a mass meeting to protest further nuclear tests (AS, 4/2/1954). Thus, the politically powerful fishing industry began its anti-nuclear campaign, and even now continues to be one of the chief lobbies against nuclear power development in Japan. No amount of assurance of the safety of the tests by American doctors, or the joint Japanese-American team investigating the incident, could appease Japanese public opinion.

The Japanese scientific community, with the support of government agencies, initiated its own marine survey of the distribution and ocean transport of radioactive materials deposited in the Pacific. A research vessel, the Shunkotsu-maru, was sent to test waters in the Bikini area in April while Operation Castle tests were still in progress (Map 8). Thus, the events of March 1954 in the Pacific set in motion an intensification, on an international scale, of medical and biological



<u>Map 8</u>. <u>The voyage of the Shunkotsu-maru, Japanese survey ship, April 1954</u>.

research related to nuclear fallout and radioactive contamination of the ocean. The 1954 incident had created an awareness that radioactivity deposited at a point in the vast Pacific could be distributed to the far reaches of the ocean through its natural air and water circulatory systems.

It is interesting to compare this situation with the present (1983), when Japan is planning to dump low-level radioactive waste into the Pacific Ocean. Despite the sensitivity of the Japanese toward radiation risks, the Japanese government has been surprisingly unsympathetic with regard to the concerns of the people of Pacific islands, whose cultures and diet, and possible future economic potential, are as marine-based as Japan's.

The global scale of fallout from weapons tests in the 1950s was not only realized in the scientific community, but also by the general public, and the topic dominated reports in Pacific newspapers. The Asahi Shimbun (3/21/54) and the Sydney Morning Herald (3/23/54:1) reported that Kyoto University (Japan) researchers had recorded a higher level of radioactivity two days after the tests at Bikini than at any time before or afterwards. A physicist at the University of Sydney warned of ocean pollution from the tests (SMH, 3/29/54:2).

In Fiji the press was still very colonial and published reports from British papers a week after the news of the Japanese fishermens' injuries appeared (FT, 3/27/54). No emphasis was given in the Fiji

Times to the problem of contaminated fish in the Pacific region.

The Pacific reaction. It was not until April 1954 that the Pacific Islands Monthly for the first time included a meaningful comment on the nuclear testing in the Pacific. Rather than giving an islander's perspective, however, the editorial essay took a view strongly biased by contemporary Australian and Western political sentiment. It was a scathing anti-communist harangue asserting the necessity of holding nuclear tests for the security of the western world.

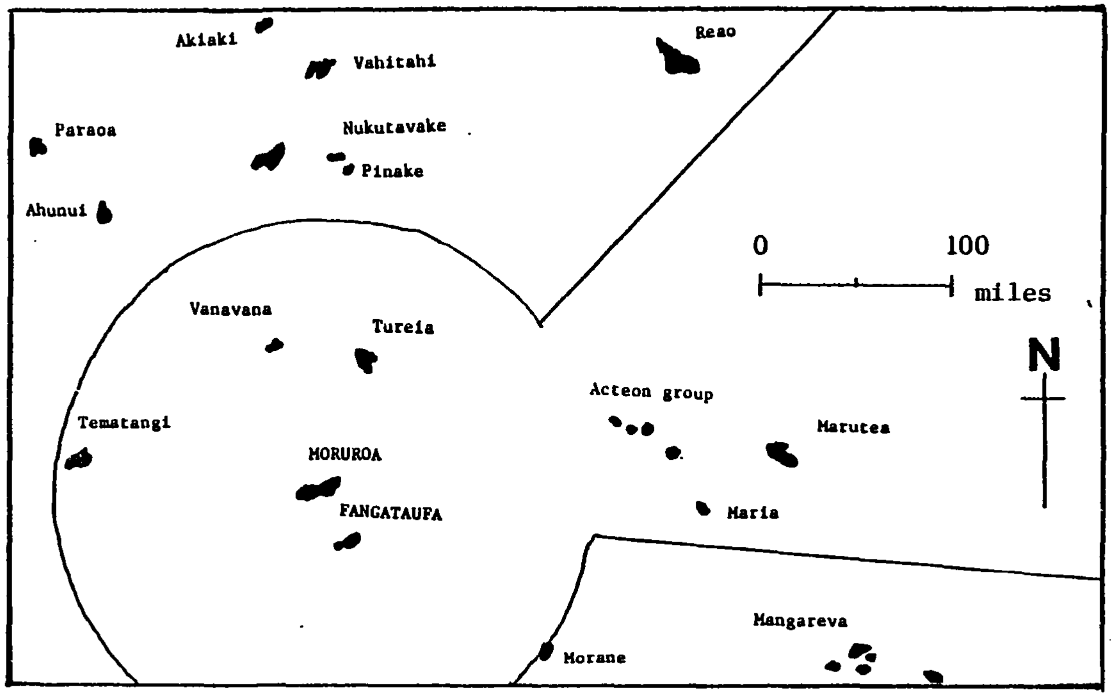
> The terrifying explosion of the H-bomb in the Marshall Islands has started an international scream by all the little people for an end to this lunacy... But it is our continued superiority in this branch of scientific horror, and America's manifest determination to use the new weapons if attacked, that have persuaded the Reds to remain behind their Iron Curtain for the moment... In the view of most Americans, and many millions who are not American, it is better to accept this risk of extermination rather than the certainty that, without these dreadful weapons, we shall be overwhelmed by Red Muscovites and Asiatic hordes... The choice before the Anglo-American leaders is plain: Either the bomb or Muscovite communism - possible extermination, or a certainty of shameful slavery. What real man would hesitate in the choice?
>
> (PIM, April 1954.)

In 1954, this was a far-cry from the anti-colonial sentiment that was to dominate Pacific Island politics in another 15 to 20 years.

4. The first French test at Moruroa - 1966

When the French began their weapons testing program in the South Pacific in 1966, it was apparent in the newspapers that a general change of attitude in the Pacific toward atomic testing had taken place. The atomic bomb was no longer viewed as an exciting scientific achievement. In the late 1950s and early 1960s many events happenied to influence the public view of atomic energy: the Cold War of the late 1950s; Cuban missile crisis (1962); the Test-Ban treaty (1963); the anti-bomb and anti-fallout movements in the United Kingdom and the United States, particularly. The period between 1955-1961 was also a time of substantial press concern over the safety of nuclear power plants in the United states, and the Windscale accident of 1958 in Britain[56] was widely reported. A storm of protests was generated from governments and anti-nuclear groups around the world by the announcement of the first test on Moruroa Atoll on July 1, 1966 (Map 9). French officials in Paris were quoted (PIM, 7/66) as describing the protests as "irritatingly moralizing" (Fig. 26).

The press in Tahiti is strictly controlled by the French government, and consequently very few reports of anti-nuclear activities in other parts of the Pacific are published in La Depeche, the major daily newspaper. In July 1966 La Depeche published official statements from France justifying the test at Moruroa, comparing the French test with the American explosions in the Marshalls and the British tests on Christmas Island, and emphasizing the great distance between Moruroa and Mexico, South America, New Zealand and Papua New Guinea. No mention was made of the Polynesians living on nearby islands. Other than official statements about the test from the French government, La Depeche included a report by the French Academy of Medicine (L'Academie Nationale de Medecine) stating that, in its estimation, radioactive



Map 9. Location map for Moruroa and Fangataufa Atolls, French Polynesia, and the restricted zone around the nuclear test site.
Source: B. and M.T. Danielsson (1974)

"Ah, Messieurs - but you have always maintained that we French are A-moral!"

Figure 26 Irritatingly moralizing protests.

Source: NZH, 7/5/66:8)

fallout from the test was not dangerous and that radiation from the test could be compared with natural background levels. News of radiation hazards elsewhere was also played down. Chilean reports of high radioactivity from the Moruroa explosion was reported in Tahiti, but was said to be below the permissible limit (LD, 7/5/1966). A report on a United States government film "Return to Bikini" was written in a optimistic tone (LD, 7/9/1966:5), but no mention was made of the compensation that the United States was paying to the Marshallese for the 1954 Bikini accident.

Pacific press reports of the explosion on Moruroa emphasized the proliferation implications of the test: the fact that France and China had not signed the 1963 Test Ban Treaty and were the only countries still conducting above-ground nuclear weapons tests.

Another change was in attitudes toward the rights of Pacific islanders. The New York Times (7/31/1954:7) reported at length on the negative economic changes wrought in Tahiti through preparations for the French testing program. Reflecting its new role as an increasingly influential political voice in the Pacific, Pacific Islands Monthly (8/1966) also published a report on the disadvantages to Tahitian society of the "bomb prosperity", describing the vast upheavals in a previously rural and agricultural society, now beset by inflation and over-crowding in Papeete. The changes were so great that Tahitians already spoke of their history as "devant la bombe" and "apres la bombe". Directly beneath this report on Tahiti, Pacific Islands Monthly published a report on the compensation of $10,000 per person that the United States was paying the victims of the 1954 Bikini accident (PIM 8/66).

In Fiji, also, less colonial and more Pacific-oriented reporting was now evident. An editorial (FT, 7/15/66) expressed concern for pollution of fisheries resources of the South Pacific. In Japan fears were revived that "Ashes of Death" would fall from the French test (AS, 7/3/1966:3).

Articles in all papers surveyed reveal that in 1966 there was a much greater public awareness of the health effects of radioactive fallout. An editorial in The Norfolk Islander protested that "no child anywhere in the world can drink milk that is free from radioactive poison" (PIM, 8/1966). The risk of milk contamination by iodine-131, a fission product present in large amounts in weapons fallout, through the grass-cow-milk-human being pathway, was common knowledge by 1966. Public concern over radiation hazards increased as more information became available. In New Zealand after the French test there was a debate over whether the practice of supplying daily milk to school children should be suspended for a certain period (NZH, 7/4/66:3). New Zealand's concern for a valuable economic resource, and for its reputation as a clean dairy producer is evident here, and may be compared to the Japanese concern for the fisheries industry after the 1954 Bikini accident.

Australia and New Zealand were most active in protesting the 1966 French tests in the South Pacific. Several private Australian and New Zealand yachts, sponsored by the Greenpeace organization, have made protest voyages to the restricted zone around Moruroa[57] and trade unions placed bans on the handling of French goods. The culmination of the opposition was a joint Australia-New Zealand petition to the International Court of Justice in the Hague in 1972 (joined by Fiji in 1973), requesting an injunction against the French tests. In June 1973, in the strongest government action taken against the tests, New Zealand sent a warship to French Polynesia, and in the same month, the World Court urged France to avoid nuclear tests that caused the deposition of radioactive fallout on Australian and New Zealand territories. At that time France officially informed the Court that it did not recognize the latter's jurisdiction. France did stop atmospheric testing in 1973, but has continued to conduct underground tests at Moruroa to the present (1983).

5. <u>The accident at Three Mile Island - 1979</u>

The accident at Three Mile Island (TMI) (see chapter I) had a world-wide influence on public opinion concerning the safety of nuclear power. This was partly because of the media propensity to exaggerate the potential catastrophic nature, rather than the successful day to day operations, of nuclear power plants. During the last few days of March and throughout April, 1979, the Pacific press gave full details of the accident and the sequence of events that followed. Certain characteristics of the radiation hazard were clearly emphasized.

Radiation doses received by the public around TMI were small (Levine, 1980), but the adverse psychological effects were great. The accident had a profound effect on commercial nuclear power in the United States, and to a lesser extent, throughout the world.
The TMI accident revived public fears of radiation as a sinister and uncontrollable hazard.

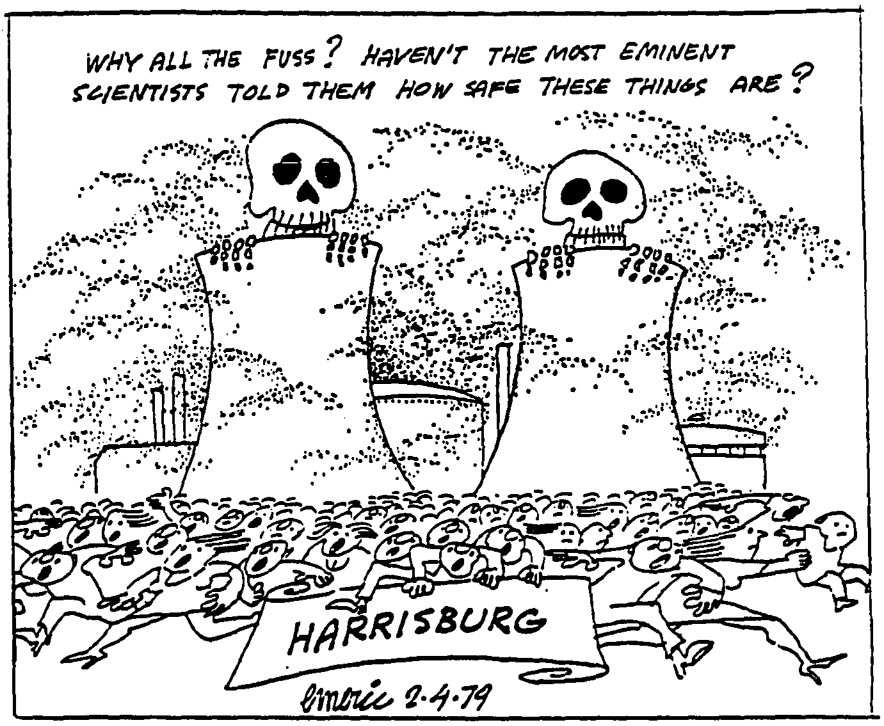
Perhaps one of the most important effect of TMI was that it severely damaged the credibility in the eyes of the public of experts and officials connected with the nuclear industry (Fig.27). Scientific and technical people disagreed in the most polarized way on the basic danger of the accident. As Harrisburg became a battleground for critics and proponents of nuclear power, each side flew in their own experts whose opinions were reported by the press.

> My own measurements on a flight to Middletown this morning were 15 times the normal background radiation from natural sources. This corresponds to a major fallout pattern from a bomb test. (Professor Ernest J. Sternglass, NYT, 3/29/1979:1)

The previous day the same newspaper had included the following statement by an NRC official:

> the amount of radiation that has escaped poses no serious threat to the people in the area.
> (NYT, 3/29/1979:1).

It seemed as though Federal officials, reactor operators, politicians, and scientific experts were offering a profusion of contradictory statements and explanations (Fig.27). Opponents of nuclear power



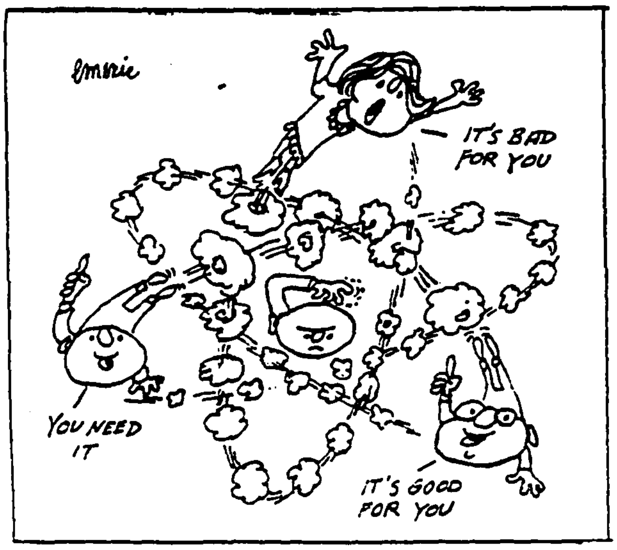


Figure 27 What the experts tell us.
SMH. 4/7/79:17.

condemned the accident as proof that although the technology had thus far maintained a good safety record, catastrophe was eventually inevitable. Proponents of nuclear power hailed the accident as proof that the safety system had worked excellently to avert a major disaster in the face of human and mechanical failures. Who was to be believed? The public does not have sufficient scientific knowledge of such situations to make judgments, and the conflicting reports simply added to the escalating tension and distrust.

Experiments in cognitive psychology have shown that availability, or familiarity, leads to judgmental biases in both professionals and lay people (Tversky and Kahneman, 1974). Availability through news coverage provides a mechanism by which occurrences of low probability may appear more likely than they actually are. This has been shown in studies of perception of causes of mortality (Lichtenstein, Slovic and Fishcoff, 1978). A parallel can be seen when one person dying of a venomous spider or snake bite receives front page coverage in Australia, leaving the public with an exaggerated perception of the risks of dying from these causes, while the risks of smoking cigarettes are relegated to a rare, scientific report on an inside page of the newspaper. The death from a snake or spider bite is immediate, and somehow has a more frightening image than death from lung cancer induced by a history of voluntary smoking. The risks of nuclear power are highly "available" not because many people have experienced them, but because their extensive, and often sensational coverage in the news media keeps them in the public eye. It is clear that, although the end result is the same, some kinds of deaths are viewed as more horrific than others. Risk of death or illness from radiation seems to be far less acceptable than that from other kinds of risks.

The gap between public and expert perception of the risks associated with the use of nuclear power was brought into sharp focus during the TMI debate. The public response to the risks of nuclear power, involving pre-existing images of the horror of nuclear, war was again clear[58].

> What really clinched my opposition to the plant (in Sendai, Japan) was an instinctive feeling that nuclear power and the nuclear bombs that fell on Hiroshima and Nagasaki were essentially the same phenomenon. That was the root of the opposition. It still is.
>
> (Fusaichi Hirano, 65 years old tangerine farmer. Quoted in AS, 5/8/1979:9).

Diametrically opposed to this is the opinion expressed by an "expert", who views a nuclear death as the same as a road death.

> It is inevitable there would be some deaths in the nuclear power industry. But what is one nuclear death to 2,000 road deaths? We have to get a balanced view.
>
> (Professor George, AAEC, quoted in SMH, 3/30/1979:5).

Some say that if the public knew more about nuclear power and radiation risks, opposition would decrease. There seems to be a desire expressed in the media for more information. Several newspapers emphasized the role of public information in responding to nuclear hazards, and some (NYT, SMH) included glossaries of nuclear terms in their reports. An editorial in the Sydney Morning Herald (4/1/1979:2) noted that one of the main problems associated with the TMI crisis was the lack of a cohesive system for channelling information to the public about the emergency. Similarly an Asahi Shimbun editorial emphasized the importance of gaining public confidence by providing frankly all possible information.

> We believe the only way to win the people's confidence in nuclear power development is to make all correct information concerning safety available to the public.
>
> (AS, 4/9/1979:12)

The Los Angeles Times (4/20/79) held a public discussion among nuclear critics, nuclear engineers, and a spokesman for the California Edison electric company, on the accuracy of the nuclear technology portrayed in the film "China Syndrome." The pros and cons raised were almost irreconcilable because they brought very different value judgments to bear on risks and benefits. The publicity given to the nuclear debate, nevertheless, seems to have heightened peoples' fears of radiation hazards in the United States.

The Japanese reaction. The response in Japan to the TMI accident illustrates Japan's energy dilemma well. The Japanese government ordered a safety check on plants that were of the same design as TMI, while the anti-nuclear lobby called for the shut-down of all nuclear plants in Japan. Electric power utilities responded in a very pragmatic appeal to the public. The annual power consumption in Japan rises to a peak in August, the hottest and most humid month in the Japanese summer, when people return from school and work, turn on the air-conditioner full-blast and watch (usually) the high-school or professional baseball tournaments on their large color televisions. The Kansai Electric Power

Company said that if its nuclear plants were closed down, 6.37 million households in the Kansai area would face the "grim prospect" of watching less television and doing without their air-conditioners (AS, 4/15/79:2).

The "nuclear allergy" of the Japanese has been receding in recent years as public sentiment incorporates the concern for Japan's energy needs that arose after the first oil-shock in 1973. The effect of TMI was not strong enough to change this. An editorial in the Asahi Shimbun expressed the position well.

> Whatever damage in public relations may have been done by the TMI accident, the fact remains that nuclear energy is the most promising energy form for Japan and countries of Western Europe not blessed with adequate reserves of fossil energy sources.
>
> (AS, 4/5/1979:12)

In the eyes of the general public in Japan, it seems the benefits of nuclear power outweigh the risks (see above, Questionnaire Results). Japanese group-oriented psyche works exceeedingly well to arrive at a public consensus where issues affecting national security are concerned. The use of nuclear power for Japan's energy security is one such issue. This situation is very different from that of the United States where the public is quite equivocal about the relative risks and benefits, and from Australia, where the public generally acknowledges few benefits. The situation is an opposite one from that of the Pacific Islanders who perceive themselves as receiving none of the benefits and many of the risks through nuclear waste disposal plans. As a counter-argument to this, it has been pointed out that the Pacific Islanders do receive indirect benefits of nuclear power through their use of imported Japanese goods (Wakabayashi, 1983).

6. Two nuclear waste issues - 1979

By the late 1970s nuclear waste had become a subject of general public concern. In West Germany in March 1979, there was a rally attended by 35,000 against the plan to build the underground waste disposal facility in Gorbelen (see chapter III). In the Pacific in 1979 there were two nuclear waste issues that made front page news, bringing the subject more into the public forum than it had ever been before.

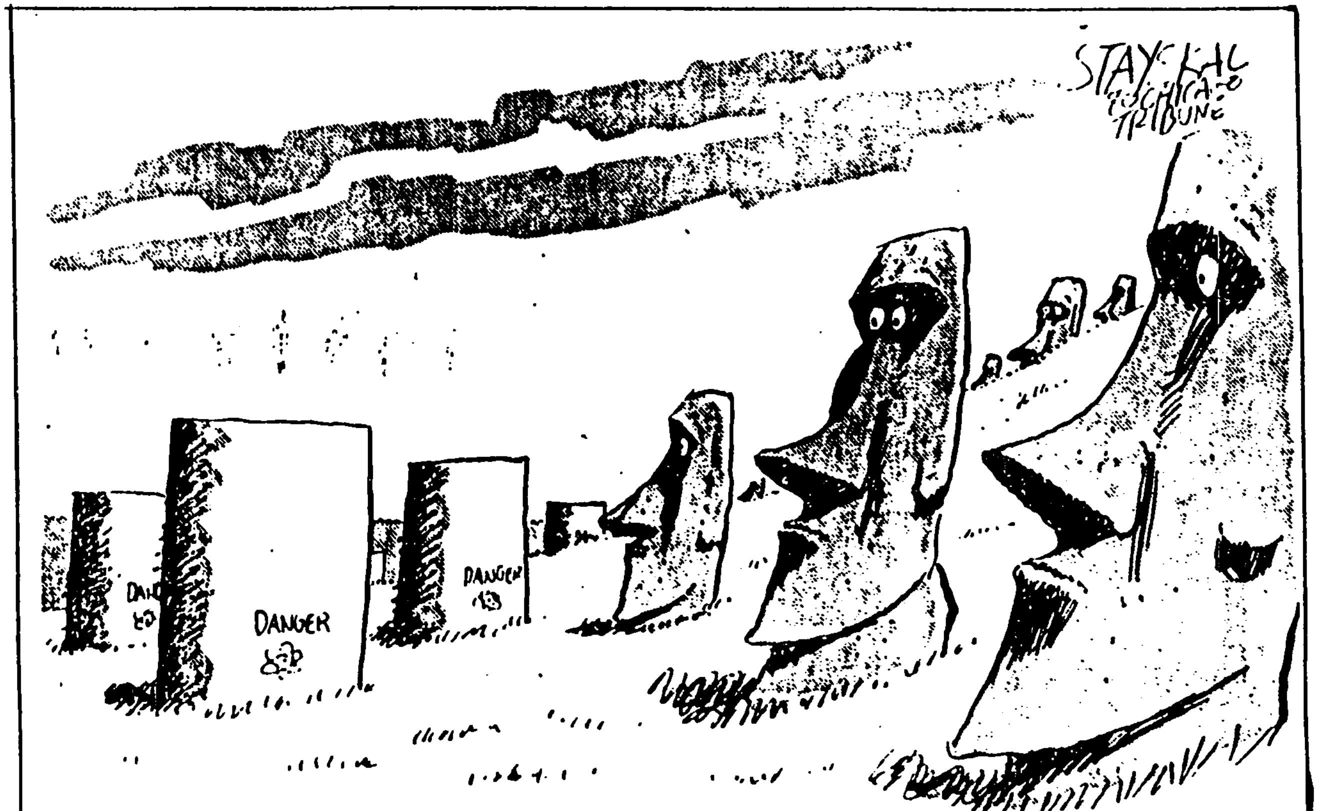
(i) Visit of the Pacific Fisher. The transportation of nuclear waste became a contentious issue when, in June 1979, the Pacific Fisher, a ship owned by British Nuclear Fuels Ltd., carrying 70 tons of nuclear waste for reprocessing from Japan en route to Britain and France (via the Panama Canal), requested permission to dock in Honolulu Harbor to refuel. Environmental groups in Hawaii engaged attorneys and sought a court order to keep the ship out of Hawaiian waters. The appeal was unsuccesful, but the ship was only allowed to dock in Pearl Harbor, a military port, instead of Honolulu Harbour. The State of Hawaii sent a team to examine radiation levels on the exterior and interior of the ship. Leakage was found to be minimal but the incident made headline news in Hawaii for one week, with editorials emphasizing a fact that has become increasingly important in debates on radiation hazards in the Pacific: that Pacific islanders make no distinction among the risks associated with various nuclear activites such as weapons , high-level waste, low-level waste, power plant emissions, and nuclear-powered ships.

> The fact is that many people in the Pacific don't draw the distinctions. For them, anything nuclear is best avoided if possible.
> (HA, 6/10/1979: H-2)

Although the Pacific Fisher was engaged in transporting nuclear waste, no mention was made in the press reports of the comparative risk of transportation versus final disposal, an important concern in comparative risk analysis of nuclear waste disposal systems.

(ii) The Palmyra Plan. In 1979 the United States State Department announced a proposal to study the use of an American-owned Pacific island as a regional storage base for spent nuclear fuel from Japan, other Asian countries and possibly the United States (Fig.28). The plan was part of the Carter Administration's non-proliferation initiatives. A two-year feasibility study was to be conducted jointly by the United States and Japan to investigate the possibility of using Wake, Midway or Palmyra. Attention focused on Palmyra, a coral atoll in the Line Islands group (Map 10)[59] owned by the Fullard-Leo family of Hawaii. During World War II the atoll, which consists of 52 islets joined by causeways, was garrisoned by 6,000 American troops who built an airstrip, bunkers and a road.

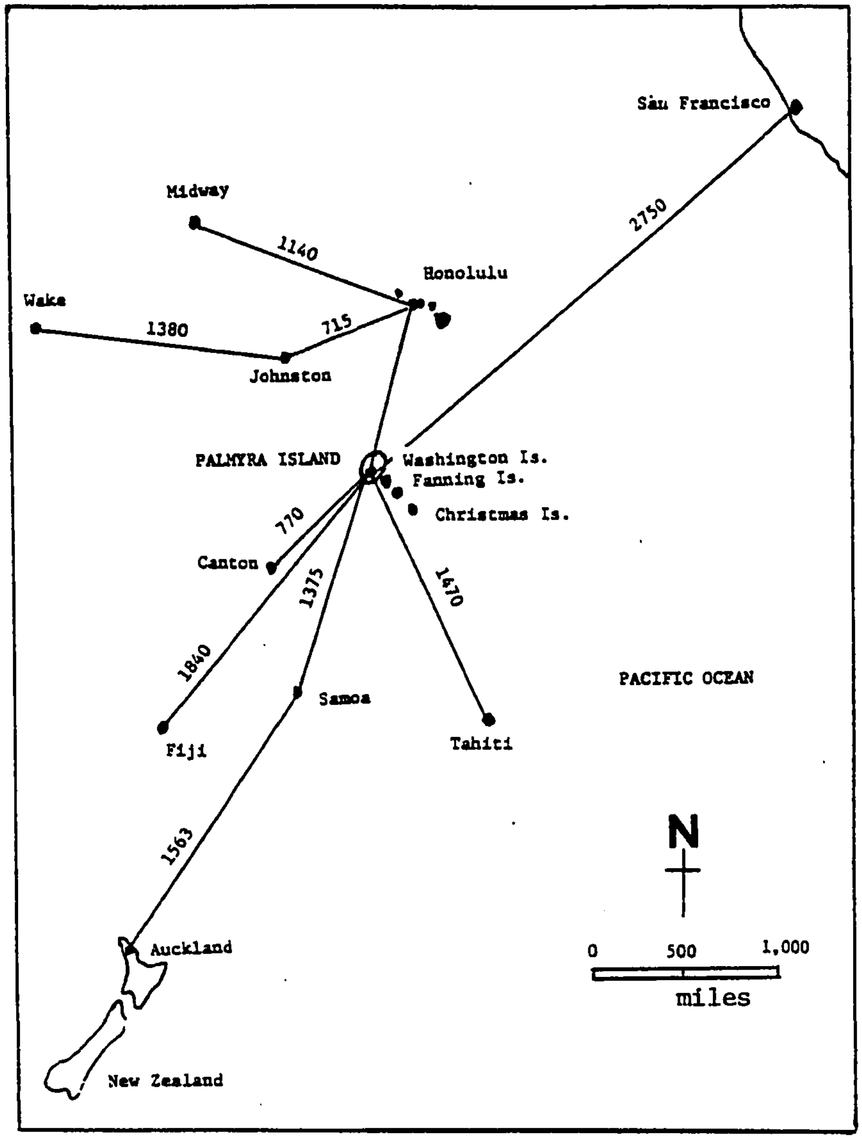
It was proposed that a compacted coral fill platform could be constructed in the centre of Palmyra lagoon (Map 11) on which concrete storage towers would be placed. (Fig. 29). The spent fuel was to be



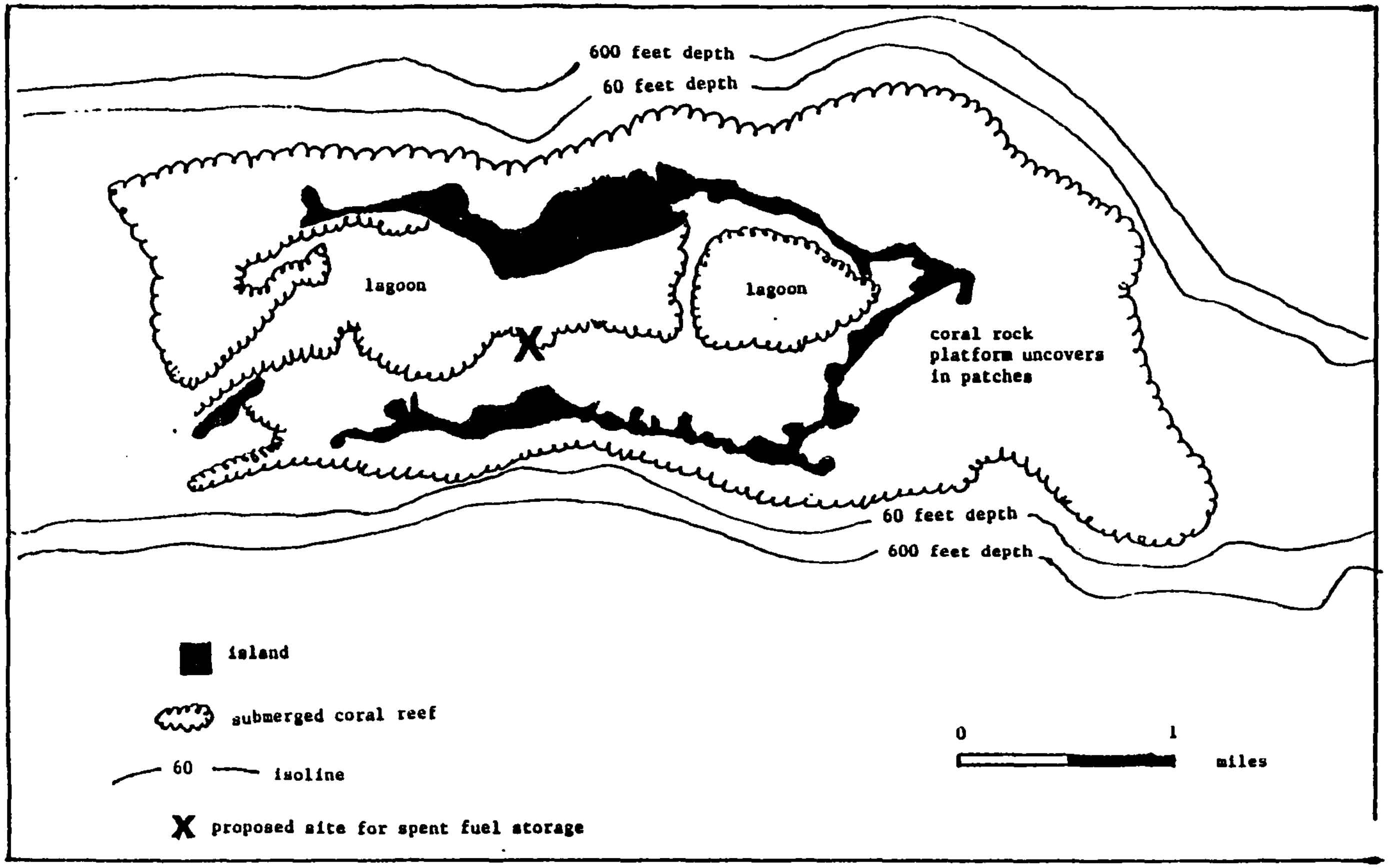
Dumping nuclear waste in 100-ton concrete silos on Pacific Islands.

Figure 28 Island storage.

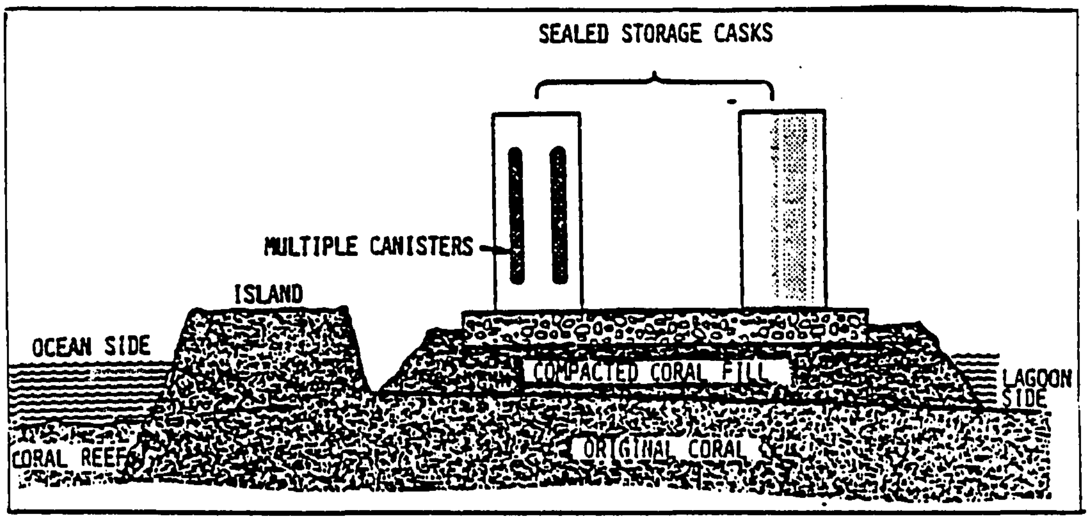
Source: Honolulu Star-Bulletin, 1/24/81.



Map 10. Mid-Pacific location of Palmyra Island.
Source: United States Senate (1979)



Map 11. Proposed site for spent fuel storage, Palmyra Island.
Source: United States Senate (1979).



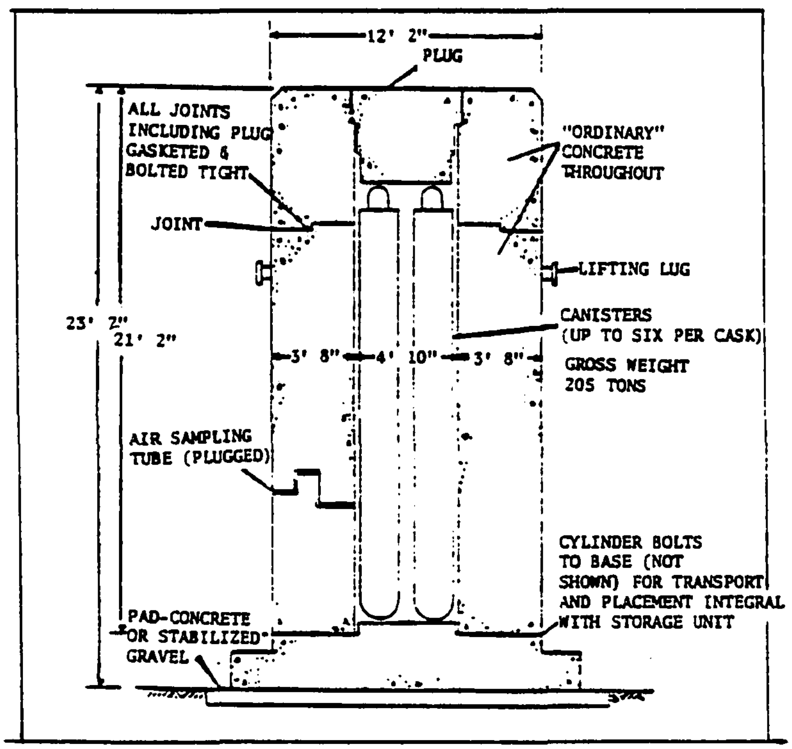


Figure 29 Tower concept for storage of spent fuel on an island.
Source: United States Senate (1979).

stored for approximately thirty years in steel containers and placed in concrete towers erected on the island until a permanent disposal method was found. The estimated cost of the project was $2 billion for storing approximately 10,000-30,000 tons of spent fuel. News of the proposal broke in the Pacific press in August 1979. The Los Angeles Times quoted state Department officials as saying:

> The atoll, rising 6-10 feet above sea level has a good harbor, enough land for airstrips and buildings, tranquil weather and long-term geologic stability.
>
> (LAT, 8/23/80:Sec.I:3)

This contrasts sharply with a statement by Fullard-Leo:

> Palmyra is totally unsuited to the disposal or storage of nuclear materials. We are opposed to the proposal because of the environmental risks it would pose to the Pacific area. It is an extremely high rainfall area with heat, humidity and corrosive salt-laden winds. We have trouble storing anything there. Palmyra's waters feed three equatorial currents, two of which are known to flow west and the other flows east. They are rich in tuna.
>
> (HA, 8/18/1979:4)

The proposal was reported early in Japan (JT, 4/19/1979:2) emphasizing in a rather positive tone the official non-proliferation reasons for helping Asian nations to find a nuclear storage site. The Carter Administration was opposed to reprocessing because this can separate out weapons-grade plutonium. If Asian countries were able to store their spent fuel at a site such as Palmyra, the incentive for governments to invest in reprocessing technology would decline, even though Japan is not considered a proliferation risk at present, and this would lessen the number of reprocessing facilities in the world. This reasoning was challenged when, in early 1980 the International Nuclear Fuel Cycle Evaluation (INFCE) came out in favor of reprocessing for Japan and European countries, and Japan went ahead with its plans to build reprocessing plants.

In August 1979 the United States government made an offer of $18 million to buy Palmyra. The Fullard-Leo family rejected the offer saying that they were opposed to the storage plan. Negative reports of the Palmyra proposal appeared in Sydney Morning Herald (8/21/1979:1), where the Fullard-Leo rejection of the $18 million made headline news: "Paradise is not for sale". A letter to the editor in Los Angeles Times (8/28/1979, part II:4) expressed strong opposition to "polluting unspoilt Pacific islands" and calling the Palmyra proposal a "ridiculous plan." A United States senator (J. Bennett Johnson, D. La) raised the issue of transportation risks. What happens if a ship sinks carrying spent fuel to the island?" (HA,8/18/1979:4). Marvin Moss of the Department of Energy replied that if the casks were not recovered from the ocean bottom one would certainly have the makings of certainly a severe accident. Large quantities of radioactivity would be released into the floors of the ocean.

The Tenth South Pacific Forum meeting in Honiara in July 1979, passed a resolution strongly condemning any move to use the Pacific as a dumping ground for nuclear waste and expressing grave concern about the environmental hazards.

> Noting the proposal currently under examination by the United States to store its spent nuclear fuel in either Midway, Wake or Palmyra in the Pacific;
>
> Believing that in a continental area such as the United States, leaching of nuclear waste would be less likely to be an environmental hazard than in the case of an island, such as Palmyra, with a mass of moving water containing marine resources in its immediate surround;
>
> Bearing in mind their determination to protect the livelihood of their peoples and the Pacific environment;
>
> Express their grave concern at the possible environmental hazards in the event of the Pacific becoming an international dumping ground for nuclear wastes notwithstanding that the expressed intention of this proposed measure is to further limit the possibilities for the proliferation of nuclear weapons;
>
> Strongly condemn any move to use the Pacific as a dumping ground for nuclear wastes, urge the United States to store its nuclear wastes in the United States continent and request the chairman of the Tenth South Pacific Forum to convey this resolution to the government of the United Sates of America.
>
> (South Pacific Forum Bulletin, July 1979)

The decade of the 1980s began with protests against nuclear issues all around the Pacific. The 1980 series of French tests at Moruroa aroused bitter protests from Australia, New Zealand and the Pacific Island states. The Fiji Times was one of the first newspapers to include an accusation that France had exploded a neutron bomb (3/26/80:3). The Palmyra plan received sporadic attention in editorials and letters throughout 1980, and the issue of the return of the Bikinians and Enewetak people to their homes was a much debated subject. Fiji was critical of the Chinese missile tests in an area to its north-west. In the 1980s the newly independent island nations have shown feisty opposition to the continuance of nuclear activites of the former colonial powers in the Pacific "backyard". The islanders perceive the benefit-risk ratio as unfavorable to them, and this at the heart of the opposition.

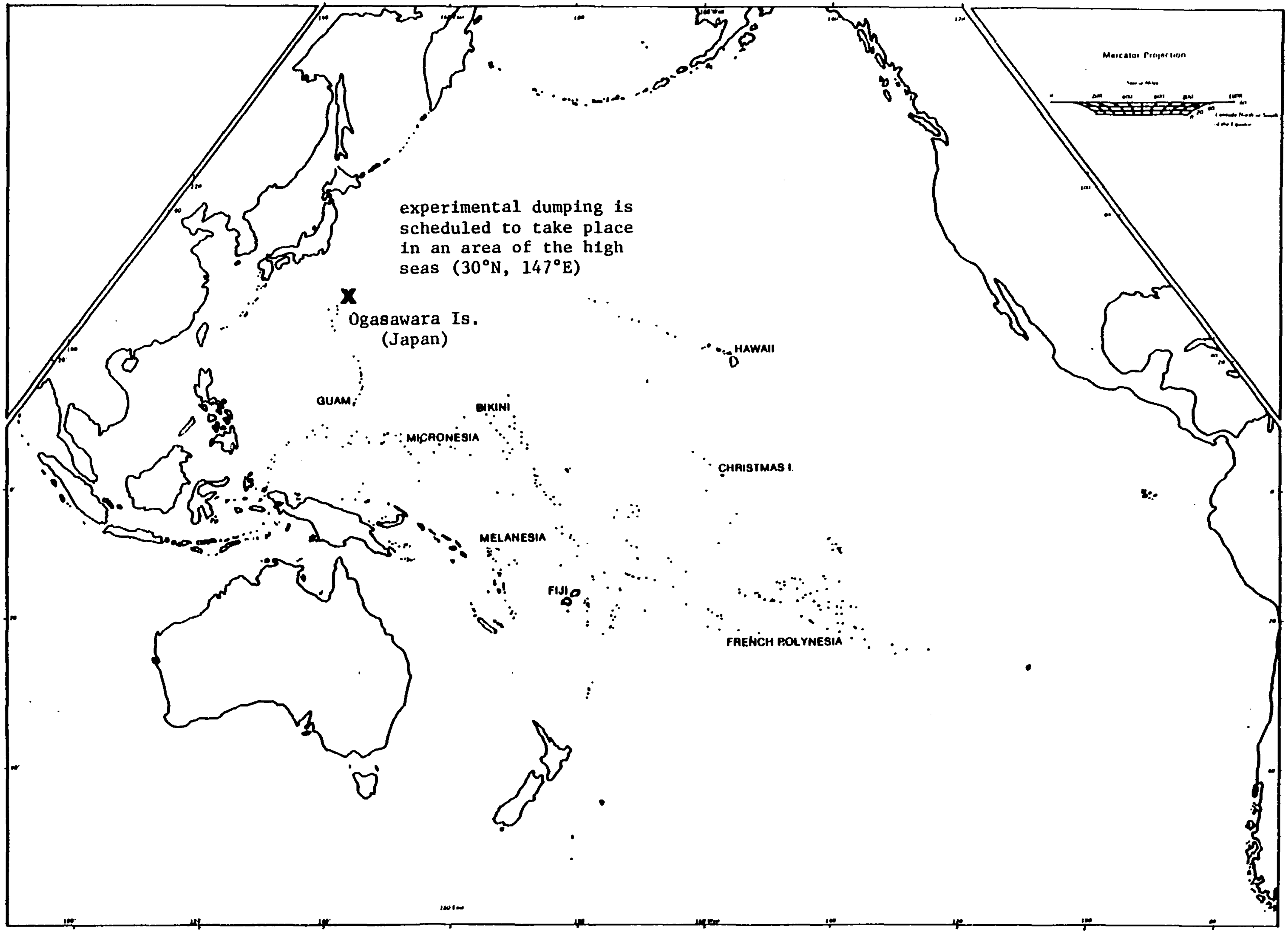
The nuclear issue has become a rallying cause for the people of the disparate island states of Micronesia (who had already suffered from radiation hazards), Polynesia (who were realizing the dangers inherent in French testing), and Melanesia (who were determined it would never happen to them), and an opportunity to show unity and test their political muscle in opposing the OECD powers. The nuclear issue is inextricably entwined with the independence struggles of the island nations, particularly in Micronesia, and French Polynesia (see Chapter VI). The _Pacific Islands Monthly_ has been particularly thorough in its reporting of nuclear issues since the late 1970s. It is now unusual to find an issue that does not include a report on some nuclear topic relevant to the Pacific. Most Pacific island leaders read and respect this journal, and therefore the information it contains and the attitudes it presents can potentially influence the political stance of island countries.

7. The Japanese dumping plan - 1980

The most recent nuclear "hot potato" is the Japanese plan to dump low-level radioactive wastes into the Pacific. The Pacific press took up the story with great enthusiasm in 1980. The Japanese planned to conduct an experimental dumping of 5,000-10,000 drums of low-level waste at a depth of 6,000 meters in international waters just to the east of Japan's marine jurisdiction in the Ogasawara (Bonin) Islands (Map 12). The Ogasawaras are volcanic islands 600 miles southeast of Tokyo, half-way between Japan and Guam. They are now Japanese territory, but the population is racially mixed, being descendants of mariners from New England, Hawaii, the Philippines, Africa and Japan. Japan asserts that the London Dumping Convention of 1972 (see Chapter V) permits such experimental dumping (Radioactive Management Center, 1980), and further emphasizes that Britain still continues to dump in the Atlantic and that the United States dumped radioactive waste into the Pacific and Atlantic between 1951-1962 with no harmful effects.

The Japanese dumping plan caught the attention of many active Unions, as well as local anti-nuclear groups spearheaded protest movements in various countries. Labor Union representatives meeting in Nadi in November 1980 proposed a ban on all Japanese and French goods, and the Japanese unions expressed their support for the move (FT, 11/13/1980:2).

By 1980 nuclear waste disposal within the continental United States had become a hotly debated issue with the compact agreements under negotiation[60]. An article in the Los Angeles Times (7/2/1980, Section 8:5) gave a thorough background history of ocean disposal options for both low-level and high-level waste. The Japanese plan must have seemed to many Americans just one more problem in a line of nuclear waste issues. The American papers showed support for the islanders' protests,



Map 12. Location of proposed Japanese experimental dumping of low-level waste. Information provided by Radioactive Waste Management Centre, Tokyo.

a difference from the reporting of the Palmyra plan. The New York Times (10/5/1980:13) took up the cause of the islanders with a lengthy and sympathetic report by Robert Trumbull. The Honolulu Advertiser monitored the protests from Pacific island states, particularly from Kiribati and the Commonwealth of the Northern Marianas (HA, 8/3/1980; 8/17/1980:13). The South Pacific Forum meeting in Tarawa in July 1980, again voiced strong opposition to Japan's disposal plans (Fig. 30).

In a move to gain a consensus on the issue, the Japanese government sent a four-man team of scientists from the Atomic Safety Unit of Japan's Science and Technology Agency on a public relations tour of the South Pacific. The Asahi Shimbun reported (8/12/1980:2) the departure of the Japanese scientific team, but it is interesting to note that just at the time when the scientific team was touring the Pacific trying to persuade western Pacific nations of the safety of the dumping plan, ironically the Japanese government and public were up in arms over the intrusion of a damaged Soviet nuclear submarine, which might contaminate Japanese waters with radiation leaks[61]. Protests by Gensuikin (Japan Congress Against H and A Bombs) against plans to build a reprocessing plant on Yaeyama Island in the Ryukyu chain of southern Japan, also received more attention in the Japanese press than did the dumping plan. Low-level waste disposal in the Pacific Ocean was not a headline issue for the Japanese press, except in Ogasawara where the fishing community threatened to blockade ships carrying the nuclear waste. In August and September 1980 the Japanese team visited Guam, Australia, New Zealand, Fiji, Papua New Guinea and Western Samoa. A second team was sent in

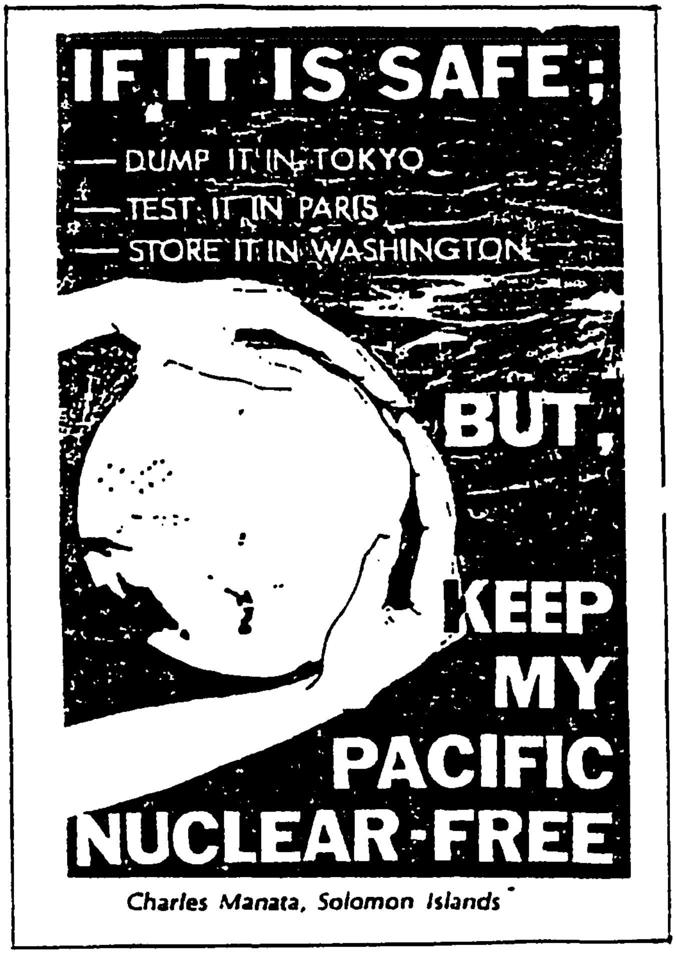


Figure 30 Not in my backyard!

November to the Cook Islands, Niue, Tonga and Tuvalu. The antagonistic reception that the tour met in most countries is an indication of the unity of feeling in the Pacific over the issue. In Guam the Japanese team ran into blunt questioning from Micronesian leaders who had gathered there for the Pacific Basin summit conference.

In Suva, Fiji, a crowd of 500 students and community leaders protested the visit of the Japanese scientific team. A letter to the Pacific Islands Monthly by a University of the South Pacific student expresses well the concern for uncertainty relating to the risks of disposal:

> The Japanese claim that such waste will be of low radiation level and therefore quite safe. My question is: if such an assertion is true, then why is it that Japanese scientists will minitor the dumped waste? Does this not clearly show their uncertainty and that they are still experimenting? And indeed if such waste is of low radiation level, why doesn't Japan dump it off its coast?
> (PIM, 11/1980:9)

Papua New Guinea politicians were the most outspoken of the island leaders and the Post Courier carried front-page coverage of the Japanese dumping plan and tour of the scientific team during most of August and part of September. PNG Councillor John Kosi referred to the economic resource question as he rebuked the visiting Japanese team:

> We don't have to be scientists to know whether marine life will be affected by this experiment. The tuna fish industry may become unviable.
> (PC, 8/26/80:9)

So far scientific calculations have not persuaded Pacific Islanders that the risks involved in dumping low-level radioactive waste into the

Pacific Ocean are small. The vigorous protests in Fiji and Papua New Guinea reflect fears that a leak of radioactive material would endanger fishing, potentially the most important resource of the new island states. The danger to fishing was raised at the United Nations General Assembly by Fiji in October 1980 (FT, 10/11/1980:3). The situation, in the eyes of the island states, was potentially similar to that of 1954 when Japan's fishing industry was adversely affected.

Australia and New Zealand seemed more sympathetic to the Japanese. Comments by New Zealand prime minister, Mr. Muldoon, exemplify this;

> What the Japanese are proposing is to put this low-level waste in a deep trench in the Pacific, but in accordance with all the rules and safety proposals that have been internationally accepted.
> (NZH, 8/29/1980:5)

The position of Australia's Prime Minister, Mr. Fraser, was similar;

> Australia recognizes the problems Japan faces in disposing of its nuclear waste. Australia opposes the indiscriminate and uncontrolled dumping of nuclear waste in the Pacific, but Japan has assured Australia that its plan would conform to the strictest international standards.
> (SMH, 8/29,1980:5)

Pacific Island nations saw the Australian and New Zealand responses as ambivalent and "soft". In both Australia and New Zealand, however, news of the Japanese plan brought forth some strong public protests, such as a letter from two geologists protesting the plan on the grounds of the geologic instability of the Mariana-Bonin Trench area (SMH, 8/19/1980:6).

Conclusion

The public perception of risks associated with nuclear energy has been largely shaped by indirect experience through the news media. Newspaper accounts of events that have taken place over the past 35 years have disseminated information to the public concerning radiation hazards and nuclear technology. Reporting has been colored by a sensational bias toward anything labelled "nuclear", and has emphasized certain characteristics of radiation hazards. The dread aspect, originating in the connection with nuclear weapons, is the most obvious characteristic. The risks of nuclear waste disposal are seen as uncontrollable, unknown, and long-lived. The unequal distribution of benefits and risks of nuclear technologies is especially emphasized in the Pacific Islands press.

Since TMI information on radiation hazards in news reports has become increasingly detailed and sophisticated. Nevertheless, public opposition to nuclear power, and particularly to nuclear waste disposal schemes, appears to be increasing. This conclusion is supported by the results of public opinion polls and the questionnaire survey. It is too early to tell whether or not the public fear of radiation will diminish with increased familiarity, but the newspaper survey has shown that information is becoming more available. So far, familiarity appears to have reduced peoples' confidence to deal with the risks associated with nuclear waste disposal.

NOTES

47. I am indebted to Professor Yukiko Bedford, Department of Geography, Setsunan University; Dr. Yasuo Noguchi, Geography Department, Bunkyo University; Professor Junjiro Takahashi, of the Department of Economics at Keio University; and Professor Hiroaki Wakabayashi of the Department of Nuclear Engineering, University of Tokyo, for their help in conducting the questionnaire with their students.

48. I am indebted to Professor Andris Auliciems, Department of Geography, University of Queensland, and Professor Arthur Brownlea, School of Australian Environmental Studies, Griffith University for their help in conducting the questionnaire with their students.

49. Both universities in Brisbane have a small percentage of mature-age students, and the sample populations included several individuals in their 30s and 40s.

50. Most of the world's major industrial pollution diseases, resulting from either air pollution or from the ingestion of polluted food and water, appeared first in Japan. They began with the mercury (Minamata) and cadmium (Itai-itai byo) poisonings, and reached critical levels in the late 1960s (McKean, 1981).

51. The major site for hazardous chemical waste in Brisbane, in the suburb of Willawong, has been the subject of much controversy over the past two years because of poor management and leakages of waste into a nearby stream system. The Willawong facility has been discussed by R.D. Carlisle, in "The Disposal of Hazardous Wastes with Particular Reference to the Brisbane Area", (1981).

52. Substitution of the word "radiation", for "nuclear-electric power" in Q.IV(1) would probably have elicited a more emotional response.

53. Attending the Conference on Nulcear-Electric Power in the Asia-Pacific Region, Jaunary 24-28, 1983, East-West Center, Resource Systems Institute, Honolulu.

54. Percentages do not add up to 100% because there were various answers given for (f), "other", the most popular alternative being transmutation.

55. Bravo was detonated with a yield of 15 megatons, 750 times more powerful than the bomb detonated in Operation Crossroads in 1946.

56. A partial meltdown at the Windscale reactor contaminated a large area of farmland. The accident led to the slaughter of thousands of animals, prompted the dumping of large quantities of milk into the Irish Sea, and caused a marked increase in radiation levels over London, 300 miles away.

57. In April 1972 the "Greenpeace III" sailed from Auckland. The boat was rammed by a French naval vessel in July inside the test zone and towed to Moruroa. In March 1973 the "FRI" sailed from Auckland and entered the test zone in May, when it was joined by "Spirit of Peace". In July 1973 "FRI" was boarded by French officials and towed to Moruroa. In May 1974 Australian yacht "La Flor" left Sudney for Moruroa. In December 1981 "Vega", with an international crew from Australia, Canada, and France, entered the prohibited test zone. In April 1982 the Austalian yacht "Pacific Peacemaker" was rammed by a French naval vessel inside the test zone and impounded in Tahiti. For a detailed description of the Greenpeace III voyage see McTaggart (1973).

58. For example, see P. Pahner, "The Psychological Displacement of Anxiety: An Application to Nuclear Energy". In D. Okrent (Ed.), Risk-Benefit Methodology and Application, Proceedings of the Engineering Foundation Workshop, Asilomar, California, University of Los Angeles Press, Los Angeles, 1975.

59. Washington, Fanning, and Christmas Islands, previously of the Line Islands group, are now part of the independent nation, the Republic of Kiribati (see Map 3). Palmyra is outside Kiribati.

60. The Compact Agreements are regional arrangements concerning the disposal of low-level radioactive waste between states that do not have disposal facilities and those that do. The state of Hawaii belongs to the Western Compact that includes California and Washington. Every year Hawaii sends shipments of waste to the state of Washington for disposal.

61. In August 1980 a Soviet submarine that caught fire off Japan's southern coast entered Japanese territorial (12 mile) waters. It was reported that nine crewmen aboard the submarine had died in the fire. The Japanese government at first refused to allow the disabled submarine to enter Japnese waters because it might be armed with nuclear weapons, and could cause contamination of the sea off Japan's coast through a radiation leak. The Japanese Cabinet later ruled that the incident be regarded as "an instance of innocent passage" under international law (Japan Times Weekly, 8/30/80).

CHAPTER V. NUCLEAR POLITICS: JAPAN, AUSTRALIA, AND THE PACIFIC ISLANDS

> The white missionary (at Oenpelli) said that he had at last been sent a copy of the Fox Reports, but had not had time to read the Second one properly; he had tried to explain some of the findings to the (Northern Land) Council but it would take a long time. To translate it into the language of the people, and explain it, would take about five years, he said. He had, of course, three weeks.
>
> Eventually, one of the councillors, Nathaniel, said hesitantly that he supposed it was all right, but he and his people didn't really understand what was going to happen about radiation. Could they control it or not? The missionary said he didn't know, and that the Second Fox Report had said that the traditional owners of the land were opposed to mining. Was that right? More silence. Finally, James said he thought it was very hard for the Oenpelli people to say yes or no because, after all, they didn't have the power.
>
> (MacCallum, "Dr. Strangeloves in Ancient Australia" 1977.)

Who has the power? Whose problem is the disposal of nuclear waste? Scientists present opinions on the risks of radioactive waste disposal based on research. Citizens show a pervading fear of the risks of nuclear waste, and sporadic active concern when the issue is highlighted by the news media. The problem is more political than technical. In the final analysis, it is the politician, under pressure from lobbyists, who has the difficult task of reviewing scientific evidence and assessing the divergent "expert" and "public" views of the risks associated with an energy source.

No one perceives any benefits in having nuclear waste in their backyard. Short-term political costs and benefits are important considerations for legislators and politicians with their eyes on the next election, a situation that is not conducive to the formulation of long-term policy required for nuclear waste disposal.

Japan, Australia, and some of the Pacific islands, have already encountered the nuclear waste hazard on different levels of involvement. These countries have systems of government in which public participation is incorporated, by various means, into the process of policy-formulation. Internal politics are less important under other, more authoritarian, regimes such as exist in Taiwan, South Korea, and the People's Republic of China, where citizens' movements have little or no influence on national policies.

In Japan, where there is strong collaboration between central government and the nuclear industry and a large commercial nuclear energy program, public opinion has had minimal effect on nuclear waste management and disposal policies. Australia, so far, has been involved only in the uranium mining section of the nuclear fuel cycle, and here opposition groups have had moderate and fluctuating effects on the export of uranium and the disposal of low-level waste. In the Pacific islands, where populations are smaller, politics are more personalized, and there is no involvement in the nuclear industry, government and public opinion has recently had a significant effect on nuclear policies in the region, particularly on Japanese waste disposal plans. The balance between pro-nuclear forces and anti-nuclear sentiment in each country has important implications for the feasibility of a waste storage or disposal scheme for the region.

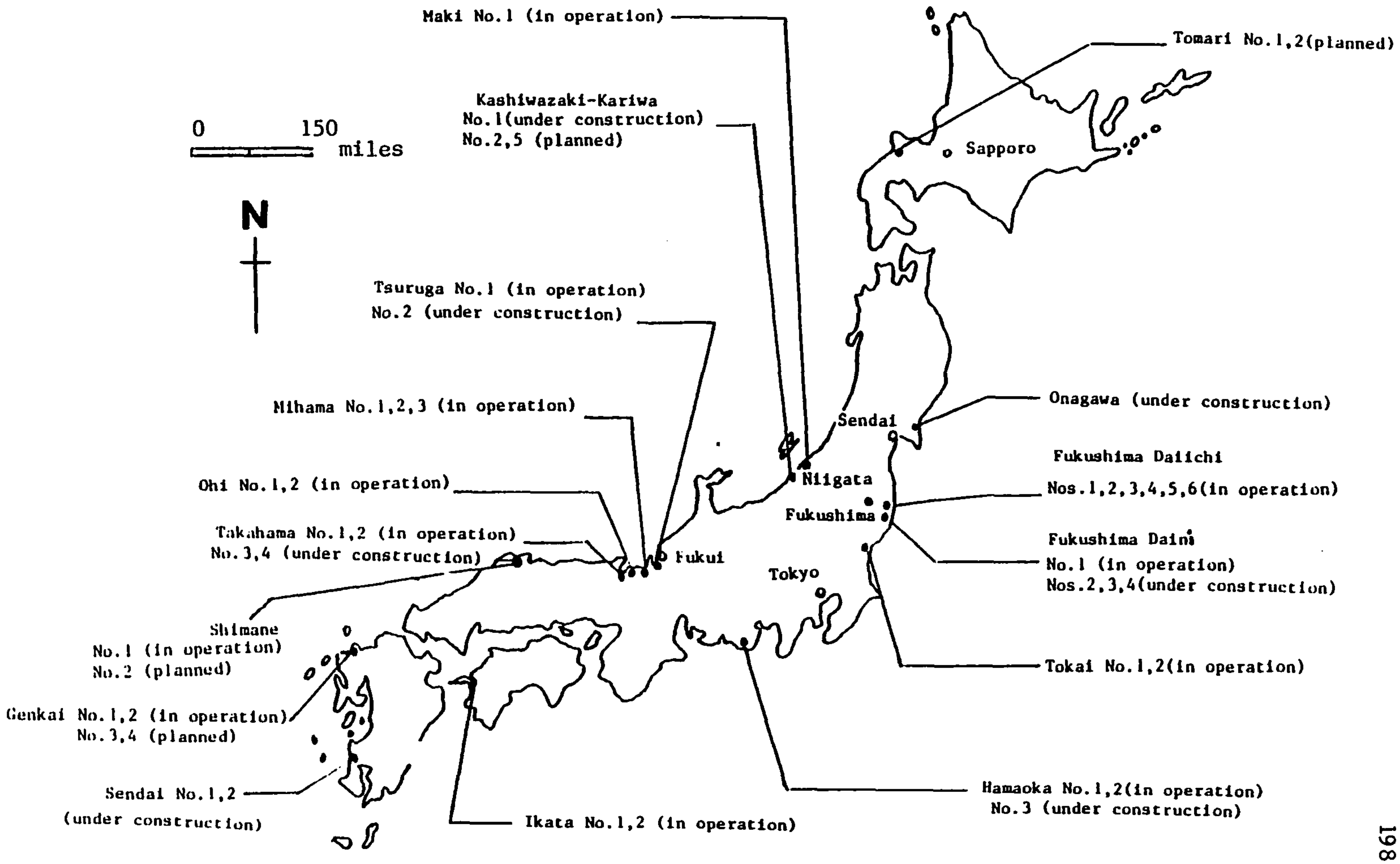
Japan

As a result of the Peace Treaty with the United States after World War two, Japan was not permitted to engage in nuclear activities until about 1955, but despite this late start, the country now has the world's third largest nuclear power program. It has perhaps the most difficult nuclear waste disposal problem, because of its geologic instability and dense population.

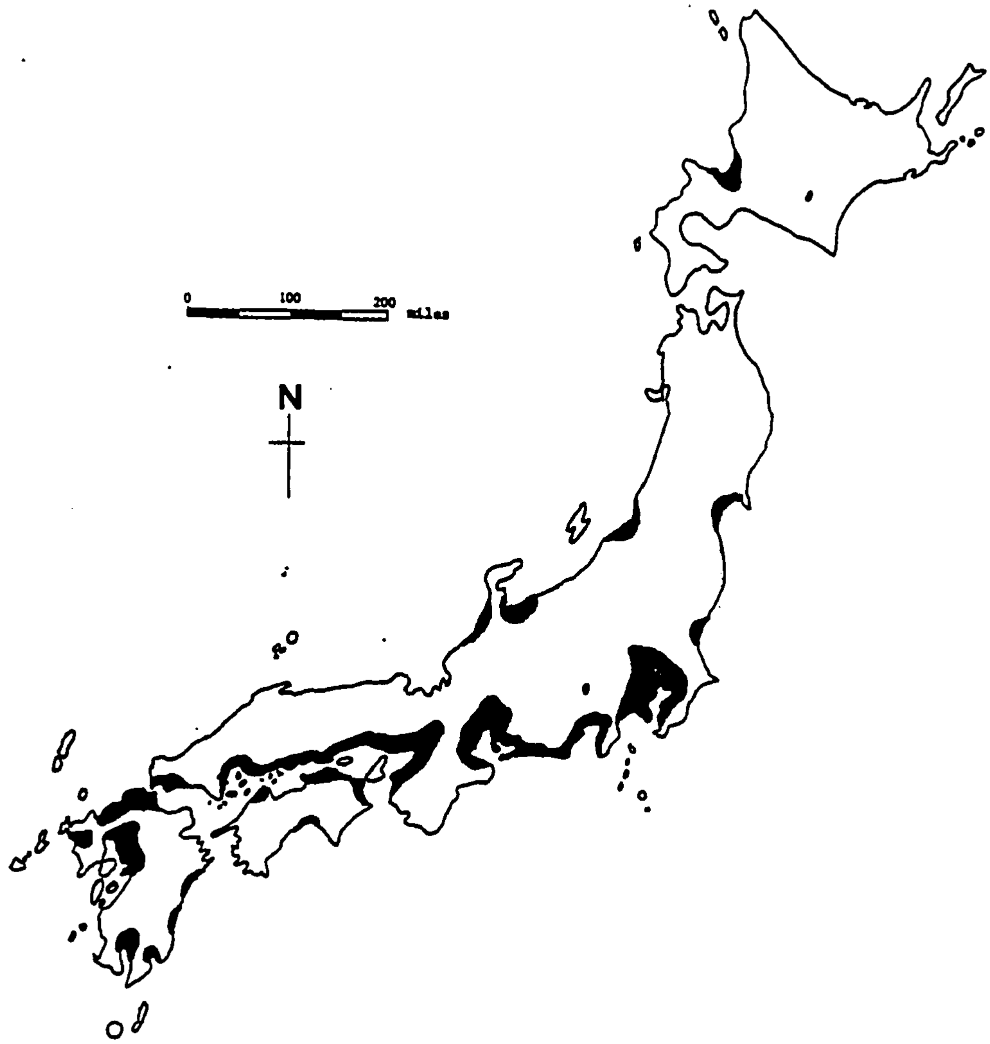
Nuclear power program

The Japanese nuclear power program began with the operation of a small (11 MW) demonstration boiling water reactor at Tokai-mura in 1963. Between 1964-65 eight of the nine electric utilities announced plans to build nuclear power stations, and in 1966 the first commercial reactor began operation at Tokai62. The construction of nuclear plants continued around Japan's coastline throughout the 1970s (Map 13).

The ruling Liberal Democratic Party (LDP), which has been in power for 36 years, has pursued an ambitious program for the development of nuclear power which should be considered in light of the country's basic geographical characterisitcs: poorly endowed by nature with mineral resources, Japan is a technologically advanced, island nation with a population of nearly 120 million people crowded onto the narrow coastal plains (Map 14). More than 80 percent of Japan's energy raw materials are imported, and for oil this figure is 99 percent (Business Week, 1983). The country's continued economic prosperity is contingent upon the availability of secure and reasonably priced energy sources. In the



Map 13. Nuclear Power Plants in Japan.
Source: Murata (1983)



Map 14. Major urban areas and population concentrations in Japan. Adapted from Teikoku's *Complete Atlas of Japan*, (1977).

1970s, from the 1973-1974 "oil shock" onwards, unstable Middle-East supplies underlined Japan's vulnerability to factors beyond its control, and led the Japanese government to press ahead with the development of its nuclear energy program. This has been achieved in traditional Japanese style through close government-private sector collaboration in industrial structure, research and development, siting and licensing of power plants, and in various international activities ranging from uranium acquisition to non-proliferation. The present structure of agencies with nuclear responsibilities in Japan is shown in Figure 31.

In 1983 Japan's 25 operating nuclear power plants produce 17.3 GW which represents 13 percent of the country's electricity generation (5 percent of total energy), (Ministry of Foreign Affairs, 1983). The present government aims to raise this figure to 90 GW, or 30 percent of electricity generation (18 percent of total energy) by the year 2000 (Ministry of International Trade and Industry, 1982). The current international recesssion, increasing construction costs, lengthening lead times between the planning stage to start-up[63] and growing public opposition all mitigate against the achievement of this goal and projections are being scaled down as the plan is continually revised.

Japan has relied heavily on the United States and Europe for nuclear technology in the past, but is moving rapidly toward independence. Over 90 percent of plant and equipment is now supplied by domestic firms (Murata, 1983). Research is progressing on advanced

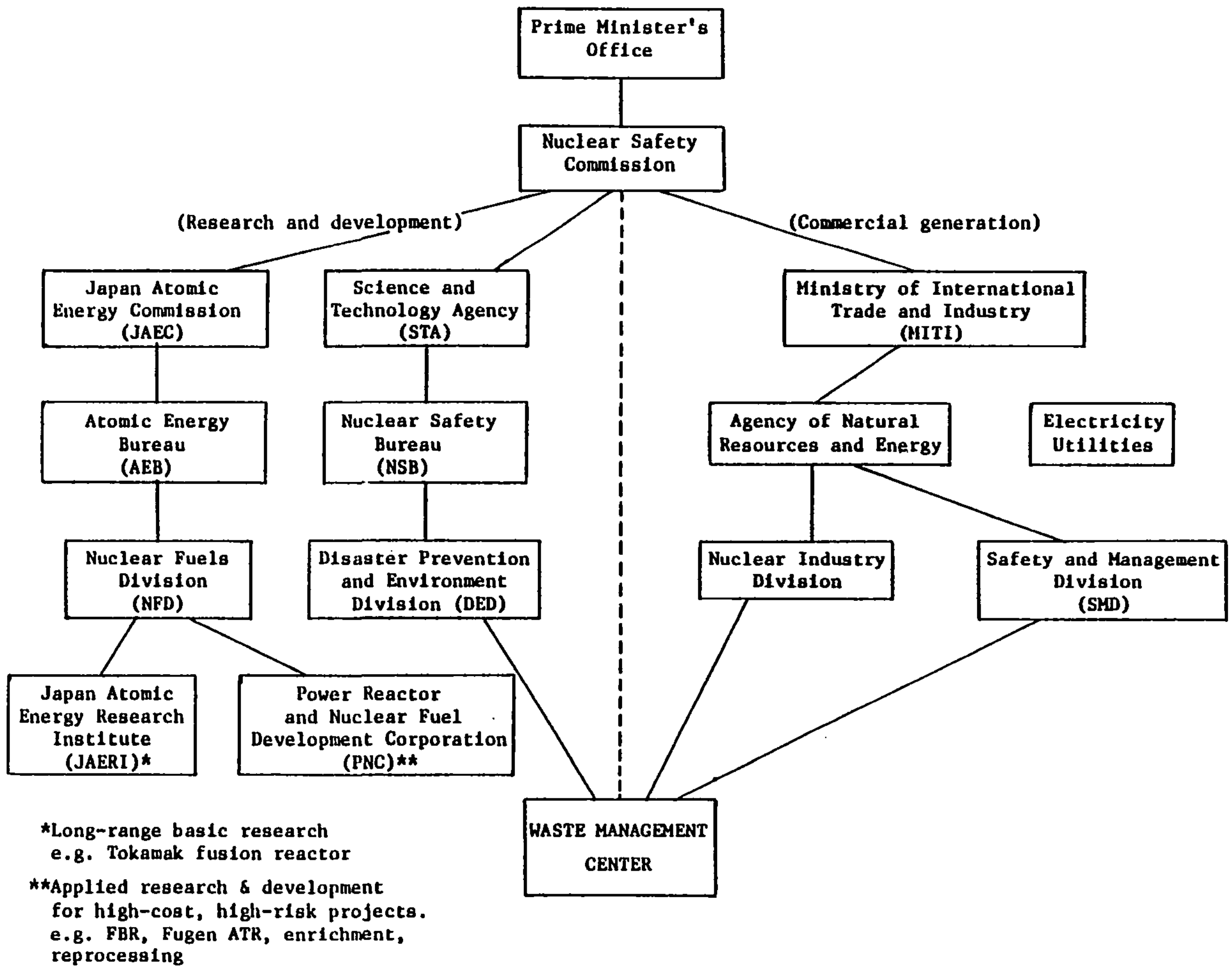


Figure 31. Institutional framework for radioactive waste management in Japan.

nuclear projects such as the advanced thermal reactor (ATR), fast reeder Reactor (FBR), and nuclear fusion, and there is some interest in Japan in using small-scale reactors to supply steam for space-heating and cooling, and for industrial boilers for the petrochemical and pulp and paper industries (Murota, 1983). Pilot uranium enrichment and reprocessing plants already have been established. Reprocessing is a key element in Japan's plan for the development of a domestic nuclear fuel cycle, as plutonium and uranium recovered from spent fuel will be counted as domestically produced energy resources to be used in future ATRs and FBRs. In January 1982 the Japanese government announced plans for a second reprocessing plant to be built and operated by a new private company, the Japan Nuclear Fuel Services (JNFS), which will have responsibility for waste returned under reprocessing contracts from Britain (British Nuclear Fuels Ltd., at Windscale) and France (Cogema, at La Hague)64. Japanese plutonium will be stored in Europe until at least 1990 (Rochlin, 1979). The only plan at present for dealing with the waste returned from Europe is to store it for 30-50 years. Some Japanese nuclear scientists have expressed the opinion that Japan might pay Britain and France to continue storing the Japanese waste held there after the contract expires65.

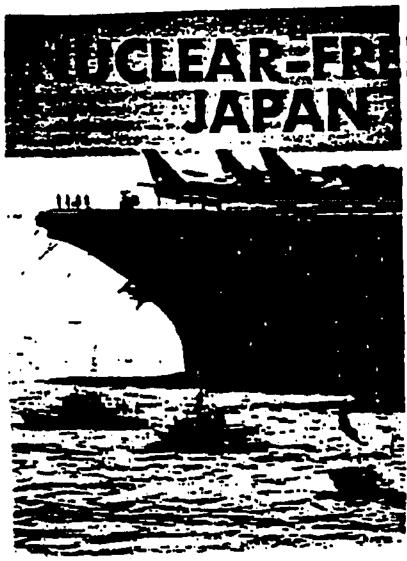
Because of the difficulty in obtaining new sites, Japanese utilities have pioneered the development of "nuclear parks", clusters of power plants at one site. For example, in Fukushima Prefecture (seven units in operation, three under construction); Kashiwazaki-Kariwa in Niigata Prefecture (one unit under construction, two planned); Takahama (two units in operation, two under construction), Mihama (three units in operation), and Ohi (two units in operation) in Fukui Prefecture. This clustering of nuclear power plants in specific rural areas has affected the political success of the nuclear power development program, as explained below.

Anti-nuclear groups

Opposition to Japan's nuclear program has come from well-established anti-nuclear groups within the country, endorsed, and in some cases actually created, by the major political parties (Fig. 32). These groups become visible whenever there is controversy over a nuclear issue in any part of the country, such as the building of a new nuclear power plant, a leak of radioactive material, or the announcement of a waste disposal plan.

The Japanese anti-nuclear movement began after the bombing of Hiroshima and Nagasaki, with small discussion groups led by intellectuals. The remnants of these groups still exist, in the Peace Studies Association of Japan and the Japan Peace Research Association. The Gensuikyo (Japan Council Against Atomic Weapons), the first Japanese peace organization with a national following, grew out of citizens' campaigns, led by fishing communities, after the Fukuryu-maru incident of 1954 (see Chapter IV). It was this incident that made an impact on the general public large enough to create a mass peace movement in Japan, and one that has developed with strong anti-American overtones. In August 1955, announcing that it had gathered 33 million signatures on

Thousands Protest Alleged Presence of U.S. N-Arms



'Public' Hearing on N-Plant Held As 8,000 Protest Construction

Hearing on Takahama N-Plants Opens

Train drivers lead Japan's N-protest

Niigata Fishermen's Cooperative Approves N-Plant Construction

Japanese Fisherpeople's Fight Against Nuclear Power Plants

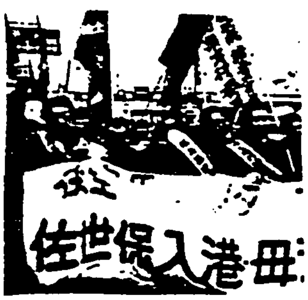
Nuclear Power Industry Exceeds One Trillion Yen Level

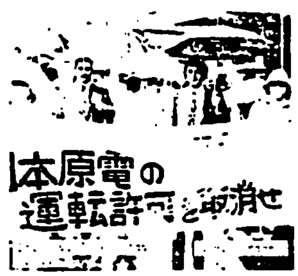
Japan's N-mishap stirs no big furor

Abatement of Allergy

Polls Indicate Notable Changes in Attitudes Toward N-Arms

Pro-Nuclear Mayor Fujito Re-Elected in Kubokawa





Face-Off Over Nuclear Dumping in Pacific

Japanese Road Show Panned in Guam

Japan faces hot time over nuclear waste

Japanese concerned about the lack of storage for nuclear wastes were quoted as saying, "We have built a house with no toilets."

Figure 32. Anti-nuclear movements in Japan.

petitions urging the banishment of atomic weapons, the *Gensuikyo* held the first of what were to become annual peace conventions in Hiroshima, but the populist motivation soon fell prey to political manipulation. The Japan Communist Party (JCP) and the Japan Socialist Party (JSP) seized the leadership and turned the Hiroshima conventions into anti-American rallies, sometimes bringing in Soviet speakers (Jameson, 1983). *Gensuikyo* remains affiliated with the JCP and in some respects is quite conservative, for example in its concurrence with the LDP's program for the development of commercial nuclear power.

Feuding between socialists and communists within *Gensuikyo* forced a split that was formalized in 1964 when the JSP formed its own peace group, the *Gensuikin* (Japan Congress Against Atomic Weapons). The *Gensuikin*, backed by the JSP, which is akin to a European "Green Party" in philosophy, has gradually won support from a broader segment of the community. It is a more radical group than the *Gensuikyo* and opposes both nuclear weapons and commercial nuclear power generation. The ruling LDP officially sanctions the peace movements, but not the anti-nuclear power movement.

The large socialist labor union, *Sohyo* , has supported grass-roots anti-nuclear movements in communities in many parts of Japan, with members receiving small stipends from the union to help defray the cost of travel, food and other expenses incurred while participating in public demonstrations against power plant construction (Edmonds, 1983). Power plant workers belong to the other major labor union in Japan, Domei, which is relatively conservative. Domei has not supported the anti-nuclear power movement.

Religious bodies in Japan have also founded their own peace groups. The Soka-gakkai (Value Creation Society), a politically active Buddhist sect that supports its own political party, the Komei (Clean Government) Party (CGP), has a very active body of young members66. The peace groups in Japan are strongly influenced by the actions of their counterparts in Western Europe and America, with a time lag of a year or two. For example, the United States Catholic Bishops' Pastoral Letter on Disarmament (date) will surely be picked up by Japanese religious bodies in one or two years' time. Most of the peace groups, have turned their attention to opposing the construction of nuclear power plants and plans for the disposal of radioactive waste.

Citizen protests against nuclear facilities in Japan should be viewed in the broader context of the the Japanese environmental movement. The publicity given to major lawsuits over pollution as these went to trial in the 1970s stimulated the government to create stringent environmental legislation, and contributed conspicuously to the expansion of political participation in Japan (McKean, 1981). In the rural periphery the strong sense of community encourages participation, as opposed to the lonely crowd in the cities of the Japanese urban core that stifles it. The rural periphery is exactly where the nuclear parks are located, and citizen protests against the construction of nuclear power plants have forced utilities in many areas into lengthy negotiations with rural communities.

At recent mayoral and gubernatorial elections, the nuclear issue has become important. The first such occasion was in March 1981 when the Mayor of Kubokawa, in Kochi Prefecture, Shikoku, was recalled because he supported the construction of a nuclear plant in the area[67]. He was later re-elected on the same pro-nuclear platform[68], but on the promise to hold a referendum on the acceptibility of a nuclear plant in the township (Atoms in Japan, April, 1981: 10-13). The recall was a blow to the central government's energy policy and after the Kubokawa case, mayoral recall proceedings were initiated in other parts of Japan for similar reasons[69]. To some extent the small citizens' groups scattered all over Japan are linked through the activites of the national peace movements, but local politics are far more important than any degree of identity with national or international anti-nuclear campaign[70].

The JAECs plan for dealing with public opposition hinges upon convincing the public of the safety of nuclear power stations through an accident-free record, a goal which has been thwarted on several recent occasions by accident reports such as the cover-up incident at Tsuruga power station in April 1981[71]. This accident revived the worst fears of the nation's fishermen concerning the damaging effect of rumors of radioactive contamination on local fish markets. In an effort to change negative public attitudes and to satisfy calls for community participation, public hearings on new power plants were introduced in Japan in 1980. The hearings permit only a few selected members of the local community to give evidence, and clashes often occur between riot police and large crowds demonstrating outside the public hearing[72].

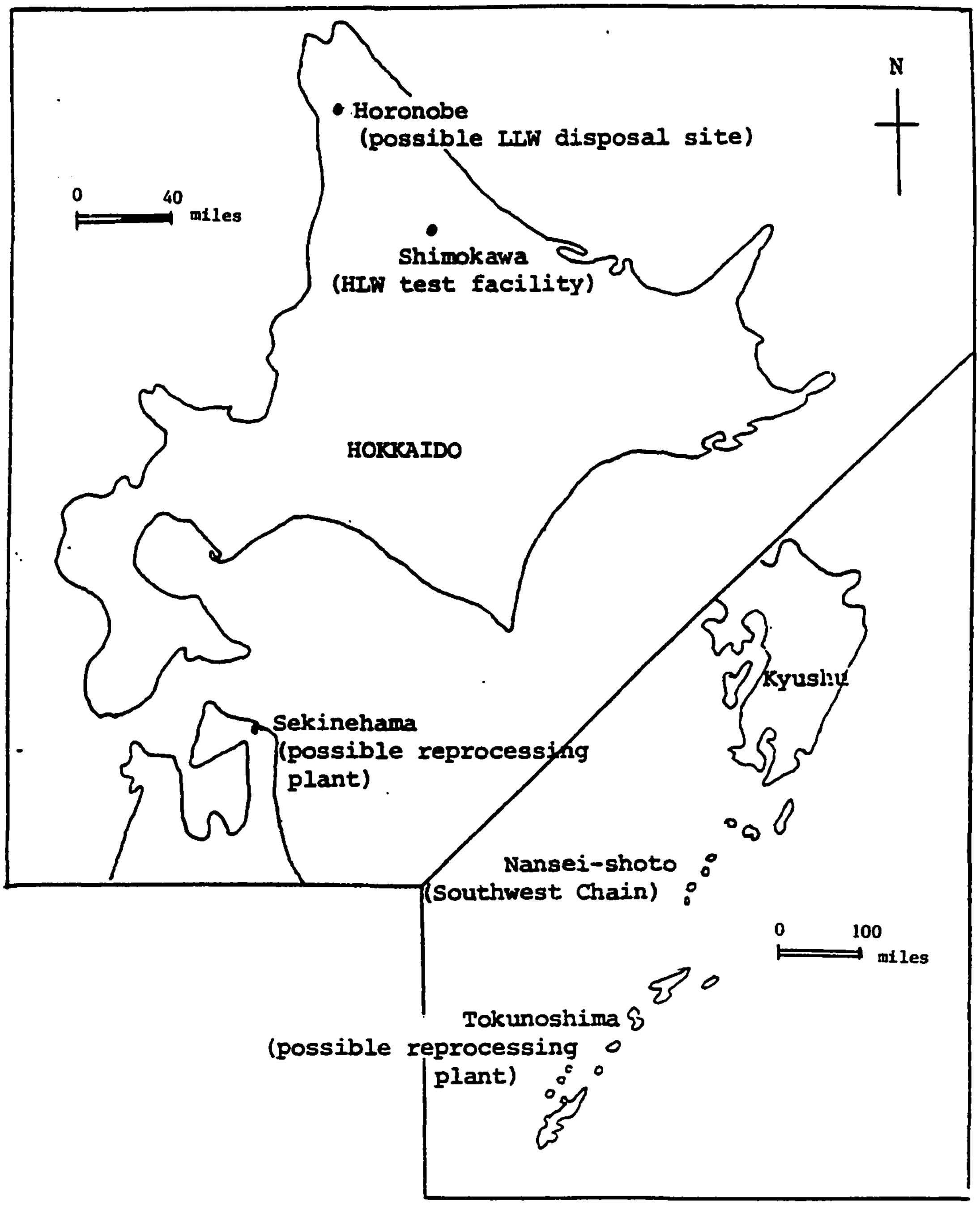
Rather than exemplarizing a method for incorporating public involvement in decision-making, the hearings illustrate the central government's control, through the Ministry of International Trade and Industry (MITI), and the utilities, in nuclear matters.

Japan's nuclear waste

Japan's nuclear waste situation has been described as a "house without a toilet" (Powell, 1983), because Japan has continued to store an increasing volume of radioactive waste while pushing ahead with nuclear power development projects. The 1980 Japan Atomic Energy Commission's report regarding waste disposal was typically vague.

> With a view to working out definite measures for the disposal of radioactive waste, a specialized committee... is deliberating on various options." (Powell, 1983).

Japanese licensing laws require that a plan be established for handling all spent fuel over the life of each reactor (Nuclear Law Bulletin, 11, OECD/NEA), but a plan to send spent fuel to Europe for reprocessing, regardless of what happens to the reprocessing waste is sufficient to fulfil this requirement. A test facility for high-level waste has been established at a disused copper mine in Shimokawa, Hokkaido, (Map 15) by the Mitsubishi company for testing rock strength under heat and pressure stress. Members of the local community were skeptical when told that Shimokawa was merely an experimental site, and would not necessarily be chosen for a final repository (Ogose, 1981).



Map 15. Possible locations of nuclear waste facilities in Japan.

Japan produces approximately 60,000 drums of low-level waste annually (Powell, 1983), and at present this is stored in on-site warehouses at power stations. From the beginning of the Japanese nuclear power program, ocean-dumping was the method envisaged for the disposal of low-level waste. When Japan actually proposed beginning its ocean dumping program in the Pacific Ocean in 1980, there was strident opposition from the Pacific island nations (see Ch.IV). The dumping was rescheduled to October 1981. The Japanese government bowed to protests from around the Pacific and delayed the experiment, again in 1982. Pressure from further afield has also helped to persuade the Japanese government to delay its dumping plans even longer. At the February 1983 meeting of the London Dumping Convention countries[73] a non-binding resolution calling for a moratorium on all ocean disposal of radioactive materials was passed. In July 1983, bowing to this pressure, the Japanese Science and Technology Agency (STA) issued a statement to the effect that, although sea-dumping would not be abandoned as an option, land-disposal in Japan was considered appropriate for low-level waste (Mainichi Shimbun, 7/6/83). This is undoubtedly related to the recent London Dumping Convention resolution on the dumping of radioactive wastes in the ocean.

The Horonobe case

An example of the politics surrounding LLW disposal in Japan is the case of Horonobe in Hokkaido (Map 15). This small town had been chosen in 1982 as the site for a large low-level waste disposal facility, and the local community had agreed on a compensation figure, but the

Hokkaido prefectural government blocked the plan. Hokkaido has traditionally been a pioneer area, much less densely populated than the three other main Japanese islands and with progressive socialist leaders[74]. Hokkaido people have a resentment, typical of pioneer areas in most countries, against domination by the national government. Thus, the opposition to the waste plan could be viewed as political opposition to the ruling national LDP. It seems likely that the Japanese government will try to pursue its plans for disposal of both high and low-level waste in Hokkaido if domestic disposal is required, but the political situation with this prefecture will be difficult to overcome.

Local protests have delayed the siting of many plants in Japan, but nuclear power and nuclear waste disposal have yet to become issues for the national consensus. The average Japanese is more concerned with energy supply than with the hazards of nuclear power plants and nuclear waste disposal (see Chapter IV, Questionnaire Results). Local objections tend to be inchoate and do not go through the national legislature. The Tsuruga accident, Japan's most serious power plant accident to date, was not enough of a disaster to bring nuclear power to the dimensions of a national issue like the Three Mile Island accident in the United States. Unlike in the case of some European countries, Japan's anti-nuclear movement has never threatened to play a role in bringing about a change in government.

Japanese public attitudes toward the "hazards" of nuclear power, are seen by some as more of a desire to negotiate for the highest possible compensation, than a real concern for the risks[75]. Such compensation is not regarded as a bribe in Japanese society, which already has a tradition of formalized gift-giving in business and official circles[76]. The anti-nuclear groups are active and have strong backing from opposition political parties and religious bodies, but so far they have not been able to sway the government from its commitment to nuclear power, nor to convince the unconcerned majority of the Japanese public that the government's nuclear policy is unacceptable. As with the siting of nuclear power plants[77], the acquisition of sites for waste disposal facilities is likely to be successful in areas of the rural periphery where the economic outlook is relatively pessimistic, such as communities that center on obsolete mines, or where nuclear plants already exist, and the economies are to some extent dependent on continuing nuclear construction. If Japan is forced to look for domestic disposal sites for nuclear waste, it seems likely that a solution to the problem will be found through the traditional mechanism of negotiation with rural communities, followed by heavy compensation.

Australia

In Australia official nuclear policies vary greatly according to which political party is in power in the federal government in Canberra. The Australian Labour Party (ALP) has traditionally followed an anti-nuclear policy, while the Liberal-Country Party coalition has been more in favor of developing various stages of the nuclear fuel cycle in Australia.

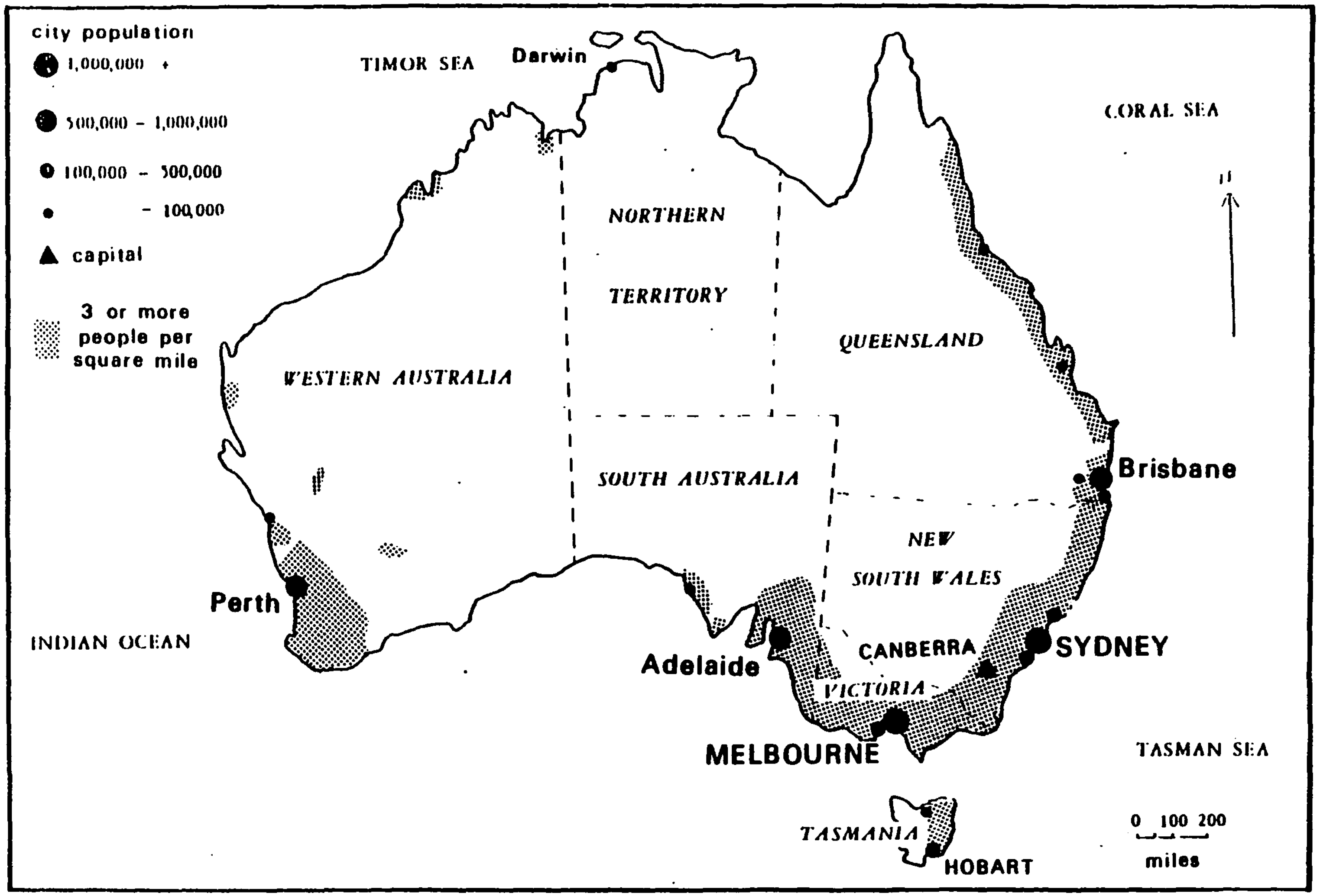
So far Australia has not been forced to seriously consider the nuclear power option for domestic energy supply. With only 0.3 percent of the world's population, the country has approximately 4 percent of the world's technically and economically recoverable black coal, and approximately 7 percent of the brown coal (Wilson, 1983). These coal resources are considered to be more than adequate to meet Australia's domestic needs and allow a significant expansion in its already high level of coal exports (Wilson, 1983). The electricity utilities in the more populous eastern states of Australia have shown little interest in nuclear power. The Northern Territory and Western Australia, states with less abundant coal but large uranium resources, have shown sporadic interest in building nuclear power stations, but in view of the relatively small capacities of their grids it will be a long time before they will be in a position to use a modern nuclear power station efficiently. There is a sophisticated nuclear research program at the Australian Atomic Energy Commission (AAEC) in Sydney that uses a High-flux Australian Reactor (HIFAR) to produce radio-isotopes for medical purposes and to conduct basic nuclear research.

The Liberal-Democratic government under Prime Minister Fraser (1975-1983) was investigating the possibility of developing further stages of the nuclear fuel cycle in Australia. The Uranium Enrichment Group of Australia (UEGA) was formed with Japanese, United States, and European firms to study the feasibility of building an enrichment plant. A proposal from a European consortium was finally accepted by the Fraser government in 1982, but no decision on whether to build a plant was reached. Mr. Hawke, Prime Minister of the present Labor government, has not stated that he will approve the plan. If Australia did build the plant it would be the only country in the world with enrichment capacity but no power plants. With no internal market for the product, the investment of more than a billion dollars is seen as a large risk by some (Robotham, 1980)78.

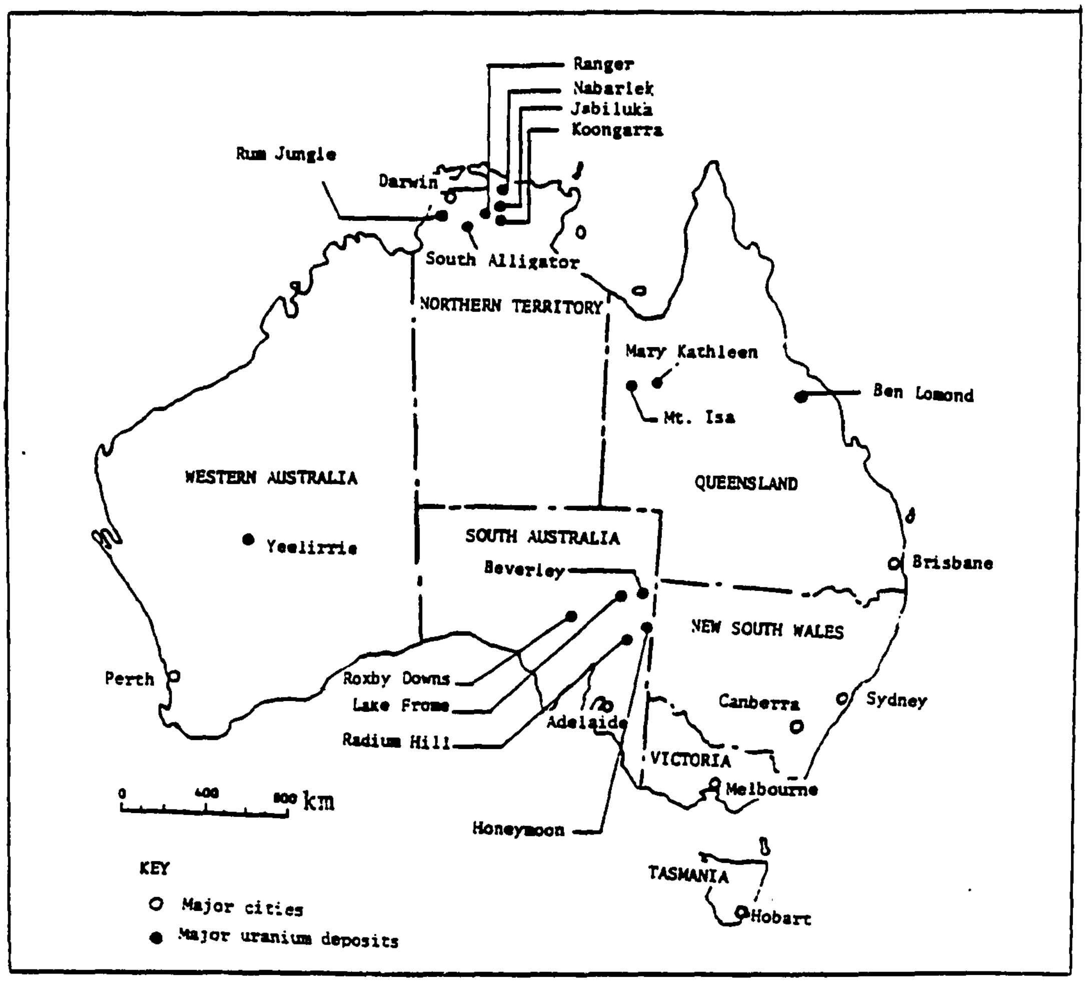
Uranium mining

The source of the major conflict over radiation hazards in Australia is the uranium mining industry. The uranium deposits are situated far from the centers of Australia's very urbanized population (Map 16), but, as with the Japanese nuclear power program, there are groups in rural areas that have both been disadvantaged environmentally, but have benefitted financially from the industry.

As far back as 1894 uranium deposits were recognized in Australia. The first mine began operation at Radium Hill in South Australia (Map 17) in 1906, but the real search did not begin until 1944 when Britain requested the Australian Government to help find uranium for defense needs. In 1947 the government launched an incentive program that included a $50,000 reward for any uranium discovery that became an operating mine. The first important discovery was in 1949 at Rum Jungle in Northern Territory, a preview of the huge reserves that would later be found in that area. In Queensland, Mary Kathleen mine began operating in 1958, and exported uranium until its closure in 1982, to Britain, the United States, West Germany and Japan. In the 1960s there



Map 16. Population distribution of Australia.



Map 17. Uranium mines and deposits in Australia.

was a ten-fold increase in general mineral exploration in Australia involving many overseas companies. The result was the discovery of large new reserves of iron, copper, nickel, and uranium. In the early 1970s new uranium deposits were discovered in South Australia (Lake Frome, Olympic Dam, Beverley), Northern Territory (Nabarlek, Ranger, Koongarra, Jabiluka), and Western Australia (Yeelirrie). The Roxby Downs (Olympic Dam) ore body has been described as one of the world's largest undeveloped mineral reserves containing much copper and gold as well as uranium (Financial Review, 11/11/82:33). According to project operators (Western Mining and BP), it will cost at least $1,400 million to develop (Op. cit.,p.33). The present Labor government in South Australia has justified allowing the project to go ahead by emphasizing the general mineral character of the ore body.

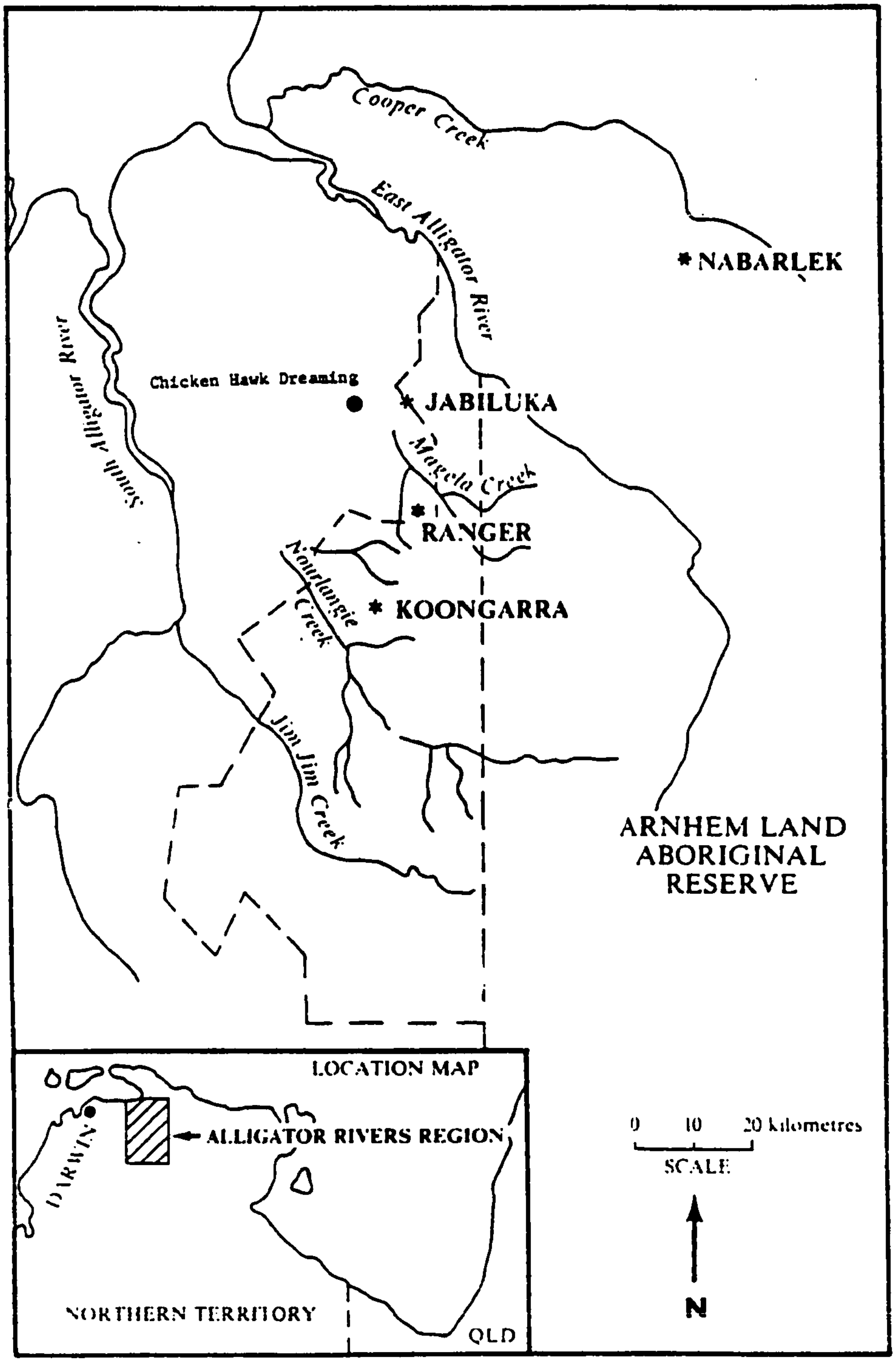
Aboriginal land rights

Controversy over the uranium mining issue is inextricably tied to Aboriginal land rights and the policies of Australia's powerful trade unions. Mining has played a crucial role in the formulation of Australian land rights legislation. In the early 1960s, Aboriginal claims for better working conditions on cattle stations and higher pay brought Aboriginal causes into the public eye for the first time, and later led to land rights claims. In 1974 all Aboriginal reserve lands in the Northern Territory became Aboriginal property and Land Councils were set up (Southern, Central and Northern) to protect Aboriginal interests. These councils have been prominent on several occasions in bitter disputes over pastoral leases and mining rights. Many uranium deposits are in traditional Aboriginal areas particularly in the Northern Territory (Map 18), and often include sacred sites. This has been a problem because the Aborigines are reluctant to tell Euro-Australians where sacred sites are, and there is a grey area between what is sacred and what is simply a gallery of rock paintings.

Australian law separates land ownership from the right to exploit minerals found in the ground, which is the prerogative of the state. Further to complicate the situation in the Northern Territory, the Atomic Energy Act of 1953 vests ownership of the uranium not in the state, but in the Crown (represented by the federal government). Thus, the uranium mining issue in the Northern Territory has been a legal struggle between land and mineral rights. The Land Rights Act of 1976 reserved all mineral rights for the Crown, and thus effectively ensured that the Aborigines had no power of veto over major mining ventures on lands they claimed in the Northern Territory. The Act guaranteed monetary compensation but no control. Thus, although their numbers are small[79], the Aborigines constitute a lobby that has played a role in delaying the development of the uranium industry. As with fishermen and farmers in Japan, they have often been equivocal in their opinions, vascillating between the prospects of becoming millionaires and of preserving for future generations the tribal lands and sacred sites unscarred by mining activities.

The Australian labour party

The most influential anti-nuclear lobby in Australia is the



* Uranium deposits

--- Proposed national park boundary

Source: Commonwealth of Australia, Ranger Report No.2 (1977)

Map 18. Uranium reserves in the Northern Territory of Australia.

Australian Labour Party (ALP), with direct and implied connections with the trade unions. At the end of 1972 a Labour government was elected on a strongly nationalist platform. Prime Minister Whitlam's policy was to limit foreign ownership and control of Australian natural resources. The Whitlam government introduced environmental legislation on the United States model, including the Environmental Protection Act (Impact of Proposals) of 1974, that enabled the Federal government to undertake envionmental impact inquiries on major projects.

The Fox inquiry

The Ranger uranium project had submitted an Environmental Impact Statement in February 1975, but in July of that year the government initiated a major public inquiry into the environmental aspects of uraniun mining at Ranger. The Fox inquiry, as it became known[80], was a landmark environmental inquiry for Australia and became an important case study into the risks and benefits of the nuclear fuel cycle in the world context, along the lines of the Flowers Report in Britain (1976) and the Ford-Mitre Report in the United States (1977). After three months of parliamentary debate on the First and Second Fox reports (issued respectively in 10/76 and 5/77), the government, then a Liberal-country party coalition under Prime Minister Fraser[81], announced the decision in August 1977 to proceed with the "controlled development" of Australia's uranium resources and the country's nuclear policy reversed direction.

The Hawke Government

The present Labour government, elected in April 1983 and led by Mr. Hawke, has an anti-nuclear policy, that has been modified since the 1970s. In 1977 the ALP had called for the repudiation of all existing uranium export contracts. In July 1982 the National Labor Party Conference changed this policy to allow existing contracts to be honored, but maintaining a gradual phasing out of uranium mining and export. The Hawke government has been caught on the horns of a dilemma in the matter of the development of the large new Roxby Downs project in South Australia. To allow mining of the uranium would break the election promise not to open any new uranium mines. The Roxby issue has reopened the uranium mining debate on a nationwide scale in Australia, and amid much controversy within the highest level of the Labour Party itself, the Cabinet voted in November, 1983, to allow the Roxby Downs project to go ahead. It is doubtful whether export licences will be granted to the Koongarra and Jabiluka leases not yet in operation in the Northern Territory, and an export license for the French uranium project at Ben Lomond in Queensland has already been refused. These mines are unable to meet strict ALP guidelines on environmental controls and majority Australian ownership requirements. The Ben Lomond refusal is also seen as part of the ALP's stand against French weapons testing at Moruroa. Nabarlek and Ranger are the only uranium mines operating in Australia at present, and these will be allowed to fulfill their contracts which last until 1996.

A long-term uranium policy has yet to be defined by the present government. Mr. Hawke has stated that his government opposes the testing or storage of nuclear weapons in the Pacific, and also the depositing of nuclear wastes on the ocean floor, but he has not taken any steps to ban United States nuclear-powered warships from Australian territorial waters or ports[82].

All states in Australia, except Queensland and Tasmania, have labour governments at present. This trend toward labor has implications for nuclear developments. In South Australia, Premier Mr. Bannon has halted the Honeymoon and Beverley uranium projects. Honeymoon was to have been mined with a controversial *in situ* leaching process[83]. Environmental action groups and local communities opposed this on the grounds that there was a serious risk of contaminating underground water supplies in one of the country's driest areas.

Trade unions

Almost every sector of the Australian economy has, at one time or another, been disrupted by the actions of the country's militant and politically powerful trade unions. Certain unions, dominated by the far left of the political spectrum, have taken highly publicized and active positions against the mining and export of uranium, sometimes enforcing work bans that have prevented delivery of shipments. In May 1976 the Australian Railway Union called a 24-hour strike to halt the first shipment of uranium since the 1960s. After a delay of three months routine export was established. This happened again in 1981 with the first shipment from the newly-opened Ranger mine. On the other hand, the large Australian Workers Union (AWU), which represents the uranium miners themselves, in a similar position to the nuclear power plant workers' union in Japan in their stand on nuclear power,has taken an active position in favor of uranium mining, because of employment opportunities for miners.

The mid-1970s was a period of intense national interest in the uranium mining issue, and the Australian Council of Trade Unions (ACTU) was forced to take a position with one or the other of these two strongly held and completely opposite views. In 1977 the ACTU reached a compromise which effectively transferred the intra-union conflict to an ACTU vs. the government arena by recommending Prime Minister Fraser to hold a national referendum on uranium mining and export, a suggestion with which Fraser did not comply. The recent discussions over Roxby Downs mining has re-opened the uranium mining debate.

Citizen anti-nuclear groups

The anti-nuclear movement in Australia grew in the 1960s as an offshoot from organizations with broader environmental concerns, such as the Greenpeace Foundation, Friends of the Earth, and the Australian Conservation Foundation. The first French nuclear weapons test in the Pacific in 1966 marked the beginning of a decade of active anti-nuclear campaigning, that was especially vociferous when the Australian and New Zealand governments began protesting to the World Court in 1973 (see Chapter IV) over the French tests, and during the mid-1970s when the uranium mining debate was gathering momentum. Anti-nuclear groups exist in all state capitals. They include the Movement Against Uranium Mining (Canberra, Sydney, Melbourne), the Campaign Against Nuclear Energy (Perth, Adelaide), the Campaign Against Nuclear Power (Brisbane), the Uranium Moratorium (Hobart), and the Movement For a Non-Nuclear Future (Darwin) (Fig.33). Most of Australia's 17 university campuses also have subsidiary branches of these organizations.

All these groups work closely with the trade union movement to lobby against the further development of the nuclear fuel cycle within Australia, visits by United States' nuclear-powered warships to Australian waters, and Pacific nuclear issues such as the Japanese ocean-dumping plan, and the French tests in Tahiti. During the past five years the strategy of the anti-nuclear movement has emphasized the establishment of nuclear-free zones in Australia (117 in 1983), including small towns, cities and some states (South Australia and Victoria). A definition of Nuclear free zones was propounded at the 1978 Nuclear Free Pacific Conference held in Ponape, Micronesia:

> Article 1: That a Pacific Nuclear-Free Zone be declared, including all that area of the South Pacific bounded by the Latin Amercian, Antarctic, Indian Ocean and ASEAN zones, and extending to 10 degrees N and also including all of Micronesia and Australia;

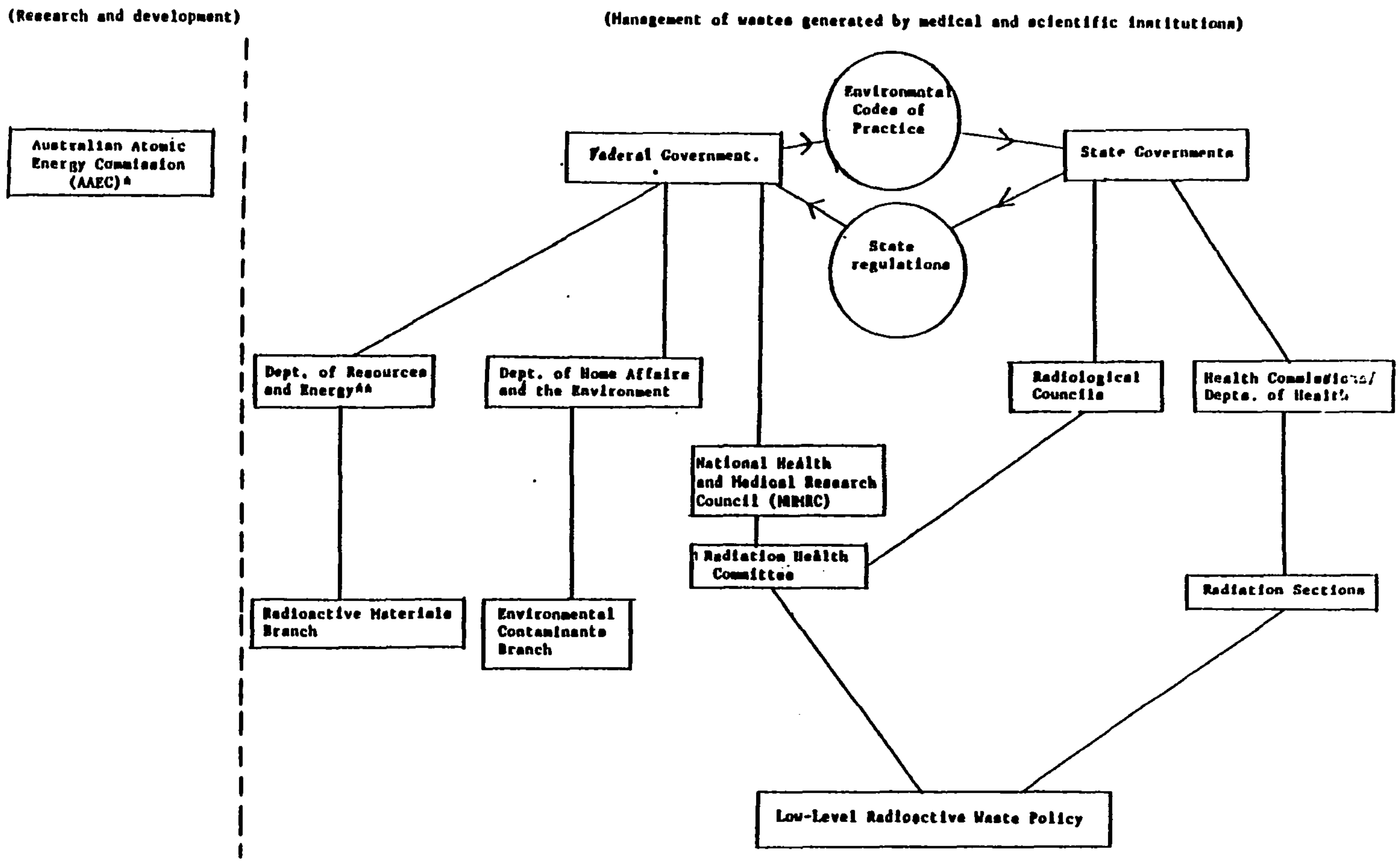
The aim is to create a nuclear-free Australia through the coalescing of these zones, an objective that is impossible while there are operating uranium mines in the country.

Figure 33 Anti-nuclear movements in Australia.

Nuclear waste problems

The agencies with responsibility for radioactive materials are shown in Figure 34. The limited amount of high-level radioactive waste generated by the AAEC is stored at the Lucas Heights facility in Sydney. Most radio-isotopes used in the medical field are allowed to decay on the shelf and the remainder are sent to Lucas Heights for storage.

Low-level waste management difficulties have arisen at the uranium mines in Northern Territory. Having noted the experiences with hazardous, dry tailings piles in the western United States (see Chapter I), Australian lawmakers required that mill tailings be covered by two meters of water. There are problems involved in containing mine tailings in the monsoonal climate of northern Australia (Fig.35). High seasonal rainfall and inadequate dam freeboard have caused leakage of contaminated water to local streams on more than one occasion. In March 1981 water spilled from the mill tailings pond at Nabarlek after heavy rains and radioactivity 5 to 10 times the normal was reported in soil near the mine (The Australian, 12/4/81). There was a strong possibility that radioactive water had escaped into the nearby creek system. Conversely, successive seasons with abnormally low rainfall can lead to the tailings ponds drying out. The exposure of the upper layers of tailings increases radon emissions, and results in dust that bears radioactive elements. This situation occurred at Ranger in November 1981. The mine was closed only four days after it was officially opened, because an island of tailings was noticed in the tailings dam.



* Responsible for uranium mining & milling; high-level radioactive waste generated from AAEC HIFAR at Lucas Heights.

** Responsible for import & export of radioactive materials.

*** Compiled from Federal and State sources by D.Bourke and I. Childs, 1983

Figure 34 Institutional framework for radioactive waste management in Australia.

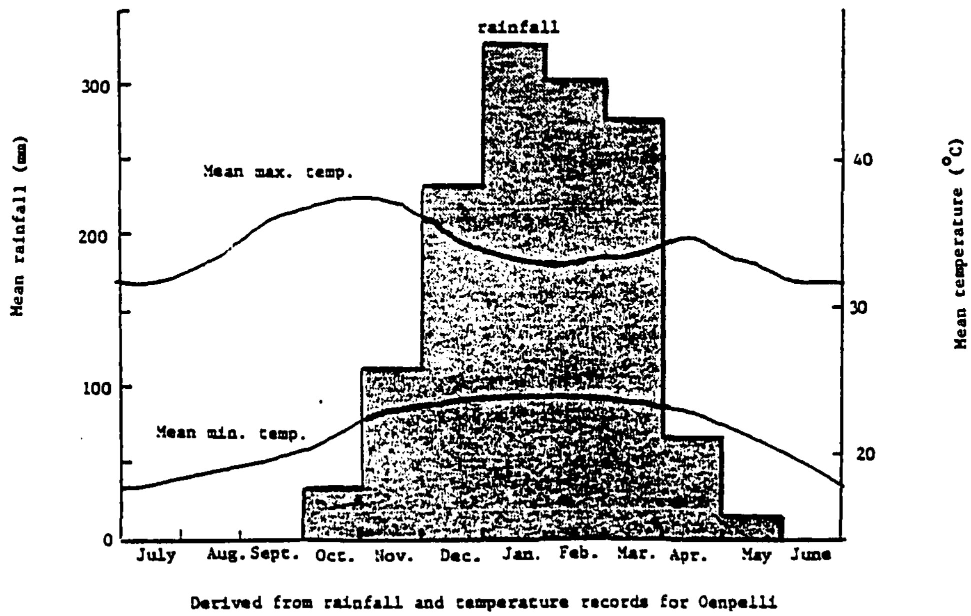


Figure 35. Monsoonal climate of Northern Territory's uranium province.
Source: Australian Government (1977) Ranger Report, No.2.

The federal government does not claim that defense purposes are involved in uranium deposits and mines, and therefore radiation matters are generally handled by state legislation with the exception of the Northern Territory as noted above. The Federal government controls national nuclear policy that affects Australia's role in nuclear matters in the Pacific region, but within Australia, waste disposal problems are complicated by inter-state politics and the "NIMB" syndrome in much the same way as the state authorities hold sway in the United States, and prefectural authorities have control in Japan.

The Hunters Hill case

An illustration of interstate problems is the Hunters Hill case. A now affluent, harbor-side suburb of Sydney, Hunters' Hill was the site of a watch factory between 1910-1916. In 1910 the Radium Hill mining company in South Australia transported 500 tons of uranium ore to Hunters' Hill where radium was extracted for the purpose of making luminous watch-dials. The tailings from the extraction process were left scattered over six suburban blocks and houses were built on top of them.

In 1966 rumors that several residents of the Hunters Hill area were dying of leukemia prompted an official investigation, but the tailings were found to constitute "neglible hazard" (The Canberra Times, 2/15/78). Ten years later, in 1977, a health physicist's report indicated that there was a serious radiological hazard at Hunters Hill from radon emanating from the tailings (Commonwealth of Australia, 1982). Radon is a daughter product of radium-226, which is part of the uranium-thorium decay chain (see Chapter I). When radon escapes from soil into the open air, dose-rates to human-beings may be low, but when the radon is trapped inside a building, such as a house constructed on foundations containing radioactive soil, concentrations of radon build up inside the house and exposure rates increase. After further investigation and much wrangling it was decided that approximately 1,000 cubic meters of soil should be removed from the area, but the question was where should it go, and who would remove it?

The New South Wales (NSW) government's attempts to find a disposal site within the state ran into the NIMB ("Not in my backyard") problem. In 1978 a site was proposed at Manara, a small town in western New South Wales, but the plan was thwarted by stiff public opposition, particularly from local Aborigines who make up about one third of the town's population. Cattle and sheep station owners, and anti-nuclear and environmental action groups opposed the plan and the railway workers union threatened to call a strike if the disposal went ahead. Faced with such opposition the New South Wales Premier asked the South Australian government for permission to dump the contaminated soil in the obsolete Radium Hill mine where it had originated. Unions in South Australia threatened to place a ban on transporting and handling the waste from Sydney. The Labor opposition leader (now premier) said that South Australia would not be used as a "nuclear dustbin" (The Australian,6/25/81:4). The NSW request was turned down.

Finally, in late 1982, after six years of examining and rejecting proposals, the NSW government announced plans to demolish two of the affected homes in Hunters Hill. These were to be used as a dumping ground for the contaminated soil, which was to be covered with 1.5 meters of clean soil and fenced off from the public. Even this plan failed. The owner of one of the selected houses refused to sell her property, and the Federated Engine Drivers and Fireman's union threatened to obstruct any attempt to use non-union labor to bury the radioactive waste on the site (The Australian, 21/3/83). At this writing the matter still has not been resolved.

The citizen anti-nuclear groups in Australia are enthusiastic in their aims, but although there may be much passive support among the Australian public, the anti-nuclear cause lacks the broad-based active support that has been demonstrated in some European countries. The ALP and the trade unions are the strongest source of anti-nuclear political power, and they have made appropriate disposal of domestic low-level waste difficult in some cases. If the Hunters Hill debacle is representative of the complications that are likely to arise over the disposal of LLW originating within Australia, it is inconceivable that a plan to locate a regional HLW disposal repository accepting waste from Japan, Taiwan and South Korea, for example, would be feasible in the present political climate.

The Pacific (Melanesia, Micronesia, Polynesia)

The island Pacific at present plays no role in the region's commercial nuclear industry, yet nuclear issues are among the most politically and emotionally volatile in the newly independent island states. The nuclear issue is firmly entangled with the independence movement in the island Pacific. The struggle is between small island communities and former colonial powers, for example between Micronesia and the United States, French Polynesia and France, Palau and Japan.

The 1954 exposure of Marshall islanders to radioactive fallout from the United States weapons test (see Chapter IV) sensitized the Pacific islanders to all things nuclear. Plans by the United States and Japan to dispose of, or store nuclear waste in the Pacific are seen by many as "yet another example of callous transferral of nuclear risks to the people of the Pacific" (Dorrance, 1980). In most islanders' minds there is no discernible benefit for the Pacific to be gained directly from nuclear activities, and generally they make no distinction between weapons tests and waste disposal (Van Dyke, Smith and Siwatibau, 1983).

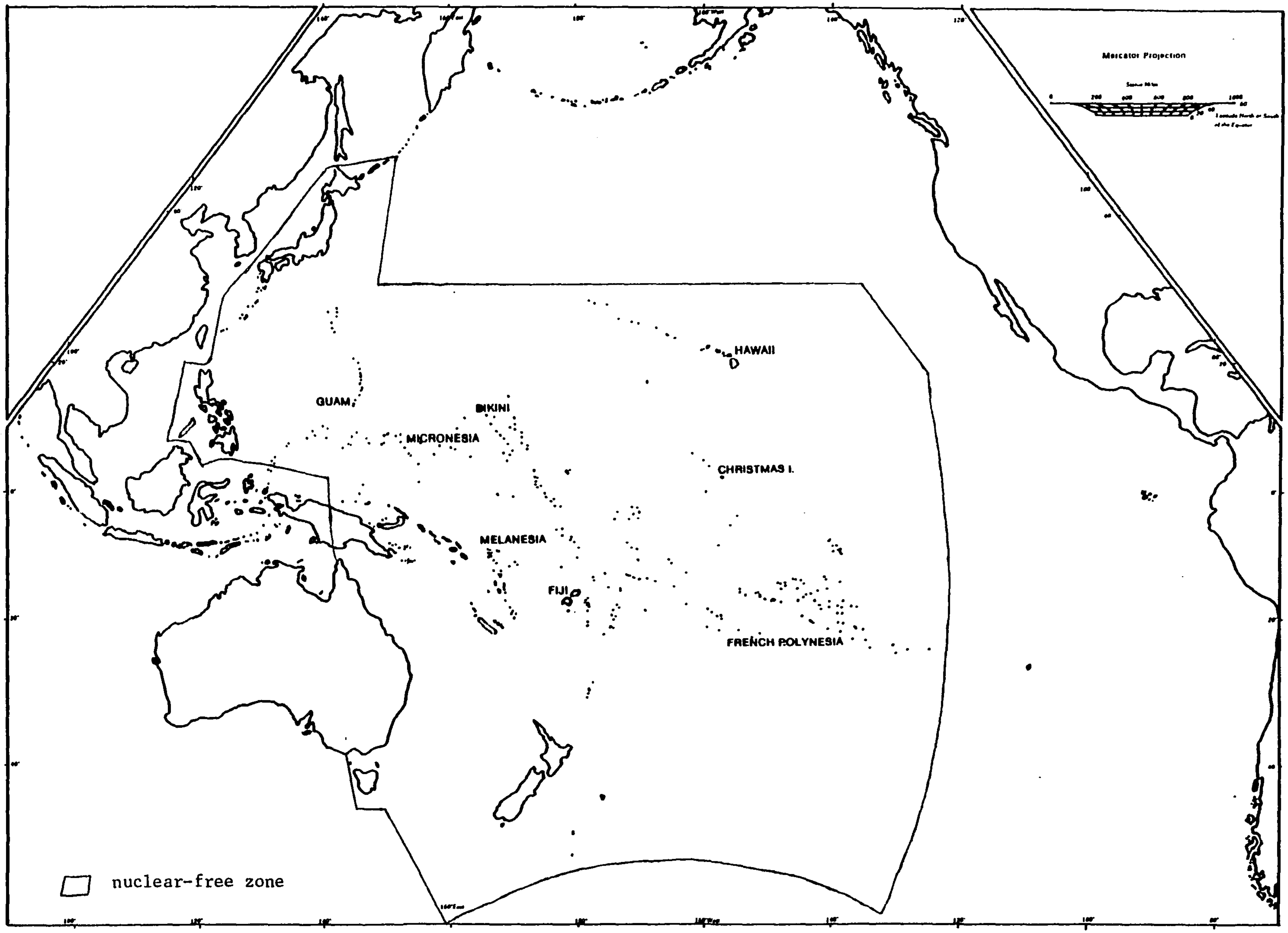
The policies of the eleven independent island states[84], are adamantly anti-nuclear, with strong anti-nuclear support in the highest ranks of administration. At the 14th South Pacific Forum meeting in Canberra in August 1983 resolutions on nuclear issues were considered that covered the prohibition of testing and storage of nuclear weapons, a ban on the dumping of nuclear waste, and the establishment of a Pacific nuclear-free zone, (Australian Consulate General, Honolulu,

<u>Information Bulletin</u>, August, 1983). The geographic limits of the ban were not defined in the resolution but the United States saw it as having the ultimate intention of extending to international waters and, therefore, could not endorse the proposal which would interfere with the transit of American naval vessels in the South Pacific[85]. The area included in the Nuclear-Free Pacific proposal by the anti-nuclear groups is shown in Map 19. Concerning the establishment of a nuclear-free zone, former United States ambassador to Fiji, William Bodde, has stated,

> The United States must do everything in its power to counter the Nuclear Free Pacific movement.
> (Johnson, 1980a)

This lack of support for the Pacific Islanders' desire for a nuclear-free Pacific may lead to a further decline in the reservoir of goodwill toward the United States in the Pacific. Many islanders thought that if they controlled their own external affairs the possibility of denuclearizing the Pacific would increase. To this end, the anti-nuclear groups expanded their lobbying for a nuclear-free Pacific to include the issue of independence for island territories. Thus, the nuclear issue became intertwined with the struggles for independence.

The strength of the anti-nuclear movement in the islands is such that no government can afford to ignore it (Fig.36). Two nodes of particularly strong activity are the University of the South Pacific (USP) in Fiji, and the Pacific Concerns Resources Center (PCRC) in Hawaii.



Map 19. The proposed Pacific nuclear-free zone.
Source: Micronesia Support Committee (1983).

Figure 36 Anti-nuclear movements in the Pacific Islands.

Fiji

The Fijian anti-nuclear movement began with the establishment of a branch of the YWCA in Suva in 1962. At first the group focused mainly on the 1945 Japanese bombings and the 1954 Marshalls incident. Those who had been exposed to radiation were portrayed as victims of super-power rivalry, and already erosion of goodwill for the United States can be seen here. The Fijian group switched its attention to the French tests on Moruroa in 1966.

In 1969, one year before Fijian independence, the first large anti-nuclear rally in the island Pacific was held in Suva. Most of those who marched were students from the newly-established (1967) USP, but teachers and prominent community leaders also participated. The march was led by the Roman Catholic Archbishop of Fiji and the Head of the Methodist Church, a fact which caused much controversy at the time in religion-conscious Fiji. Ratu Sir Kamisese Mara, then Chief Minister, is reported to have stated after the rally that he wished the Archbishop would consult him before doing anything political (FT, 6/69). The Archbishop replied publicly that the Chief Minister should consult his priest before uttering things which dealt with matters of the spirit. Already the nuclear hazard was acknowledged as an important and emotional issue by the highest levels of political and religious leadership in Fiji.

The election of Labor governments in New Zealand and Australia in 1972 encouraged Fiji to play an active international role commensurate with its independent status, especially regarding the nuclear Pacific issue. Fiji joined Australia and New Zealand in protests over the French nuclear tests in the World Court in 1975. The first Nuclear Free Pacific (NFP) Conference was held in Fiji in 1975 and was attended by representatives from anti-nuclear groups around the Pacific Basin. Subsequent annual meetings have helped to form a network of Pacific-wide anti-nuclear activists who work toward raising public awareness of nuclear issues through educational campaigns in their own countries[86]. It has been pointed out[87] that many of the participants of the 1975 Suva NFP Conference are now leaders in government or trade unions in their countries, and this is one reason for the strong anti-nuclear stance of Pacific island governments in the 1980s.

Hawaii

Although part of the United States, Hawaii plays a special role in Pacific politics by virtue of its position as a mid-Pacific outpost of American policy and military strength, and because of its multi-ethnic population, with cultural roots on both sides of the Pacific, as well as in the island groups of Polynesia and Micronesia. Hawaii has well-established branches of mainland anti-nuclear organizations such as Ground Zero. One of the biggest issues for the anti-nuclear people in Hawaii is the presence of the large arsenal of nuclear weapons stored on Oahu in the various military bases[88], although it is difficult to mobilize the powerful military presence in the Hawaiian islands.

Hawaii's most important role in the Pacific anti-nuclear movement is that of a liaison and communication base at the Pacific Concerns Resource Center (PCRC). The Pacific groups have created an effective network centralized in the PCRC in Honolulu, which disseminates information to anti-nuclear and environmental organizations throughout the Pacific. The rhetoric and aims of all Pacific groups are therefore very similar: no storage or testing of nuclear weapons in the Pacific; no storage or disposal of nuclear waste; no visits by American nuclear-powered warships in Pacific ports; no nuclear power plants. The Micronesian Support Committe is also based in Honolulu, and campaigns for compensation to the Marshall Islanders for damage incurred through weapons tests, as well as for the broader nuclear free Pacific issue.

French Polynesia

French Polynesia (Tahiti) is the most obvious example of an island territory where economic aid is used as an argument against independence and as a lever by France to gain an island site for nuclear activites. The nuclear weapons testing conducted on Moruroa is a primary target of opposition from anti-nuclear movements around the Pacific, but within French Polynesia itself protests are limited. French money controls the economy of the islands and many in Papeete support the status quo.

The issue of independence for French Polynesia has been associated with the nuclear tests since the late 1950s, when rumors of the establishment of the Centre D'Experiment du Pacifique, (CEP), in the islands were first heard. Supporting independence for French Polynesia has proved to be a risky business. The French government considered Tahitian leader, Pouvanaa o Oopa, a strong proponent of independence, a threat as it laid plans to establish the nuclear base. Pouvanaa was arrested in 1958 on a bogus charge of arson and was taken to France where he was held in jail for eleven years[89]. The French government has also banished French nationals who speak out against the tests. In 1962 anthropologist Louis Molet was ordered back to France after he published a protest in the local newspaper.

The Assemblie Territoriale, the autonomous local governing body, has always included in its ranks a small group who have worked toward independence and an end to the nuclear tests. In 1979 the Assembly asked the French government to allow foreign scientists from Japan, New Zealand, and the United States to study radioactive pollution caused by the tests (Shaw, 1981), but the request was refused. The Assembly's budget comprises mostly French money, and many political and business leaders in Tahiti are reluctant to criticize the nuclear experiments too openly for fear of jeopardizing the territory's economic prosperity. Everyone wants autonomy, and few would argue that independence is not inevitable in the long run. The argument is between those who want independence, and by extension an end to the testing, as soon as possible, and those who favor continuing to use the nuclear base as a bargaining point to build up more economic infrastructure in the islands before the French leave[90].

The local Tahitian press is generally silent on the nuclear issue. The most widely read newspaper, La Depeche, (see Ch.IV), is controlled by the French government and gives only the barest of facts concerning nuclear activities on Moruroa, and elsewhere in the Pacific. Two other local newspapers, Les Nouvelles and Le Journal de Tahiti, have smaller circulations, but are more liberal and occasionally publish letters and articles that question the nuclear experiments[91]. The average Tahitian probably has little knowledge of radiation hazards and thinks of Moruroa as a small atoll far from Papeete. It is difficult to mobilize the Polynesian population to participate in activities that are likely to disrupt a peaceful existence and the generous flow of material goods brought to the islands by the French. The only active anti-nuclear citizens group in Tahiti is the Ia Ora te Natura, an environmental action group led mostly by expatriates.

There is far more anti-French and anti-nuclear sentiment outside French Polynesia than there is emanating from within the territory. In the early 1970s news of these growing protests in the South Pacific reached metropolitan French newspapers and generated some opposition within France. In June 1973 several French anti-nuclear activists, led by retired French army general Bollardiere, arrived in Papeete to participate in the biggest political rally ever held in French Polynesia. It was attended by some 5,000 people supporting independence and an end to nuclear testing (Shaw, 1981). In the eyes of the island Pacific, France will continue to play a pariah role as long as it persists with the nuclear tests, and is reluctant to grant independence to French island territories.

Micronesia

Micronesia is even more complicated than French Polynesia with respect to nuclear politics. The nuclear issue has been part of the area's relationship with the United States since the weapons tests of 1946. The issue is now entangled in the decolonization process as Micronesia changes its political status. In 1981 four new political entities emerged from the United Nations Trust Territory of the Pacific Islands which had been administered by the United States since 1946: (i) the Commonwealth of the Northern Marianas, where people will have American citizenship under their new status, as in the case of Puerto Rico; (ii) the Republic of Palau, (iii) the Marshall Islands, and (iv) the Federated States of Micronesia (FSM)[92]. Palau, the Marshalls and the FSM will be independent nations in free association with the United States, an arrangement that is somewhat similar to that which the Cook Islands and Niue have with New Zealand. The Compact Agreements with the United States allow the three island groups to attain independence in both domestic and foreign affairs, but with the United States maintaining responsibiity for defense.

The missile range on Kwajalein Atoll in the Marshalls, and the proposed military base in Palau are of particular concern to the United States, but these bases are obstacles to the nuclear-free Pacific aims of the island nations. The major stumbling block over the Compact with the Marshalls has been the settlement of claims against the United States for damage to health and property caused by the 1950s nuclear tests[93].

Palau[94] has demonstrated the strongest commitment to the nuclear-free Pacific cause during the Compact negotiations. Palau became part of the United Nations Trust Territory in 1947. In 1979, as a prelude to the change in political status, Palau became the first nation in the world to adopt a consitution that banned the storage, testing and disposal of nuclear materials within its territory, effectively creating a nuclear free zone around the island group (Fig. 37). The only comparable situation is that of the 1958 Antarctic Treaty which bans the presence of nuclear materials in Antarctica. Complications have arisen in negotiating the Palau Compact of Free Association with the United States which emphasizes "strategic denial" guarantees. This means that military use of the islands would be denied to other nations for 100 years. The Compact Agreement contains a provision (Section 314) for respecting the non-nuclear clause in the Constitution:

> (a) Unless otherwise agreed, the Government of the United States shall not, in Palau, the Marshall Islands or the Federated States of Micornesia:
> - test by detonation or dispose of any nuclear weapon, nor test, dispose of, or discharge any toxic chemical or biological weapon; or
> - test, dispose of, or discharge any other radioacitve, toxic chemical or biological materials in an amount or manner which would be hazardous to public health or safety.

The United States has not accepted this provision, and has proposed an amendment to the Compact for Palau which circumvented the non-nuclear clause. In February 1983 a plebiscite was held in Palau on whether or not to accept the Compact Agreement with the United States. A majority

C O N S T I T U T I O N

O F   T H E

R E P U B L I C   O F   P A L A U

Jonathan Koshiba
Convention Secretary

PALAU CONSTITUTIONAL CONVENTION

January 28 - April 2, 1979

Koror, Palau

ARTICLF II

SOVEREIGNTY AND SUPREMACY

Section 1. This Constitution is the supreme law of the land.

Section 2. Any law, act of government, or agreement to which a government of Palau is a party, shall not conflict with this Constitution and shall be invalid to the extent of such conflict.

Section 3. Major governmental powers including but not limited to defense, security, or foreign affairs may be delegated by treaty, compact, or other agreement between the sovereign Republic of Palau and another sovereign nation or international organization, provided such treaty, compact or agreement shall be approved by not less than two-thirds (2/3) of the members of each house of the Olbiil Era Kelulau and by a majority of the votes cast in a nationwide referendum conducted for such purpose, provided, that any such agreement which authorizes use, testing, storage or disposal of nuclear, toxic chemical, gas or biological weapons intended for use in warfare shall require approval of not less than three-fourths (3/4) of the votes cast in such referendum.

Figure 37 The non-nuclear clause in the Constitution of Palau.

of 62 percent voted "yes". A separate measure on whether to accept the nuclear section of the Compact, (i.e. to allow the storage of nuclear materials in Palau), received a 52 percent "yes" vote, a surprisingly high figure, but insufficient to fulfill the 75 percent required to change the constitution (Micronesian Support Committee, 1983).

The Palauan situation is a thorn in the side of the United States which views military bases in Guam, the Marshalls, Palau, and Tinian (Northern Marianas) as vitally strategic. In August 1983 a compromise agreement was proposed under which United States military ships and planes with nuclear materials aboard, would be permitted transit in Palauan waters, but the storage of nuclear weapons and nuclear materials would not be allowed on Palauan territory (Takeuchi, 1983). This also failed to win approval in the Palauan senate. The situation at this writing is a stalemate, with the Compact agreement null and void.

Compensation

Japan, Australia, and the island Pacific have confronted the nuclear waste issue on different levels. Japan is a producer and potential exporter of waste, while Australia and the islands have potential repository sites. Monetary compensation is likely to play an important role in resolving the political problems of waste dispsal in the future and the precedent for compensation for exposure to radiation hazards is already established in the region.

Japan

In Japan there are legal mechanisms for dealing with public opposition to nuclear facilities. In 1974 the Japanese government passed three laws concerning compensation to rural communities designed to facilitate the establishment of new nuclear plants. These are the Dengen sampo (Three Laws on Electricity):

1. Law on the Development of Areas Adjacent to Electric Power Generating Facilities,
2. Electric Power Development Promotion Tax Law,
3. Law for Establishing a Special Account for Electric Power Promotion.

Under these laws most municipalities adjacent to power plants are required to build public facilities such as roads, parks, water systems, educational and cultural facilities, while the national government, through the Ministry of International Trade and Industry, subsidizes the costs with funds from taxes on electricity paid by all consumers. The government's obvious intention is to pour resources into communities where the greatest potential for opposition to government energy policies exists. The power companies themselves have also used financial incentives as a means to gaining public acceptance, not only in purchasing land and fishing rights, but also in paying what citizens have labelled okashii na okane ("strange money"). This appears to be more like a bribe than true compensation. It includes "friendship" money to private citizens and "development" funds to fishermens' co-operatives (Edmonds, 1983). The companies have also instituted discount charges for electricity to customers living near nuclear power stations (Arisawa, 1981). There are other mechanisms through which individuals and communities may be compensated for the risks of proximity to nuclear facilities.

(i) Fishermen. One of the major constraints on the Japanese nuclear program is site acquisition for power stations. A seismically active country, lacking appropriate sites near fresh-water resources for cooling water, Japan must build nuclear power plants near the sea, but Japan is one of theworld's largest fishing and fish consuming nations. Every mile of Japanese coastal waters has traditionally been used for fishing by people who have legal rights over areas of the sea. Large amounts of money are routinely paid by power utilities as compensation for using cooling water from the sea, and sometimes for discharge of contaminated wastewater. The money is paid to fishing co-operatives and is then distributed to individual families. An average sum for such compensation is approximately 10 million yen (US $50,000) per household, as a one-time lump-sum payment (Tanaka, 1983). The highest overall figure of 15,000,000,000 yen (US$63 million) ever paid by a utility as compensation to a community for fishing rights was in the Onagawa community (16,000 population in Miyagi Prefecture) power plant case, which involved twelve years of controversy and negotiation before the community reached a consensus and voted to give up fishing rights in Onagawa Bay (Okada, 1978).

The reason that fishermen are so highly compensated is, not so much in recognition of the high risk of the radiation hazard, or thermal pollution, but because of the economic effects on their market. As one industry spokesman put it,

> The rumor that fish may be contaminated remains the single most difficult problem ... no amount of explanation on the safety of reactors or the effect on human life, even accompanied by numerical data,

> is effective as a tranquilizer against rumors that emanate from psychological and emotional factors. On the part of the fishermen, the economic loss from a collapse in prices due to rumors cannot really be compensated for, since there is no grievance procedure. It is understandable that the fishermen are overly sensitive and nervous about such rumors.
>
> (Matsushita, 1981).

One is reminded of the reaction of the fish markets to the 1954 Fukuryu-maru incident (see Chapter IV). Japan previously dumped low-level waste at various sites in its coastal waters[95]. A renewed dumping program at these old sites would probably meet with much opposition from Japanese fishing communities and would cost the government and power utilities enormous sums of money in compensation. It remains to be seen whether farmers in rural communities will put up as much of a fight over land disposal sites for nuclear waste, but if past examples are anything to judge by, the compensation mechanism will work after protracted negotiations.

(ii)Meiwaku-ryo (compensation for psychological anxiety).

This is a regional subsidy of up to 10 million yen (US$50,000) per person. It differs from the United States National Environmental Protection Agency's provisions on psychological stress. The United States decision on psychological damage caused by the Three Mile Island accident[92] was unpopular with Japanese farmers as it could affect their compensation later, when the effect of the decision reaches Japan. Japanese government policy is not independent of international "reference cases", the most important of which is still the United States. Suttmeier (1981) asserts that the implementation of Japanese nuclear policy would be far smoother if the United States were proceeding vigorously with its own nuclear development.

Australia

Aboriginal land ownership decisions are not always bad news for the mining companies. A typical example is the case of Chicken Hawk Dreaming in the Northern Territory[97]. Big Bill Neiijie is head of the Bunitj tribe, traditional owners of Chicken Hawk Dreaming, a mountain in Arnhem Land adjacent to the East Alligator River region, a few kilometers from the Ranger uranium province. Big Bill's claim was approved by the Land Rights Commission because he was actually living on his land. He subsequently negotiated a compensation agreement with the Pancontinental Company to mine uranium on his land (The Australian, 7/27/81:1). In the words of Wesley Lanhupuy of the Northern Land Council,

> The Aborigines don't give a damn about development, but they won't stand in its way ... The Northern Land Council has benefitted financially from uranium mining. Mining has been socially drastic and environmentally bad for Aboriginal people ... but now mining is a fact of life as far as this council is concerned.
> (The Australian, 7/16/81:26)

Royalty payments from the Ranger mine are expected to reach A$5 million (US$4.5 million) annually, now that production is in full swing (The Australian, 7/16/81:26). Forty percent of this money goes to the Northern Land Council which represents approximately the 25,000 Aboriginal people in Northern Territory. A further 30 percent goes to Aboriginal communities, and the remainder to the Aboriginal Benefit

Trust Account that was established to make loans to Aboriginal enterprises. Individual wealth may not always be great.

There is tension between the Northern Territory government in Darwin, which is in favor of developing the uranium resources, the Northern Land Council, which tries to maximize monetary compensation to Aborigines from the mining ventures, and those Aborigines who do not want the mining to go ahead. The Northern Land Council does not represent the entire spectrum of Aboriginal opinion. Many urban Euro-Australians in Darwin firmly believe that the uranium should be mined. In the words of one political analyst,

> They are proud of their uranium and they are not pleased by southerners, trade unions, Aborigines and greenies telling them to leave it in the ground.
>
> (MacCallum, 1977).

The Pacific islands: foreign aid and investment

An important factor that tempers Pacific Island anti-nuclear initiatives is external aid and investment. It is debatable how far the island nations would oppose Japanese or American waste disposal plans under threat of aid and investment withdrawal. In French Polynesia this threat has always been the shadow hanging over independence and has prevented the Tahitian anti-nuclear movement from gaining more momentum over the seventeen years of French tests on Moruroa. Most of the new island states will be dependent on foreign aid to maintain viable economies for at least the next decade (Dorrance, 1980).

Levels of aid from Australia, France, Japan , New Zealand, the United Kingdom, and the United States to the island Pacific are shown in

Table 8. Australia and New Zealand provide by far the largest share of grant aid to the Pacific islands, totalling about $300 million per year, and educational and cultural links between Australia, New Zealand and the island Pacific are strong. The United States financial aid has gone mostly to the territories of Guam, American Samoa and the Trust Territory of the Pacific Islands. Educational and cultural links with the United States, particularly through Hawaii and American Samoa are becoming increasingly significant, with many Pacific Islanders seeking American graduate education, especially through the University of Hawaii and the East-West Center, in Honolulu. United States interests in the area are overwhelmingly strategic, but trans-Pacific trade also increases every year. In the future fishing and seabed resources will become more important factors in this trade. Japanese aid has been modest, and is mostly in the form of commercial loans. This has totalled about $20 million over the past few years. French aid is limited to French territories. British aid is substantial in the former British territories of Fiji, Kiribati, Tonga, the Solomon Islands and Vanuatu.

As a counter-balance to the threat of withholding aid, shortfalls in aid from the Western bloc would leave a vacuum that the Soviet Union could use to increase its influence in the region. The Soviets have established diplomatic relations with several island states, but have so far failed to set up any embassies. Soviet interests in the Pacific are aimed at establishing support bases for fishing fleets[98], and strategic interests aimed at shattering the image of the Pacific as the "ANZUS lake" (Dorrance, 1980).

TABLE 8. Ecomonic Aid to the Island Pacific from Selected Countries. ($US)

Source: South Pacific Commission (1982).

	Australia	France	Japan	New Zealand	United Kingdom	United States
American Samoa	-	-	-	-	-	35,351
Cook Islands	183	-	-	7,796	-	-
Fiji	15,341	-	802	3,631	8,358	569
French Polynesia	-	139,800	-	-	-	-
Guam	-	-	-	-	-	83,772
Kiribati	3,933	-	1,985	240	11,940	3
Nauru	-	-	-	-	-	-
New Caledonia	-	173,400	-	-	4	-
Niue	20	-	-	2,849	-	-
Papua New Guinea	235,624	286	-	2,506	420	1,080
Solomon Islands	4,244	-	353	57	20,361	487
Tokelau	-	-	-	-	1,418	-
Tonga	3,058	96	17	2,310	1,914	63
TTPI*	-	-	-	-	-	150,615
Tuvalu	1,559	-	-	165	2,568	324
Vanuatu	3,057	20,000	-	1,646	17,666	18
Wallis & Fortuna	-	7,300	-	-	-	-
Western Samoa	2,220	92	4,178	3,664	196	-

*Trust Territory of the Pacific Islands.

The People's Republic of China has also been actively cultivating relationships with Pacific Island leaders recently, through state visits to Peking and reciprocal diplomatic missions to the islands, trade delegations and cultural exchanges. The Chinese interests in the region are to pre-empt the Soviet influence, and to cultivate support of the emerging South Pacific bloc in the Third World.

Regarding private business investment, Australia and New Zealand, again, have been the primary source of foreign capital in the past. Japanese investment in the fishing, mining and timber industries in certain island groups has increased greatly over the past ten years, and Japanese tourism in particular, has become an important element in the economies of some island nations.

Conclusion

In Japan, the issue of nuclear energy development, so far, has been fought on a local level rather than in the national parliament. Nuclear waste disposal has recently begun to be treated in the same manner, and it is likely that local rural communities will be the arena in which the struggle for waste facilities will take place. The tradition of negotiation, consensus-seeking, and compensation will provide a socially-acceptable mechanism for overcoming political opposition to waste disposal facilities. This mechanism will not work when Japan tries to export waste to other countries in the region.

In contrast to Japan, nuclear power and uranium mining have been the subject of intense national debate in Australia, involving the Aboriginal rights movement, and with the politically powerful labor movement and the ALP on the anti-nuclear side. Nuclear waste disposal in Australia will be restricted to the problem of low-level waste in the foreseeable future, and will be a battle bewteen the states and local authorities, even down to suburban backyards in some cases.

In the Pacific islands the overriding political factors affecting the disposal of nuclear waste are the entanglement of the nuclear issue with the independence movement, and the counterveiling meed for economic aid from the OECD countries. Juxtaposition of these two factors in the various island nations will determine how much strength is in the arm of each in contributing to the nuclear free Pacific movement. French Polynesia and Palau present contrasting facets of the nuclear vs. self-determination issue in the Pacific.

Complex problems exist in other countries. The Philippines, a developing nation that has begun constructing a nuclear power plant, is seismically and politically unstable and will have waste disposal problems. New Zealand will probably remain a bastion of anti-nuclear sentiment in the Pacific for the foreseeable future. The above by no means covers the full spectrum of political contingencies that might affect the management and disposal of nuclear waste, but are intended as examples of nuclear waste policies in countries of widely differing geographical character, resource bases, and economic development, in the Pacific region.

NOTES

62. This was Tokai No.1, a British gas-cooled graphite reactor. For a useful discussion of the early years of the Japanese program, see Hideo Sato, "The Politics of Technology Importation in Japan: The Case of Atomic Power Reactors" (1978).

63. Lester (1978) reported that total planning lead times, i.e. the period from announcement of the intention to build the nuclear power plant to commercial operation, is 12-15 years in the United States, 9-12 years in Japan, 9.7 years in the Federal Republic of Germany, and 7.3 years in Canada. Suttmeier reported in 1981 that the Japanese figure was 15 years.

64. The first Japanese spent fuel reprocessing plant began operation in 1977 at Tokai, after a decade of negotiating with the United States over Japan's right to reprocess (which would theoretically have given Japan the ability to create nuclear weapons). The Tokai plant has a very small capacity (0.7 tons per day), and the development of another reprocessing facility is urgent as France has announced that it will only accept spent fuel that is covered by existing contracts for reprocessing. The Japanese government has been looking for additional sites for reprocessing plants. Two possibilities that have already received some attention are Tokunoshima, one of the Amami Islands off Kyushu (Han-genpatsu News, 1981), and Sekinehama, on the Shimokita Peninsula in Aomori Prefecture (Japan Times Weekly, 16/1/82; Mainichi Daily News, 7/5/82), (Map 3).

65. Shingo Tashiro, General Manager, Wastef Operation Division, Department of Environmental Safety Research, Japan Atomic Energy Research Institute. Personal comunication, July 1983.

66. Soka-gakkai members travelled to New York and Geneva during the 1982 United Nations Special Session on Disarmament to exhibit anti-nuclear displays (Han-genpatsu News, 1982).

67. See Han-genpatsu News, No.10, April 1981, p.3.

68. See Japan Times Weekly, 25/4/81:2. Suttmeier (1981) asserts that the the Kubokawa case is not significant as a democratic rejection of nuclear power, as it appears that the recall was more a rejection of a man who was "insincere" in office in relation to his campaign behavior. He had entered into an anti-nuclear agreement with the local JSP and JCP members during the election campaign, which pitted him against two LDP candidates, so he changed his platform to a pro-nuclear one.

69. For example, in Kyowa, near Tomari in southern Hokkaido in January 1982.

70. Some environmental action groups have spoken out against Japan's Pacific ocean dumping plans. For example the Jishu Koza (1/21/81) article entitled, "Don't Make the Pacific A Nuclear Dumping Ground", which protested Japan's use of economic aid to dampen opposition from Pacific Islands.
71. The Tsuruga mishap occurred in March 1981, but it was not revealed until late April 1981 that contaminated waste water had been released into the plant and that cleanup workers may have been exposed to dangerously high levels of radiation. High levels of radioactivity were also reported in Tsuruga Bay which led to a boycott of seafood from the Tsuruga area.

72. For example see "Public hearing on N-plant held as 8,000 protest construction", Japan Times Weekly, 9/5/81: 10, and "Hearing on Takahama N-Plant Opens. 500 Demonstrators outside Meeting", Japan Times, 1/18/80:2.

73. Japan became a signatory to the 1972 London Dumping Convention in January 1981. In February 1983 at the meeting of the London Dumping Convention, Kiribati and Nauru proposed an amendment to the Convention that would stop all dumping of radioactive materials. The Scandinavian delegation changed this to an amendment phasing out dumping and for a two-year scientific investigation into the effects of dumping. Spain put forward a non-binding resolution for a moratorium on dumping pending results of the scientific investigation. This passed 19 to 6, with 5 abstentions. Those against included France, Japan, the United Kingdom, and the United States (Environmental Policy and Law, 10, 1983). Although the resolution was non-binding, it was another indication of strong opinion against marine disposal of radioactive waste.

74. The governor of Hokkaido is a member of the Japan Socialist Party (JSP) and the prefectural government is equally split between LDP and JSP members: Lower House 11 LDP, 8 JSP; Upper House 4 LDP, 3 JSP. (Japanese Consulate General, Honolulu.)

75. Professor Yasumasa Tanaka, Department of Political Science, Gakushuin University, Tokyo. Personal communication, July 1983.

76. Westerners often interpret this gift-giving purely as generosity on the part of the Japanese, whereas it is actually a rigid part of Japanese social interaction and obligation, the on (burden or obligation) system. An on to an individual or institution establishes a mutual relationship within which the parties are entitled to seek reciprocal favors and have reciprocal obligations.

77. For a discussion of nuclear power plant siting in Japan see Lesbirel, 1980.

78. According to Shelby Brewer, head of nuclear power programs at the USDOE, the demand for enriched uranium in the 1970s was overestimated and the DOE is now regretting its decision to build a mammoth $10 billion gas-centrifuge enrichment plant at Portsmouth, Ohio, the largest construction project in the nation. The capacity is not needed because of a dwindling demand for enriched uranium. The surplus is expected to grow in the next few years and will not be worked off until the early 1990s, which means that demand and prices will remain depressed for the foreseeable future (<u>Science</u>, 221(4612), 19 August, 1983: 730-733).
79. The Aboriginal population of Australia is approximately 150,000; of these 25% lives in the Northern Territory (Franklin, 1976).

80. After presiding Commissioner, Justice R.W. Fox

81. In an unprecedented move on 11/11/75 the Governor-General of Australia, Sir John Kerr, dissolved parliament and appointed opposition leader, Mr. Fraser, as Prime Minister. Mr. Whitlam's Labor government had been having trouble passing budget bills in the senate and Whitlam had requested Kerr to call a half-senate election in an attempt to get more control in the senate. Australian senators are elected for a six-year term, and every three years half of them are called to election. On 12/13/75 a general House and Senate election was held and the Liberal-Country Party coalition, led by Mr. Fraser, won.

82. From remarks made by Mr. Hawke during his visit to the East-West Center, Honolulu, in May 1983.

83. In this process acid is poured into boreholes to dissolve uranium which is then pumped to the surface to be extracted.

84. The following island groups are independent states as of December 1983: Cook Islands (1965); Fiji (1970); Kiribati (19); Nauru (1968); Niue (1974); Papua New Guinea (1975); Solomon Islands (1977); Tonga (1970); Tuvalu (1974); Vanuatu (1980); Western Samoa (1962).

85. Over one third of the United States navy is nuclear-propelled, and the basic United States policy is neither to confirm nor deny the presence of nuclear weapons on ships or aircraft. The proposals for the establishment of nuclear free zones in the South Pacific complicates United States relationships with the Pacific Islands, Australia and New Zealand. Much stronger sentiment against permitting nuclear powered warships into ports exists in New Zealand than in Australia. Under the Kirk government (1972-75), they were banned from New Zealand. Under the present Muldoon government they are permitted entry, but warships are still greeted by flotillas of anti-nuclear protest vessels. In Australia Mr. Hawke's stance reflects a commitment to the ANZUS partnership. Western Samoa and Fiji have shown reluctance to permit port calls by United States warships, in the past. Tonga is the only island state outside the United States territories thus far to accept port calls by nuclear-powered warships.

86. For example see A Call to a New Exodus. An Anti-Nuclear Primer for Pacific People, by Suliana Siwatibau (1982).

87. Diane Goodwillie, ATOM (Against Tests on Moruroa) Committee, Nadi, Fiji, personal communication, May 1983.

88. Particularly in West Loch of Pearl Harbor, and Lualualei valley. See Albertini (1978).

89. For a detailed account of the history of the establishment of the CEP, and of Pouvanaa's story, see Bengt and Marie-Therese Danielsson, 1977.

90. This discussion is based on conversations with Ms. Renee Heyem, Pacific Collection Librarian, Hamilton Library, University of Hawaii, and Ms. M.L. Fourlinnie, resident of Tahiti, presently a research intern in the East-West Center, Resource Systems Institute.

91. For example, in March 1980 Les Nouvelles published a letter from Ia Ora de Natura to the Papeete press questioning reports of dumping nuclear waste in French Polynesian waters, and rumors of neutron bomb tests.

92. The Federated States of Micronesia (FSM) comprises the four island states of Truk, Yap, Ponape and Kosrae.

93. The latest agreement negotiated between Marshall Islands' president Amata Kabua and the United States provides for an interest-bearing fund of US$150 million to be allocated on a quarterly basis for the next 15 years to the four islands affected by the tests: Bikini, Enewetak, Rongelap and Utirik (Far Eastern Economic Review, 7/14/83:19).

94. In the 1930s Koror city, on Palau island, was an important outpost of Japan's Pacific empire. During World War Two Japanese installations there became the target of American attacks and many Palauans were killed. The Palauans wish to avoid being caught between warring foreign powers again.

95. Suruga Bay (Shizuoka Prefecture) and Sagami Bay (Kanagawa Prefecture) were used by the Japan Radioisotope Association, under the guidance of the Science and Technology Agency, for the dumping of radioactive waste between 1955-1969 (Tokyo Shimbun, 10/3/80).

96. In the People Against Nuclear Energy vs. the NRC case the court ruled that (1) the psychological inputs in question must be post-traumatic anxieties, as distinguished from mere dissatisfaction with agency proposals or policies, (2) impacts must be accompanied by physical effects, and (3) must be caused by fears of recurring catastrophe (USNRC News Release, 7/27/82). Thus, in the United States the liability for psychological stress from a nuclear facility only takes effect after an accident has occurred and cannot apply to anxiety for mere proximity to a facility, as in the case of Japan.

97. The "Dreaming", or "Dreamtime", is the English word the Aborigines choose to describe the mythical time of marvels and creation in the indefinitely remote past. The choice of the English word "dreaming" is an attempt to convey the relationship between the mystical quality of the dream-life to waking life conveyed by the words of their own language (W.E.H. Stanner, 1960).

98. In 1976 the Soviet Union offered Western Samoa and Tonga major aid packages for such facilities, but under pressure from Australia, New Zealand, and some island nations the Soviet proposals were turned down (Dorrance, 1980).

CHAPTER VI. REGIONAL DISPOSAL: PACIFIC COOPERATION FOR NUCLEAR WASTE

Within the circle of the sea,
It holds a fish of fame.
It holds a dolphin.
It hold a whale.
It holds a fish that touches heaven.
It holds a fish the rainbow spans.
Within the circle of the sea,
It holds my land[99].

Many advocate at regional solution to the problem of high-level nuclear waste disposal in the Pacific Basin[100]. In countries that have followed, or are considering, the nuclear option, the problems of waste disposal have been ignored in the rush to develop nuclear power as a potential substitute for oil imports. Most of the nations of the Asia-Pacific region are energy importers, notably oil, importers. An out-of-country repository for nuclear waste may remove an obstacle to the further development of nuclear energy in countries that have poor geologic conditions for waste disposal. The feasibility of a regional repository is dependent upon nuclear politics within each country (see Chapter V), and is influenced by international economic, political, and legal factors, proliferation concerns and transportation risks.

Regional Blocs

Cooperation is unlikely to be Pacific-wide, but definite possibilities exist for arrangements within sub-regions or blocs, already established for economic, political or strategic reasons. At present a Regional Cooperation Agreement, functioning within the International Atomic Energy Agency (IAEA) exists. This agreement was concluded in 1973, but is not considered adequate to meet present needs;

its usefulness being limited to the medical and research applications of radio-isotopes. There is now a call for a new forum in the region similar to EURATOM, organized for technical cooperation, to cover commercial nuclear power and waste management.

The United States and the USSR have, respectively, the largest and the second largest programs in civilian nuclear power in the world (see Chapter I). Both countries, however, have geologically suitable areas for the disposal of nuclear waste and do not need to seek disposal sites outside their territorial boundaries. The United States Nuclear Waste Policy Act of December 1982, which authorized the Department of Energy to find a permanent home for United States' nuclear waste, eliminated provisions for the storage of 100 tons of foreign spent fuel within the United States (Cotton, 1983)[101].

1. The East Asian Bloc

The potential for cooperation in the nuclear field is greatest among the East Asian bloc consisting of Japan, South Korea and Taiwan. Both South Korea and Taiwan face energy dependence on imports similar to those of Japan, and all three countries have ambitious nuclear programs.

The Republic of Korea in 1983 had one operating nuclear unit, which provides 6 percent of the total electricity generated. The South Korean national energy plan includes the construction by the 1990s of 13 more nuclear power plants, with a total nuclear capacity of 12,600 MW, or 40 percent of total electricity generation (Kim, 1983). Korea has a storage capacity of spent fuel for 10 years, but after that time there are no plans for the disposal of either low-level or high-level waste.

Taiwan has four operating nuclear power plants, which in 1983 provided 30 percent of the country's total electricity. Two more plants are under construction and the government has plans for 5 more by the year 2000 (Chu, 1983). Taiwan's National Radioactive Waste Storage facility was established in May 1982 on Lanyu Islet, off Taiwan's southeast coast, which has a 30-year capacity for storing solid medium- and low-level waste. A 10-year storage capacity exists for spent fuel in power plants, but Taiwan has yet to develop an overall waste management plan. Both South Korea and Taiwan would be willing to cooperate in a regional scheme for spent fuel storage or waste disposal, but later would probably wish to retain the option to reprocess the spent fuel (Broinowski, 1979).

Executives of nuclear power companies from the East Asian countries advocate closer cooperation. At the 1983 Tokyo meeting of the Japan Nuclear Industrial Conference, the Vice President of the Korea Electric Power Company (KEPCO) said,

> The most effective cooperation is with neighboring countries such as Taiwan and Japan. It is our hope to establish an international nuclear energy organ for the Asian area, so as to study the disposal of nuclear waste and exchange information on nuclear reactors.
>
> (S.C. Kim, Liberal Star(Japan), 5/10/83: 6)

South Korea, Taiwan, and Southeast Asia at present suffer an acute shortage of trained personnel to carry out their respective nuclear programs, covering all stages from research and development to commercial operations, including waste management. Discussions have already been conducted at the executive level on the establishment of a regional center to facilitate the provision of Japanese technical personnel in case of an emergency arising at a nuclear power plant in these countries (Murata, 1983). This would to be called the Japan International Nuclear Cooperation Center,the location of which is still undecided.

2. ASEAN

In the 1980s and 1990s, the focal point of technological strength in the nuclear industry in the Pacific will probably shift away from the United States to Japan, which will try to increase its exports of nuclear components to Asia, and to promote the use of small-scale reactors (in the 200-300MW range) for Asian cities. Competition may also come from European nuclear firms in the region[102].

The use of atomic energy in the ASEAN bloc has been restricted to medical and research institutions. Indonesia is building a 30MW research reactor, scheduled for completion in 1986, and is considering the construction, by the year 2000, of 2-4 commercial nuclear plants (Sudarsono, 1983).

In June 1982, Malaysia's 1MW research reactor began operation, and that nation is presently engaged in basic nuclear research and personnel training.

The United States donated, under the Atoms for Peace program, a 1MW research reactor to the Philippines in 1963, and in 1973 the Philippines national energy plan included 11 nuclear power plants, but by 1983 this was reduced to one. Nuclear power plays only a minimal role in the current industrialization strategy of that country, but the Philippines is still expected to be the first country in the ASEAN group to have an operating nuclear power plant (Bartolome and Refre, 1983). The 620MW PNPP-1 plant now being constructed on the Bataan Peninsula, is planned to start operating in January 1985. A ten-year storage capacity for spent fuel exists at this plant site, but after this there is no waste disposal plan.

Singapore has stated explicitly that before the year 2000 nuclear power would not play a role in the country's energy supply (Kaneko, 1982).

In 1979 Thailand discarded a plan to build two reactors at a site south of Pataya, but in its long-term energy policy, beyond 1990, is reported to be showing a revived interest in nuclear power (Kaneko, 1983).

The ASEAN bloc would be a prime target for Japan's nuclear export drive, and cooperation in waste management might be included in future trade agreements.

3. Japan-China(Peking) cooperation

Because of the development of nuclear weapons the People's Republic of China already has the technology for the nuclear fuel cycle. China (Peking) also has uranium and thorium resources, and dry, stable areas suitable for waste disposal. Although the Treaty of friendship and cooperation laid the foundation for expanded trade and cooperation between China and Japan, so far in the energy field this has been minimal. Japan continues to be "enthralled by the glittering prospects for trade that would be offered by a more liberal China" (Fryer, 1980). In the future there may be potential for cooperation in the nuclear field between China(Peking) and Japan.

4. The Japan-Australia partnership

The Japan-Australia relationship is primarily economic, but has important political and strategic implications for the region. Harris and Oshima (1980) conclude that this is eminently true in the case for nuclear energy. Since the mid-1960s Australia has been the largest supplier of non-oil mineral resources to Japan, and reciprocally, Japan is Australia's most important export market for mineral resources[103].

The critical policy issue in nuclear matters between the "East-Asian Trio" on the one hand, and Australia on the other, is energy security vs. non-proliferation. The underlying resource base of the two sides is so different that sensitivity to energy security inevitably differs. This applies also to the Japan-United States relationship. The vulnerability of Japanese import supplies colors the entire spectrum of

Japanese foreign policy, and is the reason for the increasing importance accorded nuclear power in Japan's energy strategy. Nuclear power is unnecessary to meet the overall energy needs of Australia and the future of uranium trade remains uncertain because of concerns over global oversupply and proliferation concerns. Nevertheless, the trade partnership between Japan and Australia is already well established, and if the political climate were to change so as to permit the establishment of an international facility for waste disposal somewhere in Australia, Japan would certainly be in a favored position.

Bi-lateral agreements on waste disposal may be more feasible than multi-national arrangements and may evolve through economic relationships such as exist between Japan and Australia. The dry, stable, granite structure of central Australia is one appropriate site in the Pacific region for deep geologic disposal of high-level waste, the solution generally preferred by the scientific community. The idea was first raised at a meeting of the Australian Uranium Producers' Forum in 1977 (Energy, March 1977). An area 500-1,000 miles west of Alice Springs was deemed suitable for high-level waste disposal. Later, a visiting American nuclear consultant caused a deal of adverse comment with his suggestion that Ayers Rock be used as a nuclear waste repository (op cit.). The proposal was again aired in November 1981 by a West German nuclear expert at an international conference on radioisotopes in Tokyo. He said that West Germany would "welcome any offer from Australia to store the more than 50,000 drums of waste from German industry" (The Australian, 11/30/81: 2).

Finally, as both a non-proliferation measure and as a solution to the nuclear waste problem, the suggestion that Australia should operate a closed nuclear fuel cycle without power plants, leasing out fuel rods and taking back spent fuel, a scheme similar to the Soviet Union's strict leasing arrangements, has been made by various Australian officials (New Journalist, 4/78), and academics (Ringwood, 1982). Australia would, of course, charge a substantial fee for this service, but in a uranium market that is becoming increasingly over-supplied producers who were prepared to include waste disposal in an agreement would be in a superior bargaining position.

There would be enormous public resistance to such a plan. Australia is the first country where there has been a national debate on uranium mining itself and there has already been much controversy over the risks of disposal of low-level waste of Australian origin (see Chapter V). A large percentage of the population would oppose the establishment in Australia of a high-level repository for overseas waste.

Transportation

Transportation costs and risks may be the decisive factors in the feasibility of regional disposal, because of long routes over international sea lanes. In discussions of nuclear waste disposal, a full risk accounting is not always given. The risk of the final repository is emphasized, but the risks of handling and transporting the waste to the repository may exceed those of final disposal, especially in the Pacific where distances are vast. The total risk (R) may be expressed as:

$$R = \text{handling risks} + \S(\underset{\text{per mile}}{\text{transport risks}}) \times \text{miles}^{\dagger} + \underset{\text{disposal}}{\text{risks of final}}$$

There would be a trade-off between the advantages and disadvantages of national versus regional disposal schemes. The economic costs of interim storage and transportation to an international storage facility has been estimated at approximately 3 percent of the total costs of the nuclear fuel cycle (Greer and Datzell, 1979). There is not much difference in financial cost between geologic land-based disposal and subseabed disposal (Lippschutz, 1980), but transportation to the subseabed site could increase costs considerably. The United States would probably decide to concentrate on the Atlantic seabed rather than the Pacific, because of transport costs involved in shipping waste from east to west, and then across the Pacific.

Transportation and handling risks would be of particular concern with a storage or disposal facility on a Pacific island. It is plausible that an independent island state with few natural resources could gain revenue by selling territory for nuclear waste disposal. Distances and isolation in the Pacific have always been disadvantages from the perspective of trade, but could be turned to advantage if an island nation chose to lease one of its atolls for the disposal of toxic or nuclear waste. The precedent for island storage and disposal has been set with waste scraped off Bikini and placed in a crater on the island of Runit (Marshall Islands) which is now off limits for an indefinite period (see Thomas, 1980). Britain is investigating an island off Scotland for high-level waste disposal, and Japan was considering Tokunoshima, an island off the coast of southern Kyushu for a reprocessing and high-level waste facility (see Chapter V). Japan might favor the building of a large artificial island rather than a natural one, using the principles of floating marine communities exhibited at the 1975 Ocean Expo in Okinawa. Taiwan is now using Lanyu island for storage of nuclear waste. A parallel use of an island for toxic waste storage is the use of Johnston Island by the United States for storage of nerve gas.

Newly independent island states, particularly the resource-poor coral atolls, are basing future economic growth on tourism and fishing, but in most cases at present, these are still far from being able to support viable economies.

Example 1: The Marshall Islands

Amata Kabua, president of the Marshall Islands, in September 1981, suggested that Japan abandon its ocean dumping plan and consider storing radioactive waste on land that is already contaminated. Speaking at a meeting of the Association of Chief Executives of the Pacific Basin in Guam, Kabua suggested the use of Bikini or Enewetak atoll because these had already been contaminated by United States weapons tests.

> Is it possible that a tragic misfortune which befell our people could be turned around to provide a form of economic recovery for people who have lost so much?
>
> (Pacific Daily News, 9/3/81)

Kabua sees storage or disposal of nuclear waste as a source of revenue for the Marshalls. Government leaders of other Pacific Islands sharply opposed Kabua's suggestion on the grounds that it would set a dangerous precedent in the region (Micronesian Support Bulletin, summer 1981), and Japan has now stated that it will look for domestic land sites for low-level waste (see Chapter V), but the island option could still be attractive for high-level waste in the future when spent fuel and waste storage capacity in the East Asian countries, in particular, becomes critical.

Example 2: Nauru

There are other islands in the Pacific that could be potential candidates for waste disposal. The Republic of Nauru is a small (8 square miles) island situated approximately half-way between Honolulu and Sydney, and is at present one of the richest nations in the world, on a per capita basis, by virtue of its small population (5,500) and large income from the rich phosphate deposits[104]. With an international airline, a shipping line, and consulates in many of the world's capital cities, Nauru's situation is remarkable for a nation of less than 6,000 people, and is unique in the Pacific where island nations are dependent on overseas capital and aid. There is no foreign investment in Nauru.

In the late 1990s Nauru will have no exportable resources because it is estimated that Nauru's phosphate reserves will be exhausted in 13-15 years at the present rate of excavation (Republic of Nauru, 1982), leaving three-quarters of the island a barren plateau of exposed limestone pinnacles. As a hedge against the day when the phosphate resources run out, the government of Nauru has invested phosphate profits in property and business enterprises in Australia, New Zealand, Hong Kong, Japan, and, more recently, in the United States and the Philippines. The intention is that after the phosphate mines close overseas investments will reap sufficient dividends to support the high standard of living to which the Nauruan people are now accustomed[105].

Nauru was the initiator, with Kiribati, of the anti-dumping resolution at the 1983 London Dumping Convention meeting (see Chapter V), and at present the idea of selling the disused phosphate mines for a nuclear waste dump is totally unacceptable to the Nauruans. Should the overseas investments fail to support the population in the future, however, Nauru would have to find an alternative source of revenue, and could find itself the target of offers from countries seeking space for waste disposal.

Example 3: Pitcairn

The British island of Pitcairn has a dwindling and aging population of less than 50 people. If Britain were interested in establishing an international waste facility on Pitcairn at some future date, there would be no anti-nuclear movement on the island, and no territorial complications. Disposal of British wastes on Pitcairn would mean higher transportation costs and risks than disposal within Britain, itself.

Risks of a hypothetical journey to a Pacific Island storage facility

Risks in transporting nuclear waste to Pacific islands add considerably to the risks of final disposal. At each portion of the journey, there would be handling risks. The starting point would be a power station or reprocessing plant, and from there the initial mode of transport would be either road, rail or sea. Road terminals usually need only lifting facilities to move the waste flask aboard the transporter, or to lift it off at the next terminal. Similar requirements would exist at rail terminals: the only special equipment required being an adequate crane.

Sea terminals are more complex, because both the land and sea are involved. Many power stations have their own sea terminals which simplify the land transportation leg of the waste journey. In Japan, where plants send their spent fuel to the port terminal at Tokai, there is a domestic sea journey involved in the transportation of spent fuel. The Pacific Nuclear Transport Line (PNTL) ships, "Pacific Swan" and "Pacific Fisher", load the spent fuel cargo from Tokai. The type of flask used in shipping the waste is shown in Figure 38. The port of Barrow in the United Kingdom is the terminal for the waste from Japan. Due to the shallow approaches to docks at Japanese reactor terminals, spent fuel ships cannot be larger than 3,000 tons, and can therefore only carry 100 tons of spent fuel at one time (Brown and Smith, 1980). By the end of the 1980s six ships especially designed for nuclear waste are planned to be in service (Nuclear Engineering International, 3/79). From Barrow the waste is taken by rail to the Windscale reprocessing plant. A large crane is used to transfer the waste flasks from the ship to the railway car (Salmon, 1981).

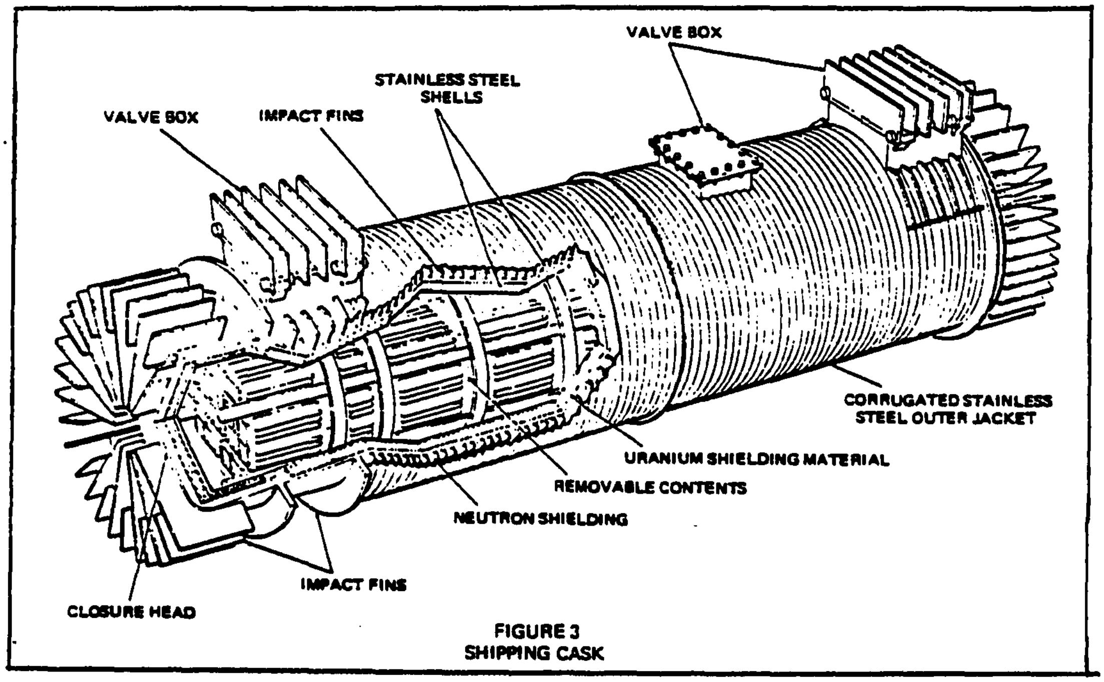
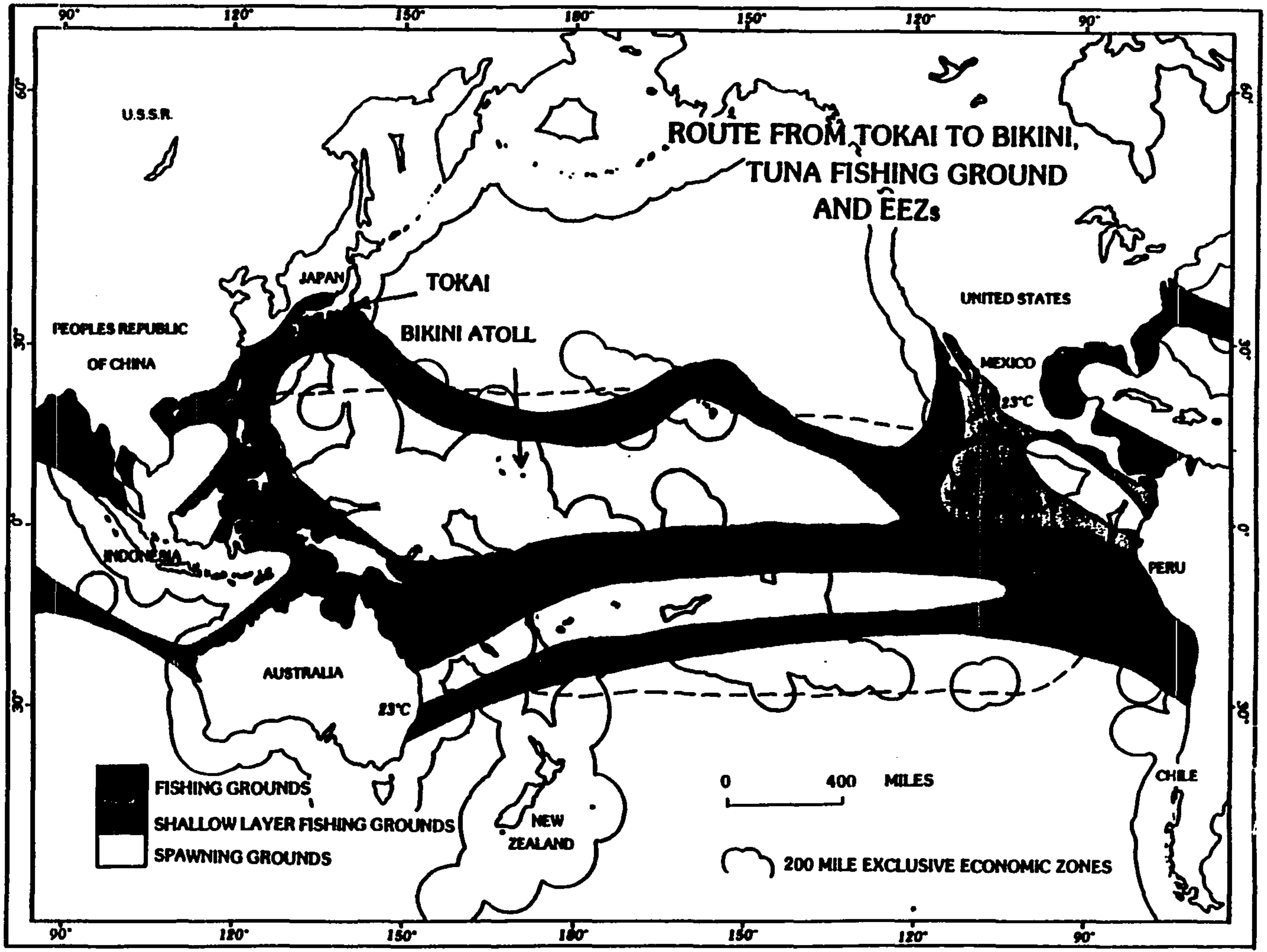


Figure 38 Shipping flask for spent fuel.

Source: United States Atomic Energy Commission, WASH-1339, 1974.

Risk may be expressed as probability x consequence. To calculate the risk of transporting spent fuel from Japan to a storage site on a Pacific Island would involve knowledge of the probability of various types of accident (e.g. collision followed by shipboard fire or sinking; sinking in a storm), and of pathways of the release of radioactive materials to the environment, and the consequence of leakage in each case. Such studies have been performed in generic terms (USAEC, 1972; Heaberlin, 1976; KBS, 1977; USNRC, 1977), and for the specific case of transportation through the Irish Sea (Political Ecology Research Group, 1980). Taking as a hypothetical case, the voyage of a nuclear waste ship such as the Pacific Fisher, from Tokai in Japan to a storage facility on Bikini Atoll, the route would pass through tuna fishing grounds and Exclusive Economic Zones (EEZs) (Map 20), during the ocean voyage.

On its June 1979 visit to Honolulu, the Pacific Fisher was carrying 70 tons of spent fuel in 25 casks (Honolulu Advertiser, 6/8/79:1)[106]. The distance between Tokai and Bikini is 2,800 miles. This would mean a total of 70,000 flask-miles per trip. Present contracts with European reprocessors have been signed for 4,600 tons of spent fuel to the year 1990 (Brown and Smith, 1980). This would mean 65 separate shipments in the Pacific Fisher. If a similar amount of spent fuel were to be stored on Bikini, a total of 4,550,000 flask-miles would be travelled. Salmon (1980) reported that there has been no accident involving damage to a flask or release of radioactivity during the 3,000,000 flask miles travelled since the first consignment in 1962 of the Pacific Nuclear Transport Line (PNTL).



Adapted from J.E. Bardach and Y. Matsuda (1980). GeoJournal 4.5, 467-478.

Map 20. Hypothetical route from Tokai, Japan, to Bikini, Marshall Islands.

The Law of The Sea

The United Nations Conference on the Law of the Sea (UNCLOS) introduces a complication for a third option for international disposal. Geologically stable areas of the ocean floor have received much attention as an international option.

Although the seabed is an area of minimal political influence, there may be serious political and legal difficulties associated with seabed disposal.

> At present, the international legal situation is inadequate for implementing or managing subseabed disposal.
>
> (Hollister, 1981).

International law is a major obstacle to the seabed option. The London Convention of 1972, which expressly forbids the dumping of HLW in international waters, does not address the question of controlled disposal of waste in the subseabed.

The potential, however small, for ecological disruption of the oceans by emplacement of radioactive wastes in the seabed, is perceived as an unacceptable risk by newly independent Pacific island states, who view the ocean as their source of traditional sustenance and future economic benefit. Oppostion to the subseabed option form these nations is likely to be staunch and enduring.

Subseabed disposal may render the surrounding area of ocean unavailable indefinitely for alternative use. For example, no seabed mining that would disturb clays could be conducted, and fishermen may not be willing to risk a public boycott of fish taken from waters in the proximity of the disposal site. This contravenes the 1958 Convention on Law of the Sea that states that high seas should be open to all nations. The area of High Seas is gradually diminishing with the "creeping jurisdiction" of Exclusive Economic Zones (EEZs) in the world's oceans. EEZs give Pacific Islands the potential to control vast areas of ocean with valuable marine resources. The establishment of overlapping or contiguous EEZs presents the possibilitiy that island states, on environmental risk grounds, could attempt to ban waste disposal from their EEZ, and the transit of vessels carrying nuclear waste[107]. The area included in the EEZs of the Pacific Island states could be regarded as their legal "backyard", particularly where nuclear issues are concerned. This is moving toward the traditional islander view of the ocean.

The Nuclear Energy Agency of the Organization for Economic Development's (OECD/NEA) is supervising low-level waste dumping in the Atlantic Ocean. No similar authority yet exists in the Pacific. Regional agreements on dumping or disposal of radioactive waste into the ocean exist in other parts of the world. For example, the Oslo Convention of 1974 which covers the European waters of the Atlantic and Arctic Oceans; Agreements for the Baltic and Mediterraneean Seas (Commonwealth of Australia, Ranger Report I, 1977:105). The Euratom agreement also contains provisions relating to radioactive waste disposal.

The International Seabed Authority (ISA) was established by the Third UNCLOS (Section 4) to supervise the exploitation of mineral resources in the 65 percent of the oceans not included in the 200 mile EEZs. The ISA is organized under the auspices of the United Nations, through the concept of the oceans as the "Common Heritage of Mankind", to control the development of seabed resources and monitor pollution arising from their development. The ISA has decided to leave the matter of emplacement of nuclear waste in the seabed under the jurisdiction of the London Dumping Convention which already covers radioactive waste[108]. It is not yet clear whether this convention on "dumping" includes emplacement in the seabed clays. A meeting of the Convention to be held in London in December 1983 will address this question. The trend in the UNCLOS negotiations has been to move away from the global to the regional level, and this encourages a regional solution to the problems of nuclear waste management and disposal in the Pacific.

Conclusion

The concept of internationalism will be put to the test in finding a solution to the problem of nuclear waste. A social mechanism must be developed to ensure monitoring over a very long period, and it is questionable whether this is possible on a regional level. Policy implementation might be easier in the control of a single agency, but the formation of an agency with real authority on the international level will be very difficult. Conditions of membership to regional arrangements would have to be worked out. This is difficult even on the national level, as is seen in example of the United States compact see Chapter IV), under which legislators and administrators at Federal, state and local levels are developing a management plan to ameliorate current space problems for storage of spent fuel. Similar waste-disposal problems exist among the states in Australia and prefectures in Japan.

The economic and political interaction among Japan and Australia and the Pacific Islands reflects different frames of reference for resource management and for coping with environmental hazards stemming from different population densities and resource bases and cultural views. Caught on the horns of a dilemma, island leaders seek aid from the wealthy OECD countries to achieve development goals, but do not want to be seen as giving way to former colonial powers on the nuclear issue.

There is a North-South flavor in the nuclear waste issue in the Pacific that is resented by the islanders. A Pacific regional solution may be dominated by Japan, the United States and Australia, just as North American and European values tend to dominate the North-South debate in global issues. Difficulties can be expected in accomodating these different concerns on a regional level in order to resolve the problems of disposal of nuclear waste in the Pacific.

NOTES

99. A chant from Aitutaki, the Cook Islands. In Voices on the Wind, by Katharine Luomala, Bishop Museum Press, 1955.

100. For example, see K. Kaneko, "A Regional Organization to Promote Cooperation in Nuclear Energy Among the Countries of the Western Pacific" (1983); W.L. Spicuzza, National Policy Implications of Storing Nuclear Waste in the Pacific Region (1982); H. Wakabayashi, "Nuclear Waste Disposal - Philosophy and Strategy" (1981).

101. Specifically, the Nuclear Waste Act authorizes the design and construction of two deep geologic repositories, 2,000-4,000 feet underground. The procedure for site selection involves environmental assessment, full-scale tests, public hearings, and consultations with state and local officials (Cotton, 1983).

102. For a discussion of the roles of American, Japanese and European companies in the nuclear industry of the Asia-Pacific, see Lester, 1983.

103. Japan is Australia's number-one trading partner, and Australia is Japan's fifth largest trading partner, following the United States, Saudi Arabia, Indonesia and South Korea (Kitazawa, 1982).

104. Phosphate rock, probably of marine origin (Sheldon, 1982), fills the interstices between coral limestone pinnacles forming a cap on the 200ft. plateau. The phosphate was first mined and exported by the Pacific Phosphate Company (Australia and New Zealand) in 1907, and since 1968, when Nauru gained independence, by the Nauru Phosphate Company. The phosphate is the sole basis of Nauru's prosperity. Even water is brought to the island from Japan and Australia in the phosphate ships on their return journey, and all food, except for a few vegetables, is imported from Australia and New Zealand. Poor, highly porous soil and irregular rainfall restrict cultivation to a narrow coastal belt around the inland coral plateau.

105. This discussion is based on a conversation with Mrs. V. Beckett, Honorary Consul of the Republic of Nauru, Honolulu.

106. At that time, an inspection team reported that none of the radiation readings taken on board the ship exceeded minimum standards set by the United States Department of Transport (Manly, 1979).

107. The issue of foreign fishing vessels commonly violating the waters of the Pacific Island nations has already created tension in the tuna fishing industry. During negotiations the United States took the position that the catch of tuna and other migratory fish should be managed regionally and not by individual states.

108. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention) is a global agreement drawn up in London in November 1972. Parties to this Convention undertake to prohibit the dumping of high-level waste at sea. The task of defining the material under prohibition is given to the IAEA (Commonwealth of Australia, Ranger Report I, 1977: 104).

CONCLUSION

> While the fall was inevitable, its exact timing, location, and consequences were unpredictable. For many people it represented a risk of unknown magnitude. The public was constantly bombarded by the mass media with bulletins of confusing information. Moreover, the information provided at any time was mainly probabilistic and varied from moment to moment, within and between the available sources. On the whole, many individuals perceived the situation as stressful.
> (Kushnir (1982), "Skylab Effects").

Nuclear fission will be an increasingly important energy source in many parts of the world during the period of transition from the oil era until alternatives such as nuclear fusion and solar energy are available in the 21st century. Several countries in the Pacific region are planning to expand or begin nuclear power programs in the period 1990-2000. This means that the problem of nuclear waste disposal will increase over the next two decades.

In 1983, excluding the USSR and its satellites, approximately 51 percent of the world's high-level radioactive waste from nuclear power plants was produced in countries bordering the Pacific region, and it is estimated (Cotton, 1983) that this figure will be similar in the year 2000. The largest proportion of the waste is from North America, but the majority of the United States' reactors are in the eastern part of the country, and it probably would be uneconomical to consider sites in the Pacific for waste from these. The Atlantic Ocean is closer. Thus, the problem in the Pacific is essentially how to dispose of the (approximately) 10 percent of the world's high-level nuclear waste generated in the East Asian countries. The regional implications of the necessity to dispose of this waste have been the subject of this study.

The problem of the disposal of nuclear waste has three major facets: (a) the technological problem of containing a radiation hazard, (b) the problem of resolving the differences in perceptions of the risks of nuclear waste (between different experts, and between experts and the public), and (c) the political problem of finding an acceptable site for a hazardous waste facility. Using (a) as a background I have examined (b) through a methodology for evaluationg the perception of hazards, and have drawn some conclusions regarding (c) for the Pacific region.

There is a consensus of scientific opinion that the technological difficulties involved in waste disposal can be overcome. Key factors in the experts' view of the risks of disposal were presented in Chapter I, and the various options proposed to isolate high-level wastes from the bioshpere have been described in Chapter III. From the review of progress made in these technologies, it is clear that in the 28 years since the first (1955) National Academy of the Sciences meeting in the United States on waste disposal, few applications of scientific knowledge to the problem of isolating waste from the biosphere have passed the pilot plant stage. This is partly because there are still large areas of uncertainty concerning the risks in all components of the waste disposal "package".

One important uncertainty that needs further research is the incorporation of the risks of handling and transportation into the overall calculation of the risks of waste disposal. The economic cost of compensating for those risks should be included in the financial risk of nuclear power plants, ("internalizing the externalities" in economists' terms). This applies particularly to the case of an international repository in the Pacific region, where transportation risks would be more serious than for disposal within individual countries.

Another area of uncertainty is the debate over linearity in dose-response curves, the implications of which are of critical importance to the disposal of nuclear waste, and to other hazardous substances in the environment. If a threshold were established, this would mean that it would theoretically be possible to dilute waste down to a safe level, below the threshold, before dispersing it into the environment. It is debatable, however, whether the public would accept this method of disposal.

Some areas of technical uncertainty, particularly the geological aspects, cannot be resolved because of the time dimension. It is impossible to simulate accurately in a laboratory experiment the conditions required to assess the effects of hundreds of years of containment of nuclear waste, both on the wasteform and on the environment. In this regard, archaeological studies may shed some light on the long-term durability of certain metals and ceramics. The long time period during which some types of nuclear waste remain hazardous is the characteristic of the hazard that makes it a difficult, though not unique, technological problem. It is this longevity characteristic that also has most often caught the public attention.

It is my view that the most acceptable technological solution to the problem of nuclear waste disposal in the Pacific region, is to follow the deep geologic land-based disposal option. There are still too many technical uncertainties involved in the use of the ocean floor for disposal. This option is politically unacceptable to most island nations of the Pacific, and is also complicated by the still evolving Law of the Sea legislation. Although isolation from large population centers is an advantage of island disposal, this option involves serious risks in handling and transportation operations. Again, this method would be unpopular with many island nations. Retrievability will also be easier from a land-based mined repository than from the sea floor.

Here, the discussion of parameters used by "experts" in assessing the risks of the disposal of nuclear waste has been followed by an examination of the public perception of the risks. Using the methodology of research in geography on the perception of environmental hazards, this study asked the question, "How does the public view the risks of nuclear waste disposal?". There are differences between the ways that geographers have examined natural hazards, and the ways that they should look at technological hazards. Clearer direction in the field is needed in the latter.

It seems that people exhibit greater anxiety over technological than over natural hazards. A major reason for this may be that people feel far more removed from the locus of control of technological hazards. That is, people expect that a much greater degree of prevention can be applied to technological hazards, such as in the case of government regulations in the use of chemicals or emission standards for power plants, than to the prevention of damage from a hurricane or volcano. Yet, people may feel that government and industry are not exercising sufficient control to prevent damage to the environment or to human health from technological hazards, and the individual citizen feels powerless to control the risks.

Nuclear power epitomizes the feeling of lack of control over a technology. This has been substantiated by psychological studies of risk perception in which characteristics of risk were compared with anxiety levels. Nuclear power and nuclear waste scored high on all the characteristics that cause anxiety. The results of the present surveys in Japan and Australia also agree with this.

It is clear that the past history of nuclear energy, especially the image of nuclear weapons, dominates public views on the risks associated with waste disposal. Certain characteristics of radiation hazards cause anxiety and these have been emphasized in the news media since 1945. The risks are perceived as being new, involuntary, uncontrollable , and unknown to science. As far as the public is concerned, as a hazard, nuclear waste is in a class by itself. Public condifence in government's ability to handle the problem of nuclear waste satisfactorily has been greatly eroded because of past mismanagement and concealment of facts concerning radiation hazards. Although the survey of attitudes in the three very different cultures of Australia, Japan, and the Pacific Islands was of limited scope, it can be concluded that respondents from different regions regard nuclear waste similarly as a unique threat.

Just as study of nuclear waste is playing a pathfinder role in the development of methods to examine the physical risks of the disposal of toxic substances, so it may also suggest a hypothesis for understanding the perception of technological hazards in general. Familiarity eventually seems to reduce anxiety, regardless of the actual risk involved. For example, the railway locomotive and the motor-car were thought to be dangerous when they were newly-invented technologies. Now, the perceived risk of riding in a train or a motor vehicle is low, despite the high number of fatalities from road accidents each year. Familiarity has lessened the perceived risk.

The term "availability" has been used to refer to the fact that people evaluate the probability of events by the ease with which relevant instances come to mind (Tversky and Kahneman (1973). Admitting that there may be a clear distinction between the terms "availability" and "familiarity" within the discipline of psychology, I am equating the two here, and using the term "familiarity" to refer to the availability of information, for example in news media, as a surrogate for personal experience. The role of familiarity in the perception of nuclear hazards seems to contrast at first with its role in the perception of other technological hazards. The very act of giving people more information on radiation risks, or the risks, however small, associated with nuclear waste disposal, can leave them with an increased fear that the worst will happen.

> Consider an engineer demonstrating the safety of disposing of nuclear wastes in a salt bed by using a fault tree analysis to point out the improbability of the various ways radioactivity could be released. Rather than reassuring the audience, the presentation might lead them to think: "I didn't realize that there were so many things that could go wrong."
> (Slovic, et al., 1979).

The more the public knows, the more it is alarmed. Yet, those who know most about nuclear waste, the "experts", fear it the least. This suggests that the public perception of technological risks depends not only upon the nature of the risks, as described in Chapter II, but is also related to the level of controversy that the hazard generates in a society.

In the initial stages of a new technology, there is little controversy because the benefits are emphasized and the risks are still being identified. As scientific information concerning the technology increases, and risk estimation and accounting proceed, controversy over the risks arises within the scientific community. As experts disagree, public faith in the ability of scientists to solve problems wanes, and anxiety over the uncertainty surrounding the risks of the technology grows. As evidence accumulates, scientists gradually resolve their differences and an evaluation of the risks by the scientific community is agreed upon. Societal risk evaluation proceeds when this information filters through the public to the policy-maker. Risk minimization strategies are then employed in the use of the technology. Thus, the perception of the risk describes a bell-shaped curve over time (Figure 39a). If controversy is strong enough and experts continue to disagree, the curve does not pass the apex point, and the technology is rejected.

Taking the railway and the automobile as examples, as information about their use became widely disseminated, the benefits were increasingly perceived as being greater than the risks, public use of trains and cars became commonplace, and finally policy-makers introduced risk-minimizing devices such as guage standardization, fire precautions, speed limits on roads, compulsory seat-belts, and exhaust reduction devices for air pollution control.

In the case of nuclear waste, disposal technologies and low-level radiation are still in the risk estimation and accounting stage. Controversy among scientific experts is rife, and public anxiety is rising. There is a need for future research to determine the shape of the curve for the perception of risks of nuclear waste (Figure 39b). The question is, will the risks be perceived as lower as uncertainty decreases over time in the nuclear waste case? Some say that it is merely a matter of time and information.

> "The best answer to the problem of public perception, public attitudes, is information ... the more people understand about nuclear power, the more they tend to favor it".
>
> (Roberts, 1975).

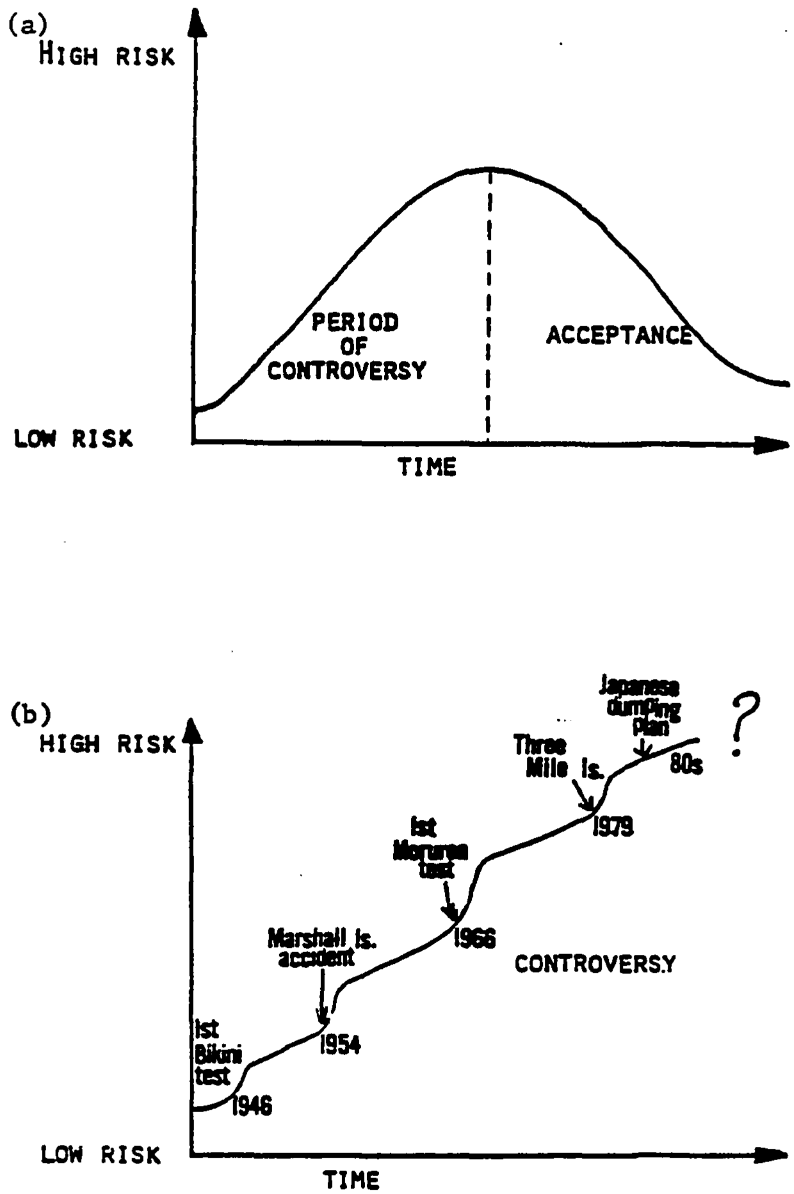


Figure 39 Public perception of (a) technological hazards, and (b) nuclear hazards.

The nuclear industry has acted on this view, waging an expensive campaign in various countries to expand its public information program[109].

I think that the current negative public attitude toward nuclear waste disposal will continue to delay nuclear power programs in certain countries, including Japan, Australia, and the United States, but that this will gradually change, as with other technologies in the past, particularly if the connection between commercial nuclear power and nuclear weapons can be severed more effectively, and as new technologies confront society with new dangers.

If societies judge the risks of nuclear waste, and the further development of nuclear power to be unacceptable, even if this decision is an emotional one, no matter what the technical risks, then nuclear power may be one of those technologies that is rejected before it has run its course of usefulness, and is made obsolete by new technologies.

Another hypothesis that may help explain the difference between the views of the public and the experts is that with education in scientific fields, the values of the experts may change with a change in their understanding of the technical risks. The question of whether the curve in Figure 39b will describe a downslope after a period of time is a question of concensus on values, but value judgments of the experts may differ from those of the public. Experts may also be motivated by self-interest in their acknowledgement of the risks of a technology in which their profession is involved.

No matter how the controversy over the future of nuclear power and nuclear waste may end, even if all nuclear power plants were closed down tomorrow, there would still be an inventory of waste awaiting disposal today. Citizens tend to forget this when they say they are "against nuclear waste". The problem is the "NIMB" (Not in My Backyard) syndrome. No-one wants nuclear waste in their backyard, even when the backyard is as large as the Pacific.

This study has taken the view that it is the policy-maker's role to evaluate the different expert and public views of the risks of the disposal of nuclear waste when considering the question "How safe is safe enough?" What are the policy implications of these different perceptions of risk for the Pacific region? In the three areas considered here, Japan, Australia, and the Pacific Islands, there are complicated relationships involving interdependence and dilemmas for all (Figure 40). The political dynamics of the nuclear issue among these three are complex and interesting.

Japan is a country not well-endowed by nature with mineral resources, and is therefore looking for energy security, and has sought to develop nuclear power as an energy source. There is a complementarity to Japan's position in Australia, a resource-rich nation seeking export markets for energy resources, including uranium. The newly-independent Pacific Island states are seeking higher levels of economic development and recognition of their political status in world affairs. Japan is seismically unstable and is seeking disposal sites for nuclear waste outside Japan. Australia, in the dry, geologically

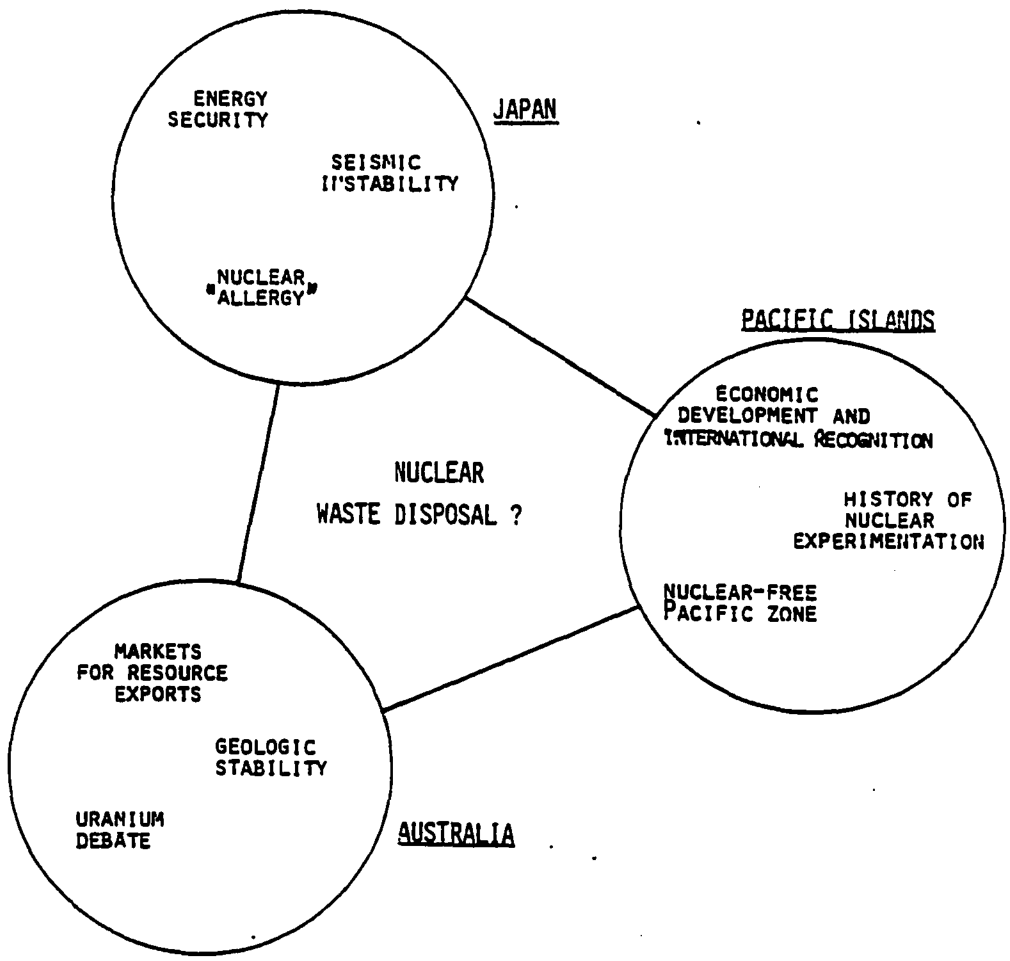


Figure 40 Dilemmas and dependence: some factors influencing the disposal of nuclear waste in the Pacific.

stable interior of the continent, has one of the best geological areas for disposal. The Pacific Islands are unwilling to accept, as they have done in the past, more risks from nuclear experimentation. Many Japanese consider that Japan has a special aversion, or "allergy" to radiation hazards, as a result of having been the first nation to have experienced nuclear attack. In Australia in 1983 the debate over uranium mining was re-opened by the Hawke government's decision to go ahead with mining large new deposits in South Australia, despite the Australian Labour Party's anti-uranium policy. The Pacific Island states meanwhile have been interested in establising a Nuclear Free Zone in the Pacific.

Several dilemmas result from these interactions. Perhaps the most important concerns weapons proliferation. Proliferation of nuclear weapons is the gravest risk that has emerged from the use of uranium fuel as an energy source. As far as nuclear waste is concerned, the connection between civilian nuclear power and nuclear weapons is closest at the reprocessing stage, as it is simpler to manufacture bombs from plutonium extracted during reprocessing than from spent reactor fuel. Therefore the issue is whether to jettison the uranium and thorium contained in spent fuel, or to reprocess to regain these resources.

It is my conclusion that the global risks of weapons proliferation outweigh the benefits of a plutonium economy, regardless of the energy situation in any one region. While nuclear fission continues to be used as a power source, technologies and institutional arrangements that separate civilian nuclear power from nuclear weapons are desirable. For example, the Japanese research effort to extract uranium from seawater[110] may be promising in this regard. The 1983 cost of natural uranium is $30-40/kilogram, and the cost of uranium from reprocessing light-water reactor fuel is approximately $500/kilogram (Rose, 1983). For reprocessing to compete economically natural uranium would have to become much more expensive. If uranium can be obtained from seawater at a low environmental cost, and a dollar cost of $500/kilogram or less, then the disposal of spent fuel without reprocessing is attractive, both from the standpoint of economics and proliferation safeguards. There would be no need for plutonium-breeding facilities or temporarily-stored plutonium, and several major links between "peaceful and warful atoms" would be broken (Rose, 1983).

The proliferation issue has great significance for political and economic relations in the region. This is the basis of the debate over Australia's role in the nuclear industry, because of the need to maintain a balance between requirements for proliferation safeguards and commercial pressures to export uranium. The argument is made that the proliferation problem would exist whether or not Australia exports uranium, and this country's ability to influence the tide of global proliferation of nuclear weapons through its uranium deposits is challenged. The present Hawke government's equivocal position on uranium mining and export, as discussed in Chapter V, is an indication that exports will continue for at least the next 10-15 years, and if so, there is a possibility that countries such as Japan which are importing from Australia, will continue to investigate the possibility of including waste disposal in the trade package.

Although Japan, itself, is not regarded as a proliferation risk, with such a high level of technological development and national wealth, it should be possible for Japan, instead of proceeding to develop domestic reprocessing and fast breeder reactors, to channel more economic resources into the development of alternatives to the plutonium economy, This initiative could provide an example for other countries that are equally dependent on imported oil. It would also lessen Japan's need to import uranium from Australia.

Because of the past history of nuclear weapons testing by colonial powers in the Pacific, islanders are adamantly opposed to anything labelled "nuclear", and in general do not distinguish between weapons tests and waste disposal. In this era of attaining national independence and political identity on the world stage, Pacific island leaders have rallied around the nuclear issue to present a united stand against waste disposal plans. The nuclear issue has already been the cause of strain in the Pacific Islands' relations with Japan, Australia and the United States. The Pacific Islands have so far rejected nuclear power as an energy source, but if the technology becomes available, the island states with rapidly expanding urban populations may face decisions in the future on whether to use small-scale reactors, manufactured in Japan, to provide energy to replace costly oil imports. I think this would be a mistake because of the environmental and economic risks of using nuclear power in island ecosystems, but the islands are even more dependent than Japan on outside sources of petroleum, and are more isolated.

Regional political solutions are most likely to succeed by using existing economic or political blocs within the Pacific region, such as the Japan-United States, or Japan-Australia partnership, and ASEAN. New cooperation has emerged among Japan, South Korea, and Taiwan, the "East Asian Trio". In the final analysis, each country will probably have to dispose of its waste by making use of the best available sites within its own "backyard". The 10 percent of the world's high-level waste produced in East Asia will thus probably have to be disposed of within the territory of the East Asian countries, but there should be ample opportunity for co-operation. These three countries have highly centralized systems of government that lend themselves more easily to national organization for resource management problems, than do the federalist systems of Australia, Canada, and the United States, that tend toward dispersal of authority and responsibility. The East Asian trio, as soon as possible, should forge an agreement for the disposal of high-level nuclear waste, instead of hoping that eventually some other country with more suitable geological conditions will accept their waste. Even if Japan, Korea, or Taiwan were successful in securing an agreement for waste disposal with Australia, a Pacific Island, or the United States, this would create much public ill-will toward the East Asian group, that may jeopardise trade and other worthwhile exchanges in the region. Japan, in particular, risks becoming a pariah country in the Pacific over the issue of disposal of nuclear waste, just as France has become one over the issue of weapons tests.

While the temptation must be avoided to implement premature and unsafe disposal strategies for the sake of appeasing political lobbies, a demonstration facility for waste disposal in one of the East Asian countries would also help to allay public suspicion and anxiety over the waste issue. The repositories to be constructed in the United States under the 1982 Nuclear Waste Policy Act are important as a demonstration that waste disposal can be achieved, but for the Pacific region, it is important that the East Asian countries demonstrate willingness to accept the risks, as well as the benefits of the economic development accruing from their use of nuclear power. This would ease the tension in relations with Pacific Island nations. In the case of Japan, the portion of high-level waste that is reprocessed in Europe may not be returned, if the United Kingdom and France can be persuaded to keep Japanese wastes, but this option would depend on public acceptance in those countries storing Japanese wastes.

Future dilemmas may arise if Pacific island nations are pressured by OECD countries to sell space for waste disposal in exchange for continuing to receive foreign economic aid. On the other hand, fishing rights might be used by the Island nations as leverage against the use of areas of the Pacific ocean for waste disposal by OECD countries. In an over-supplied international uranium market, purchase of Australian uranium by Japan may be used as a bargaining tool for eliciting waste disposal services for Japan in Australia.

To end with a thought on the time perspective, I would like to offer a quotation.

> Long ago, during the great earthquake of the year 855, the head of the Buddha of the Todaiji fell off, a terrible misfortune, indeed, but not the equal of the present disaster. At the time, everyone spoke of the vanity and meaningless of the world, and it seemed that the impurities in men's hearts had somewhat lessened, but with the coming of the new year and the passage of the months and the days, people no longer even spoke in that vein.
>
> (Kamo no Chomei, The Hojoki, (An Account of My Hut). Kyoto, Japan, 1212.[111]

This was written by a Buddhist monk in Kyoto about 1,000 years ago. A thousand years is the length of time during which the containers now being designed for nuclear waste are supposed to remain intact. I wonder if people 1,000 years in the future, if civilization endures, will view nuclear waste as a "terrible misfortune" of our present age, or will the risks then seem quaint, as the head falling off the statue of the Buddha may seem to us. Being an optimist, I suspect it will be the latter.

NOTES

109. In 1983 the nuclear industry in the United States spent $30-40 million on radio and television advertisements to promote nuclear power.

110. In August 1980 the journal Atoms in Japan (Vol.24, NO.8: 27-30) reported that the Ministry of International Trade and Industry (MITI) had established a feasibility study for the extraction of uranium from seawater. In 1981 Atoms in Japan (Vol.25, No.3: 43) reported that uramium had been recovered from seawater using a wave power generating unit.

111. Translation by Donald Keene (1955). An Anthology of Japanese Literature. From the Earliest Era to the Mid-Nineteenth Century. Grove Press, New York.

APPENDIX A THE QUESTIONNAIRE

SCHOOL ____

AGE ____

ACADEMIC MAJOR/
FIELD OF INTEREST ____

SEX ____

THE QUESTIONNAIRE

The attached page lists a number of activities (such as swimming), technologies (such as electric power), and natural hazards (such as typhoon or cyclones). This survey has four (IV) parts:

I. I would like you to judge how risky each is, at present, to Japanese (Australian) society as a whole. The specific kind of risk I want you to consider is risk of dying as a consequence of this activity, technology or natural hazard.

NOTE: Some activities are very dangerous, but involve so few people that their overall societal risk of death is very low (for example, hang-gliding). Please make sure that you rate the overall societal risk and not just the risk to those exposed.

If you need to think of a time period during which to gauge the risks, think of a whole year -- the total risk to society from each item during the next twelve months.

(for Australia)

RISKS

1. Commercial aviation	0	1	2	3	4	5	6	7	8	9	10
2. Food preservatives	0	1	2	3	4	5	6	7	8	9	10
3. Swimming	0	1	2	3	4	5	6	7	8	9	10
4. Motor vehicles	0	1	2	3	4	5	6	7	8	9	10
5. Cyclone	0	1	2	3	4	5	6	7	8	9	10
6. Uranium mining	0	1	2	3	4	5	6	7	8	9	10
7. Toxic chemical waste	0	1	2	3	4	5	6	7	8	9	10
8. Flood	0	1	2	3	4	5	6	7	8	9	10
9. Coal-fired electric power	0	1	2	3	4	5	6	7	8	9	10
10. Diagnostic X-rays	0	1	2	3	4	5	6	7	8	9	10
11. Bushfire	0	1	2	3	4	5	6	7	8	9	10
12. Smoking	0	1	2	3	4	5	6	7	8	9	10
13. Radioactive waste	0	1	2	3	4	5	6	7	8	9	10
14. Cancer	0	1	2	3	4	5	6	7	8	9	10
15. Venomous sting or bite	0	1	2	3	4	5	6	7	8	9	10
16. Oral contraceptives	0	1	2	3	4	5	6	7	8	9	10
17. Solar energy	0	1	2	3	4	5	6	7	8	9	10

RISKS (for Japan).*

1. Commercial aviation
2. Food preservatives
3. Swimming
4. Motor vehicles
5. Typhoon
6. Nuclear electic power
7. Toxic chemical waste
8. Flood
9. Non-nuclear electric power
10. Diagnostic X-rays
11. Earthquake
12. Smoking
13. Radioactive waste
14. Cancer
15. Landslide
16. Oral contraceptives
17. Solar energy

*The Japanese survey was translated into Japanese.

II. I would like you to rate each of the seventeen activites, technologies, and events on several characteristics related to risk. Each characteristic to be rated appears at the top of a separate page, with the activites, technologies and events below it. For each please mark the rating scale according to how that activity relates to the characteristic. The rating scale goes from 1 to 5.
For example:

Risk is not dreaded				Risk is dreaded
1	2	3	4	5

If you think that, for a given activity, the risks are not dreaded circle the number 1. If you think that risks are _very_ dreaded circle number 5. Use the intermediate numbers, 2,3 and 4 for intermediate degrees of dread. There are several different characteristics so there are pages of rating scales to fill out for each characteristic. Please check to make sure that you rated each activity, event or technology.

1. Common-dread

Is this a risk that people have learned to live with and can think about reasonably and calmly, or is it one that people have great dread or fear for - on the level of an emotional reaction?

	common				dread
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

2. Immediacy of effect

To what extent is the risk of death immediate - or is death likely to occur at some later time?

	effect immediate				effect delayed
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

3. Knowledge about risk

To what extent are the risks known precisely by the persons who are exposed to the risks?

	risk level known precisely				risk level not known precisely
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

4. To what extent are the risks known to science?

	risk level known precisely				risk level not known precisely
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

5. Control over risk

If you are exposed to the risk, to what extent can you, by personal skill or diligence, avoid death?

	personal risk can't be avoided				personal risk can be controlled
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemcical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

6. Newness

Is this risk new and novel or old and familiar?

	new				old
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

7. Chronic-catastrophic

Is this a risk that kills people one at a time (chronic risk) or a risk that kills large numbers of people at once (catastrophic risk)?

	chronic				catastrophic
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

8. Severity of consequences

When the risk from the activity is realized in the form of a mishap or illness, how likely is it that the consequence will be fatal?

	certain not to be fatal				certain to be fatal
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

9. Voluntariness of risk.

Do people face this risk voluntarily? If some of the risks are voluntarily undertaken and some are not, mark an appropriate spot towards the center of the scale.

	risk assumed voluntarily				risk assumed involuntarily
1. Commercial aviation	1	2	3	4	5
2. Food preservatives	1	2	3	4	5
3. Swimming	1	2	3	4	5
4. Motor vehicles	1	2	3	4	5
5. Cyclone	1	2	3	4	5
6. Uranium mining	1	2	3	4	5
7. Toxic chemical waste	1	2	3	4	5
8. Flood	1	2	3	4	5
9. Coal-fired electric power	1	2	3	4	5
10. Diagnostic X-rays	1	2	3	4	5
11. Bushfire	1	2	3	4	5
12. Smoking	1	2	3	4	5
13. Radioactive waste	1	2	3	4	5
14. Cancer	1	2	3	4	5
15. Venemous sting or bite	1	2	3	4	5
16. Oral contraceptives	1	2	3	4	5
17. Solar energy	1	2	3	4	5

III. I would like you to judge how beneficial each is, at present, to Japanese (Australian) society as a whole. Please make sure that you rate the overall benefit to society and not just the benefit to individuals. The items are listed on one page with a rating scale next to each. The scale goes from zero to 10.

BENEFITS (Australia)

1. Commercial aviation
2. Food preservatives
3. Swimming
4. Motor vehicles
5. Uranium mining
6. Toxic chemicals
7. Coal-fired electric power
8. Diagnostic X-rays
9. Smoking
10. Oral contraceptives
11. Solar energy

Part IV.

(extra questions on radioactive waste)

1. Taking into account all you have heard, or read, how do you feel about nuclear-electric power in general?

2. In order to meet the future power needs of the nation, how important do you feel it is to have nuclear power plants?
(please tick appropriate line)

_______________ extremely important

_______________ somewhat important

_______________ not very important

_______________ not important at all

3. What is your biggest worry about nuclear power?

4. Please indicate how serious you personally consider the following hazards of commercial nuclear power by rating each according to the following scale:

1. - very serious
2. - moderately serious
3. - slightly serious
4. - not serious

(please insert rating number on line).

routine emissions_________________ waste disposal__________

weapons proliferation_____________ reactor accidents________

5. Do you think the appropriate government agency and /or nuclear power companies in your country are capable of solving the problem of nuclear waste disposal in an acceptable safe manner?

(please write 'yes' or 'no' and comment if you wish)

government ____

nuclear power company __________________________________

6. What is your biggest worry about nuclear waste disposal?

7. Do you think that safe nuclear waste disposal is:
(circle appropriate letter)

(a) No problem, and that disposal is now being dealt with satisfactorily,

(b) Technically demonstrated but so far not financially supported,

(c) Theoretically proven feasible, but so far not technically demonstrated,

(d) Not theoretically solved, but a solution is close,

(e) Not theoretically solved yet, but the outlook is optimistic for a long-term solution,

(f) Impossible to achieve.

8. Which do you consider to be the most appropriate medium for a final high-level nuclear waste repository?

(circle appropriate letter)

(a) Deep land-based geological strata

(b) Deep seabed clays

(c) Ice-cap

(d) Ocean trenches

(e) Extra-terrestrial space

(f) Other (please specify)

9. If you had to choose between land-based and ocean-based geological disposal methods for high-level nuclear waste which would you choose?

land-based ______ ocean-based ______

Please indicate the reasons for your choice by ticking one or more of the following reasons:

greater geological stability ______

lower potential for resource-use conflict ______

impossibility of retrieval ______

possibility of retrieval ______

less cost ______

shorter development time ______

greater integrity of containment ______

less transportation risk ______

other (please specify)

10. Do you consider the most feasible solution to nuclear waste management and disposal in the Pacific Basin region over the next 20-30 years to be:

(please circle appropriate letter)

(a) solely at the national level i.e. each country disposes of its own waste within its own territory,

(b) through some co-operation within regional blocs(e.g. East-Asian bloc, ASEAN bloc), but mainly at the national level,

(c) mainly through regional blocs, but partly at the national level,

(d) through Pacific Basin-wide co-operation,

(e) other (please specify).

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