Why not in the ocean?

by C.L. Osterberg*

Man will always face the problem of what to do with the myriad wastes of civilization. Disposal options are limited to the air, land, or water. Things that oxidize to carbon dioxide and water are well suited to discharge into the atmosphere, although the build-up of carbon dioxide is becoming worrisome. Nevertheless, the burning of sludge and other wastes is being encouraged, with a ship licensed to burn some of the more toxic wastes at sea, away from population centers. Burning at sea is not practical for many materials, because the cost of disposal approaches or exceeds the cost of manufacture. It has even been suggested that when fusion reactors are developed (operating at millions of degrees centigrade), their exhaust temperatures of tens of thousands of degrees will make ideal "fusion torches" to quickly reduce solid wastes to the basic elements, ready for recycle [1].

Those days are clearly not yet here, leaving us with a waste disposal problem for the many materials that do not reduce to relatively harmless gases for disposal into the atmosphere or that cannot be economically recycled. Many solid and liquid wastes are in this category. For them, a place must be found either on or in the land, or in the ocean.

Man almost instinctively recoils from using the ocean for the disposal of toxic wastes. It was not always this way, but our protective attitude toward the ocean grew stronger with the flowering of the environmental movement in the 1970s. Perhaps it was a combination of things. There was a popular book called *The Frail Ocean,* and, of course, the movies by Cousteau raised our sensitivities to the oceans. And probably we felt that since we had fouled the land with the by-products of civilization, rendered most of our streams and lakes unfit to drink or to swim in, and filled our skies with smoke and smog, the least we could do for posterity was to save our seas, and bumper-stickers on automobiles carried that message. The murky coastal waters, often rich in sewage, gave ample proof of need – strong evidence, or so it appeared, that our oceans were in trouble.

Early on, radioactivity was singled out as being too toxic for marine disposal. Thus the USA, when contemplating how to dispose of the topsoil from the small island of Runit (also known as Yvonne) in the Enewetak Atoll, found its options limited. The ruling of the regulatory agency involved left no choice – the soil, contaminated during nuclear bomb tests with plutonium, would have to go on land. The debris was mixed with cement and water, poured into the cone-shaped crater left from the "Cactus" explosion, then capped with concrete. This massive concrete mausoleum, visible from outer space, is a monument to regulatory zeal run amok, for all the universe to ponder. But not forever: although the half-life of plutonium is measured in thousands of years, that of concrete is measured in hundreds. Someday it will crumble, but for now at least the ocean is safe. At any rate, that is the pious hope.

Since the critical organ for plutonium is the human lung, one might reasonably have thought that the deep ocean bottom would have been a singularly safe place to dump the plutonium-contaminated soil from Runit. Even the most imaginative pessimist would have had difficulty coming up with many pathways for the plutonium, under two miles of water, to be breathed as dust into the human lung, thus causing cancer. On the other hand, given the tropical sun, rain, and lots of time, it is not too hard to conjure a picture where the concrete-plutonium mixture turns to dust and is kicked into the air by the tradewinds, to be breathed by human populations downwind.

In the USA, recently a similar problem to that of Runit Island has come up – how to dispose of some 100 000 cubic yards of slightly contaminated soil (about 5 curies of uranium-238). This site at Middlesex, New Jersey, scene of activities in the early days of the atomic bomb project, has to be cleaned up and the ocean is being considered for ultimate disposal of the soil. Although the issue will no doubt be widely debated in the public arena, scientifically it is a non-problem. A sense of perspective makes that clear. Dissolved in the ocean is over a billion curies of uranium-238, courtesy of Mother Nature, and the top inch of the ocean floor contains several millions more. Furthermore, just one river, the Mississippi, adds 363 curies each year: 190 in the water, and 173 in the sediments [2]. Can 5 more curies possibly matter? While public concern will no doubt be focused on these 5 curies of radioactivity (I can see 5 trillion picocuries in the headlines!), the major impact – if any impact so small can be called major – will be from the silt. A lesson of the early bomb tests at Enewetak is that the mud, silt, and other non-radiological factors are bigger killers of marine organisms than radioactivity [3]. Yet most anxiety arises from the thought of putting radioactivity in the ocean.

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At the international level, the London Convention and the Barcelona Convention protect our seas from radioactivity. In the USA, Congress passed the Marine Protection, Research and Sanctuaries Act of 1972, also known as the Ocean Dumping Act. This law, as amended in 1977, has made ocean radwaste disposal impractical. And in Europe Greenpeace, an environmental group, protects us from *legal* sea disposal by interfering with ship operations at the Atlantic dump site, while protestors on land impede the transport of solid radwastes to the docks – civil disobedience for a higher cause – to protect the oceans from radioactivity. Even *Science* doesn't appear even-handed. In its article, "USA considers dumping of radwastes" [4], it chose to publicize the view against ocean dumping with scant mention of scientists with a different view. Featured prominently, in a box with large print and setting the tone of the article is the phrase "The ocean just isn't a good place to put radwaste; if you put it there, you can't get it back".

Is the evidence against ocean disposal of radwaste really that conclusive? Is there no room for doubt? So far, there has been almost no dialogue, only a monologue – indeed more a chorus of angry voices – by those who wish to keep the ocean inviolate, those who don't want to dump, those who want to "Save our seas".

There is another side to this issue. Some feel that the ocean doesn't deserve all of the legal and illegal protection it is getting. My own opinion is that if any part of Planet Earth deserves special treatment, it is the land on which we are utterly dependent for living space and which provides over 85% of our food, nearly all our fibre and building materials, and almost all our potable water.

Should we preserve the ocean at the expense of the land – for surely the laws that protect the ocean leave no option but to use our limited land for toxic waste disposal? If the earth, seas, and skies are all part of one ecosystem, the life-support system on which we depend, how can we justify protecting only the seas while punishing the land? Especially because the land is more precious, more limited, and more vulnerable – the land is the weak link.

This should not be accepted on faith: the concept is far too important for that. So, first I will give some perspective on the problem – the present burden of radionuclides in the ocean – then discuss a very important concept, the carrying capacity of the ocean, and finally look at the cleansing processes peculiar to the ocean which increase its carrying capacity, making it more suitable than land for radwaste disposal.

A radioactive world

We long thought the ocean to be a "low-radiation-dose regime", since the intervening water protected marine organisms from cosmic rays. Marine animals, therefore, received about 35 mrads per year *less* than animals on the surface of the earth – nearly one-third less radiation than man, thanks to the water [5]. So, the reasoning went, these marine animals, having evolved with less radioactivity, would be more susceptible to radiation damage than their terrestrial counterparts, who had no doubt evolved protective mechanisms against radiation. Therefore, we should not stress these organisms – polluting their low-radiation environment – by dumping radioactive wastes into the ocean.

We got this incorrect picture honestly. I remember lowering a water-tight gamma-detector on a long cable over the side of a ship, and observing the changing count rate. Poised in the air above the water, the count rate was high, but once under the water the count dropped sharply as the cosmic rays were screened out. Finally, the count rate jumped up again as the detector encountered the bottom sediments, which were rich in insoluble radionuclides and those removed from the water column by various biological and chemical processes.

Nevertheless, ocean water is radioactive, each litre decaying at a rate of about 750 disintegrations per minute, due mostly to potassium-40. There are over 400 billion curies of potassium-40 in ocean water, 40 billion curies of rubidium-87, and 100 million curies of radium [6]. It is the radium (radium-226) that had been overlooked in the earlier evaluations which mistakenly deemed the sea to be low in background radiation.

Radium-226 is a descendant of uranium-238, which, as noted earlier, is quite abundant in sea-water. Far down the decay chain from radium is polonium-210. It is the polonium that is avidly concentrated, mostly in digestive tracts of marine animals, giving them much higher doses than had been thought possible. But, since polonium is an alpha emitter, it had not been measured properly. In fact, as our knowledge of polonium grows, it has become increasingly clear that marine organisms have had to adjust to *higher* background doses of radioactivity than do most land animals.

The IAEA's Monaco Laboratory helped unravel the polonium story*. Cherry [7], an early worker, is presently at Monaco, as is Heyraud, another major contributor. Beasley, a former director of the Monaco Laboratory, is a pioneer in the field, and others, including Fowler and Holm, have contributed over the years, while Woodhead did much of the dosimetry.

Heyraud and Cherry say, "From our data it seems clear that doses from Po-210 alone of about 10 rem per year or more are the rule rather than the exception in the marine hepatopancreas; this organ must constitute one of the highest, wide-spread naturally-occurring radiation-dose domains" [8]. That is about

* See the article by A. Walton *The work of the International Laboratory of Marine Radioactivity* in IAEA Bulletin Vol.23, No.1, p. 24 (1981).

100 times the whole-body dose man receives from all sources. Until recently, the highest polonium-210 dose recorded was in the pyloric caecum of an albacore tuna – about 80 rem per year [9]. Now, a study on marine shrimp at Monaco shows that the hepatopancreas of deep-pelagic penaeid shrimp receives about 100 rem per year [10]. These doses dwarf the 5 mrem (0.005 rem) per year permitted for a person at the fence line of a nuclear power plant in the USA or the 70 mrem maximum dose to members of the public (less than 2 mrem each for the 2 million people within 50 miles) during the Three Mile Island nuclear accident. The natural radionuclides in the ocean total about 1000 times more than man's technology has produced to date [11]. Furthermore, the radionuclides from man's activities are shorter-lived and often less toxic than the natural ones which have been here since the world began. Long after existing inventories of man-made plutonium-239 (24 000 year half-life) are gone, natural uranium-238 (half-life 4.5×10^9 years) will be providing radium and polonium to marine organisms, and rubidium-87 (6.2×10^{10} years) will be only slightly diminshed.

Carrying capacity

In 1979, a National Oceanographic and Atmospheric Agency conference concluded that the waste capacity of US waters is not yet fully used [12]. It is generally, but not universally, acknowledged that the ocean can accept some wastes at a certain rate without observable effects on marine biota, or on man who feeds on these plants and animals. I will refer to the ability to absorb a pollutant without undue degradation as the carrying capacity, although other authors may call it the assimilative capacity [12, 13], or even the absorptive capacity.

Whatever the term, the important concept is that the ocean is not like a gas tank that will read "full" when it has had enough, but that the ocean can continually accept wastes at some rate – a steady state – over infinite periods of time. The cleansing mechanisms – biological, chemical, geological, and physical – will process the wastes, removing them from the system, keeping the ocean clean and capable of supporting life.

These cleansing systems have been badly overloaded in our shallow, poorly circulating coastal waters and have broken down. On the other hand, the open oceans – even the Mediterranean [14] – are relatively free from pollution. If our wastes are judiciously introduced (in reasonable amounts and in the proper chemical and physical forms) in the infinitely greater volume of water offshore, or where currents ensure rapid removal and mixing, the carrying capacity should be appreciably greater, enough to serve mankind indefinitely.

I will only summarize the cleansing processes operating in the ocean, because they are described elsewhere [15, 16, 17]:

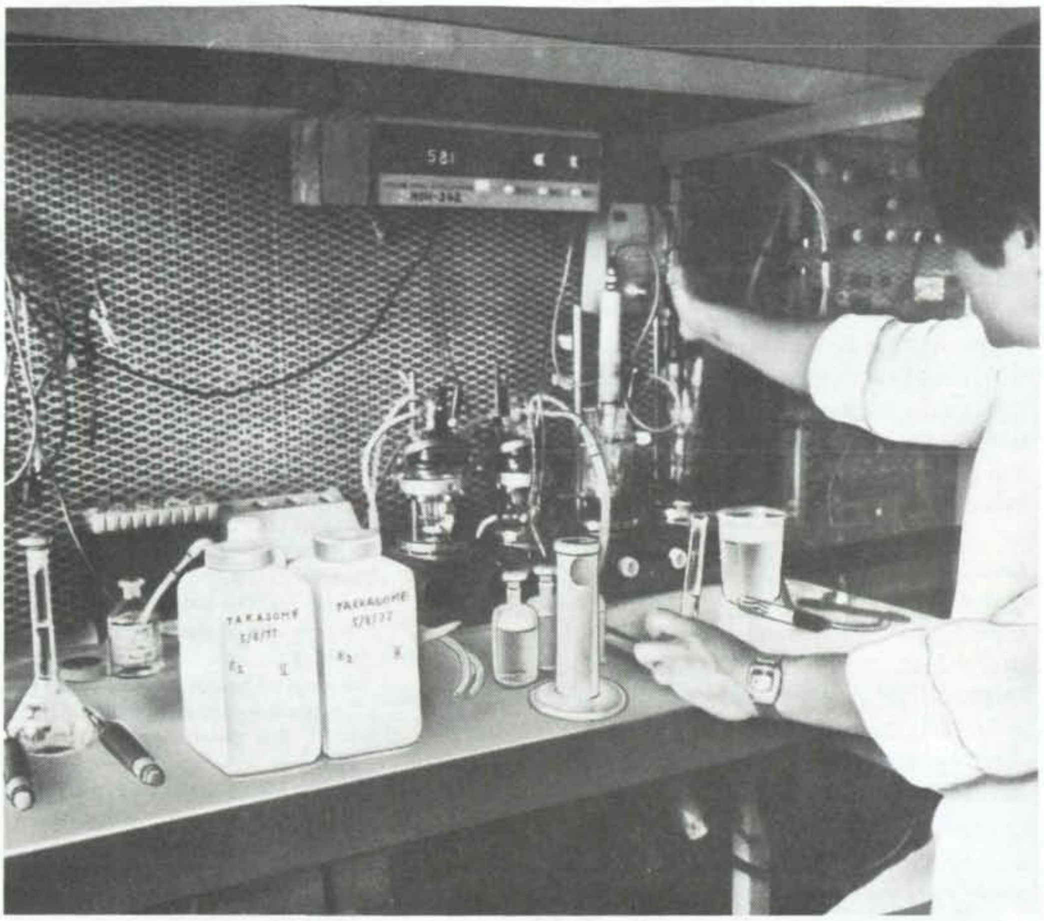
- Unlike the land the ocean is three-dimensional, so pollutants do not concentrate on the surface but eventually are stirred throughout the water column.
- Our contact with the ocean is minimal, compared with our intimate contact with the land.
- Many pollutants, probably most, tend to bind to particles and settle to the bottom. Thus many radionuclides end up in the sediments where they are more isolated from man than on land.
- The ocean is not pure water, but instead is a toxic mixture of practically every element known to man. It contains every radionuclide found on land, and every stable isotope as well.
- Marine food-chains are generally longer than on land. Thus, if there is discrimination against a radionuclide (and a report of the National Academy of Sciences [18] says that, above plankton, there is), man, at the top of the food-chain, will get less radioactivity from seafood than from a comparable amount of food from the land.

Even though the ocean covers over 70% of the earth's surface, seafood provides less than 15% of the world's annual food production [19]. But, because of both isotope dilution, which reduces the uptake of radionuclides by marine organisms, and the longer food-chains in the ocean, much less than 15% of our radioactivity comes from seafood.

On the other hand, food-chains on land are short. We eat either plants or parts of plants from the very bottom of the food-chain, or the animals – chickens, cows, and pigs – that feed on plants. Strontium-90, a particularly fearsome radionuclide on land from fall-out, deposits on the leaves of plants or on the ground near their roots, and enters the short food-chain in relatively large amounts, thus threatening man.

In the ocean, quite differently, each strontium-90 atom in the water is bathed in stable strontium – literally inundated by the far more abundant stable strontium atoms already there. Even more plentiful, chemically similar, and offering competition to the strontium, are the stable calcium atoms. Massively diluted by stable strontium and subject to chemical competition from overwhelming amounts of stable calcium, very little radioactive strontium-90 gets taken up. For organisms in the water cannot *selectively* take up strontium-90 without taking up, in the same relative abundance they are in the water, stable strontium plus some calcium. The technical term is "isotope dilution", and a related term that uses the same variables is "specific activity". We would describe the situation above by saying that the specific activity of strontium-90 in sea-water is very low, because of isotope dilution.

The concept need not be understood to make my point. That is accomplished best by data from the real world. Eisenbud [20] shows that, although 7.1 million curies out of the 17 million curies of strontium-90 produced in fall-out from nuclear-weapons tests landed in the Pacific



The IAEA's International Laboratory of Marine Radioactivity at Monaco analyses, as can be seen from this photo, samples of sea-water to assess the levels of radioactive and other pollutants.

The IAEA's Monaco Laboratory has played an important role in studies of how marine life concentrates radioisotopes. Here a scientist prepares a specimen for analysis.

Ocean (about 42%), the fish and shellfish eaten by San Franciscans contributed only 0.2% of their annual per caput Sr-90 intake. Similar findings hold for New York. For many of us, over 99% of our strontium-90 intake comes from the land.

The cleansing mechanisms of the sea do work, especially for strontium-90. Caesium-137, another bad actor on land, is also discriminated against in the ocean, but to a lesser extent. Even so, the data from Enewetak and Bikini (where 43 and 23, respectively, of the 106 US weapon tests in the Pacific which resulted in fall-out took place), show that, although both the land and lagoon ecosystems were grossly contaminated by radioactivity, the lagoon recovered much more rapidly. The radioactivity settled to the bottom, was carried down by the silt and debris, or was flushed into deeper waters, etc. These cleansing processes peculiar to the ocean caused a quick recovery so that soon the marine food-chains could provide food on a routine basis, without exceeding the safety standards for radiation. But years later the terrestrial food-chains, the coconuts, papayas, land crabs, etc., are still too radioactive to be included in the daily diets of the natives — evidence that the ocean has a greater capacity to handle and remove radioactive wastes than the land.

I have long been impressed by the ocean's ability to take care of itself. It is the land that has me concerned, particularly the fresh waters under the land. Groundwater, though it makes up less than 1% of the planet's waters (but most of the fresh), supplies the needs of nearly half the people in the USA. But 40 million in the USA drink water untreated, direct from the ground. Groundwaters are vulnerable to pollutants leaking from land disposal sites. The people drinking untreated groundwater have the most to fear from the current attitudes against sea disposal, which leave only our precious land as a receptacle of civilization's most toxic wastes.

Man's ancestors long ago crawled out of the ocean and now man's fate, like his feet, is firmly fixed to land. We must take better care of the land. The ocean has shown that it is ready to help. Shouldn't it be allowed to do so?

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