

**Remediation of Kiritimati Island and the Challenges of Hazardous Waste Disposal  
to the United Kingdom from the Central Pacific – 9526**

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**ABSTRACT**

This paper describes the work undertaken by Safety and Ecology Corporation Ltd (SEC) on Kiritimati Island, formerly known as Christmas Island. The discussion gives an overview of the type of remediation performed to remove the remains of the legacies left after British nuclear testing. The environment on and around Kiritimati Island has been greatly improved by the remediation carried out. All of the wastes that were to be removed from the island were safely removed from the island for either disposal or recycling. The end point criteria were met for the remediation project. The transportation and disposal of hazardous and radioactive wastes can be a project critical activity and needs to be planned well. Consideration should be given to removing radioactive material from a project site as soon as it is ready to be moved instead of combining it's transportation with other hazardous wastes.

**INTRODUCTION**

Kiritimati Island is a coral atoll in the northern Line Islands and forms part of the Republic of Kiribati in the central Pacific Ocean. The island has the greatest land area of any coral atoll in the world (about 124 square miles) and the island comprises over 70% of the total land area of the Republic of Kiribati. When the island was discovered by Captain Cook on Christmas Eve 1777, the island was uninhabited. The island is now occupied by over 5000 inhabitants. Its population is increasing as people are moved from Tarawa to Kiritimati in an attempt to reduce the strain on Tarawa's limited resources.

During the late 1950s, Great Britain undertook a series of atmospheric nuclear tests in the Kiritimati island area. These nuclear tests were code named Operation Grapple. Most of these nuclear tests were conducted over the ocean near Kiritimati island or were performed close to nearby Malden Island. Two balloon anchored detonations took place 450m above the south east point of Kiritimati Island as a part of the Grapple Z series of nuclear tests [1, 2]. The United States of America also used Kiritimati Island as a base for conducting the Operation Dominic series of nuclear tests in the early 1960s.

By 1969, military interest in Kiritimati Island had ceased and the facilities were abandoned and for the most part dismantled. Radiological surveys and decontamination operations were performed at Kiritimati Island prior to the base being closed down [3, 4, 5]. Some communications, transport and logistics facilities were converted for civilian use. A wide range of vehicles were serviced and left on Kiritimati Island for use by the islanders.

In subsequent years, further radiological investigations were conducted at Kiritimati Island [6, 7, 8] to assess the residual levels of radioactivity present from the weapons testing programme. During the time since the military presence on the island finished, the infrastructure and vehicles left on the island deteriorated and in the main were not used by the islanders. Twenty one radioactive radium dials were identified in the liability assessment performed in 1998 [8]. A subsequent investigation performed by Enviros Consulting Ltd in 2003 found forty seven radium dials associated with vehicles.

In December 2004, Safety & Ecology Corporation (SEC) Ltd were awarded a contract to “clean up” the military waste left by the United Kingdom’s Ministry of Defence (MOD). This waste included radium luminised dials associated with vehicles, asbestos pipework, loose fibrous asbestos, battery stock piles, large bitumen spills (see figure 1) and large numbers of heavily corroded metal vehicles and structures. These wastes were often located within villages on the island and they posed a significant hazard to the local population.



Fig. 1. Drum store and bitumen spill near the town of London on Kiritimati Island prior to remediation.

Clean up operations commenced in early 2005 on Kiritimati Island. Good engagement of the key stakeholders, principally the local community, occurred throughout the project and local labour was used to deliver this work [9]. This paper summarises the work that was performed to clean up Kiritimati Island, the methodologies used to sentence the radioactive wastes, and the work carried out to demonstrate that the end point criterion had been met. This paper also discusses the waste disposal/recycling routes used and some of the lessons learnt from the difficult process of disposing of British legacy hazardous wastes to the United Kingdom.

## **KIRITIMATI ISLAND CLEAN UP**

Kiritimati Island is one of the most remote islands in the world with little infrastructure and few commercial organisations working in the area. The mobilisation of equipment and personnel to the island posed significant logistical challenges however the disposal of waste from the island proved to be the greatest challenge of the entire remediation project. Through out the remediation project, there was a high level of involvement with representatives from the British Foreign and Commonwealth Office (FCO) and the Government of Kiribati.

Definitive end point criteria had been set at the start of the project and this helped to formulate the working methodologies used. These criteria included the removal of all identified legacy wastes, clean up of bitumen spills, removal of all radiological contamination greater than  $0.033 \text{ Bq.g}^{-1}$  Ra-226 [10] and removal of the asbestos waste liabilities (asbestos contaminant clearance level was 0.001% by weight).

The derivation of the target radiological contamination remediation criterion of  $0.033 \text{ Bq.g}^{-1}$  Ra-226 was based upon a dose of  $2.0 \times 10^{-5} \text{ Sv.year}^{-1}$  (equivalent to a  $10^{-6}$  residual risk) [10].

The presence of radioactive radium wastes on Kiritimati Island, and not asbestos legacies, was the main political driver for the clean up contract.

The first phase of the Kiritimati island remediation project required SEC staff to mobilise to the island and establish an on-island presence. This work involved the construction of accommodation, installing suitable water purification systems, and training of local people in good food hygiene standards for the preparation of the team's meals.

A health physics and gamma spectroscopy laboratory was set up at the main site accommodation compound. This laboratory housed all of the radiological protection instrumentation for the project team and a gamma spectroscopy system. Radioactive sources and reference Ra-226 standards were transported to Kiritimati Island, from SEC's instrumentation laboratory in Tennessee, for use by the project team.

A dedicated Waste Storage and Segregation Area (WSSA) was established adjacent to the main port for Kiritimati Island. The WSSA (see figure 2) was to be used for the receipt of wastes from all over the island, the segregation of these wastes, size reduction of the wastes, and the storage of the wastes pending transportation to a recycling or disposal facility.

Within the WSSA another fenced area was constructed. This was to store the friable asbestos and the radioactive materials generated by the project. This area became known as the Radioactive and Asbestos material Storage Area (RASA). All wastes destined for the RASA were to be suitably contained prior to transportation from their location on the island.



Fig. 2. A panoramic view of the WASA and RASA during operations.

Heavy equipment such as lorries, excavators, and bull dozers were not available on the island therefore all equipment that was required to deliver the clean up programme was shipped to the island from Honolulu on a barge.

The second phase of the project was to remove the various legacy wastes in accordance with approved working instructions. A significant number of local people were recruited to assist with the clean up of Kiritimati island. The local people were not used for any work with asbestos or radioactive materials.

At each work area, the presence or absence of radioactive material or asbestos containing material were established prior to any works commencing. If asbestos or radioactive material was found then these items were removed first.

All asbestos containing materials were removed using licensed asbestos sub-contractors from either the USA or the UK. In total, 383.4 metric tonnes of asbestos containing materials were removed from sites around the island. Where friable asbestos was encountered on the island, samples of soil were taken and

sent for analysis at a suitable laboratory abroad. If greater than 0.001% by weight asbestos was found then the ground was excavated until the remediation criteria had been satisfied.

The radioactive radium dials and any contaminated metal had a tie down material applied to their surfaces. The health physics technicians then cut out the radioactive section, bagged it and transported it to the RASA. In total, 90 radium dials were found by the project team. In most locations, the radium dials had deteriorated significantly and this had led to localised ground contamination being present. If radioactive ground contamination was detected, the ground was excavated until there was no detectable radioactivity on a hand held 3" NaI(Tl) scintillation detector. Samples of the excavated material were taken as they were generated and they were analysed for radioactivity. The excavated material was transferred into two hundred litre drums for final waste sentencing using in-situ gamma spectroscopy analysis at the RASA. Upon completion of excavations, a walkover survey was conducted using a NaI(Tl) scintillation detector coupled to a ratemeter, datalogger and global positioning system receiver. This allowed the generation of maps demonstrating that the detectable radioactivity had been removed. Representative samples of the ground were also taken and analysed using the gamma spectroscopy equipment in the health physics laboratory. The results of these samples were compared against the results obtained for the reference standards held on island. The gamma spectroscopy approach for demonstrating the remediation criteria had been met was appropriate as adequate time had passed since the manufacture of the radium dials to allow Ra-226 to be in secular equilibrium with its daughter progeny. Through the combination of these techniques, SEC Ltd was able to deliver the remediation criteria of  $0.033 \text{ Bq.g}^{-1} \text{ Ra-226}$ .

For most of the clean up work, the work involved the removal of scrap items. These were size reduced in-situ as necessary and then moved to a point that they could be safely lifted onto a lorry for transportation to the WSSA. As far as was reasonably practicable, the majority of the size reduction works took place in the controlled environment of the WSSA. Some cutting operations had to be performed underwater using specialised cutting equipment. In total 3471.1 metric tonnes of inert scrap metal were transported to the WSSA for processing and storage.  $125 \text{ m}^3$  of tyres/rubber were also removed from the various work locations around the island and this material was segregated and stored in the WSSA for future recycling.

There were piles of demolition rubble on the island and some old building slabs and walls that were to be removed as part of the clean up contract. These structures included the old aircraft control tower, the bomb assembly building, etc. The removal of this concrete generated around 2000 metric tonnes of material which was then re-used at London Point on Kiritimati Island for shoreline protection (a considerable number of vehicles had been deposited off the shore at London Point to provide shoreline protection in the past and SEC had removed these as part of the clean up contract).

The bitumen wastes that were present on the island was viewed as a resource by the islanders. The Kiritimati Island local land planning board made a formal request for the bitumen wastes to be left on island for their use. Therefore instead of removing the material from the island for recycling, SEC constructed a Bitumen Processing Area (BPA).

After construction of the BPA (see figure 3), the bitumen and bituminous contaminated materials were brought to the BPA for bitumen harvesting. After the bitumen was harvested, the island engineers were able to re-use the bitumen for road maintenance and the clean scrap was then transported to the WSSA for further processing. SEC also constructed a bitumen road repair wagon for the Kiribati engineers to assist in them repairing roads and facilitate re-use of the recovered bitumen. The BPA was handed over the Kiritimati Island engineers as an asset for their continued use. Local islanders were trained on how to operate the BPA prior to handover. In total, approximately  $1250 \text{ m}^3$  of bitumen was sent to the BPA for re-use by the islanders.



Fig. 3. The Bitumen Processing Area that allowed for the recovery and recycling of bitumen.

Other legacy wastes removed during the project were piles of glass and batteries. The lead was removed from the batteries to maximise the amount of recycling achieved during the project.

After removal of all of the wastes to the WSSA and RASA, the final stage of the project was to remove and recycle or dispose of the materials. Prior to shipping and disposal of the radioactive contaminated materials it was necessary to fully characterise the waste.

### SENTENCING OF RADIOACTIVE WASTES

Throughout the remediation works, SEC took all reasonable steps to segregate inert and hazardous materials at the worksite. Radiological wastes were segregated as per table I below as they were generated.

Table I: Radiological waste categories used during the remediation of Kiritimati Island

Waste category	Waste	Activity Concentration (Bq.g <sup>-1</sup> )
I	Intermediate Level Waste (ILW)	>4000 Bq.g <sup>-1</sup> total alpha activity
II	Low Level Waste (LLW)	> 4.9 Bq.g <sup>-1</sup> and < 4000 Bq.g <sup>-1</sup> total alpha activity
III	Materials exempted from control under Radioactive Substances (Phosphatic Substances, Rare Earths, etc.). Exemption order <sup>a</sup> but requiring special disposal.	> 0.37 Bq.g <sup>-1</sup> and < 4.9 Bq.g <sup>-1</sup> Ra-226
IV	Materials below UK regulatory concern <sup>b</sup> but above clearance criterion.	> 0.033 Bq.g <sup>-1</sup> above background but < 0.37 Bq.g <sup>-1</sup> total activity

<sup>a</sup> See Ref. 11.

<sup>b</sup> See Ref. 12.

All of the radium dials were monitored using hand-held NaI(Tl) gamma scintillation detectors and an ion chamber instrument. A comparison table had been calculated that interpreted the instrument readings and gave the radioactivity content of each radium dial based on a measurement at a set distance from the dial. All radium dials and contaminated metal were above the activity concentration limits of waste categories III and IV but were within the limits of waste category II therefore they were consigned as low level radioactive waste (LLW). In total 175 kg of LLW was generated during the Kiritimati Island clean up project. There was no Intermediate Level waste generated during the project.

From field measurements, it was anticipated that all of the remaining material (principally excavated sand/soil) would fall into the category of category III or IV waste. All of this material had been placed into 200 litre steel drums and left for at least 4 months before performing any gamma spectroscopy measurements. This gave sufficient time for the secular equilibrium of the gamma emitting radionuclides to be established. The secular equilibrium may have been disrupted during the excavation process due to the escape of Rn-222 gas.

A series of gamma spectroscopy measurements were made of each drum to ascertain the total radionuclide inventory of each drum. It was decided to infer the Ra-226 activity of the waste from the 0.6 MeV emission of Bi-214 as it was a readily detectable peak with a statistically significant count rate and was not visibly affected by the Compton distribution when the gamma spectrum was reviewed in the field.

Prior to assaying each drum of waste on Kiritimati, a series of measurements were made of each of SEC's reference Ra-226 sand radioactive sources. SEC held four radium sand radioactive sources on island and these were traceable back to US reference standards. These sources were sealed containers hence there should have been little leakage of Rn-222 gas and the gamma emitting radionuclides should have been in secular equilibrium with the Ra-226 parent radionuclide when the measurements were made.

The series of measurements made on the reference standards allowed for the later interpretation of the gamma spectroscopic data obtained, following measurements of drums of waste, using appropriate modelling with Microshield software. Each drum had in-situ gamma spectroscopy performed on it at 5 specific locations.

All drums of potentially radioactive waste were weighed and assayed to ascertain the total radionuclide inventory of each drum. The individual Bi-214 peak areas (emissions at 0.6 MeV) were recorded for each measurement of each drum, along with the integrated counting time utilised and the mass of each of the drums, and the calculation of the mean specific activity of each drum of waste utilised all of this information.

Following the determination of the mean specific activity of each drum of waste, the material was then classified into the appropriate waste category. In total there were 3.59 metric tonnes of class III waste and 21.38 metric tonnes of class IV waste generated during the clean up of Kiritimati island.

After the waste was assayed and the waste category determined, the waste was then appropriately packaged ready for transport and disposal.

## **WASTE TRANSPORTATION, RECYCLING AND DISPOSAL**

Prior to the commencement of the Kiritimati Island clean up project, a memorandum of understanding was established between the Government of the Republic of Kiribati and the Government of the United

Kingdom of Great Britain for the remediation of Kiritimati island following the military activities on the island [13]. This memorandum of understanding states that “all substances taken from contaminated land during the remediation process will be removed to a place outside the exclusive economic zone of the Republic of Kiribati”.

The majority of the inert and scrap wastes were collected and transported to Singapore relatively simply for recycling. The scrap waste had an intrinsic recycling value so it was highly desirable by many recycling companies. The hazardous and radioactive wastes did not have any residual value and were a significant challenge to dispose of.

Kiritimati island, and some other islands in the Republic of Kiribati have lined landfills that could be suitable for various hazardous wastes. In accordance with the Memorandum of Understanding, this disposal option was not able to be exercised for the disposal of the wastes from the clean up project. The UK Environment Agency would have preferred an appropriate on-island facility be used for the disposal of the wastes, rather than transporting the material to foreign lands both for environmental and cost reasons.

In order to dispose of hazardous and radioactive wastes in a timely manner it is essential that a suitable waste disposal route is identified for each waste stream at the start of the project. The documentation process for international movements of wastes can be the critical path of a remediation project.

The Basel Convention [14] states clearly that the transboundary movement of hazardous wastes and other wastes should be permitted only when the transport and the ultimate disposal of such wastes is environmentally sound. As the option to dispose of the waste in the Republic of Kiribati was not permitted, SEC searched for economically and environmentally suitable landfill options for the disposal of the hazardous wastes (excluding radioactive wastes) at locations relatively close to Kiritimati Island. A landfill site in Fiji was identified as being technologically, environmentally and economically suitable for the disposal of the wastes. However, the UK Foreign and Commonwealth office were not in favour of this option at the time and this option was prohibited.

Under the Basel Convention [14] every state has the right to ban the entry and disposal of foreign hazardous waste and other wastes in its territory. This can make the identification of suitable disposal facilities more challenging.

In the end, the hazardous and radioactive wastes from the clean up of Kiritimati Island were to be sent to the United Kingdom as it was British legacy material. Within the United Kingdom it was necessary to identify a suitable disposal facility or recycling facility or intermediary facility for each of the waste streams so that the material could enter the country smoothly. Early in the project, not all of the waste streams nor their quantities were known. It is important to know what the material is and where it is destined as this significantly affects how the waste is treated, packaged and transported.

One of the greatest challenges for the project team was to identify a site in the United Kingdom that would accept the class III and class IV wastes as they contained trace levels of radioactivity and these lightly contaminated coral sands may have also had Japanese knotweed seeds in it. A suitable site was found.

The class II waste, the Low Level Radioactive Waste (LLW), was termed as “Defence Related Military Waste” from the outset of the project. It was known that this material had to come to the United Kingdom and there is only one final disposal destination possible for it. The LLW was destined for the Low Level Waste Repository (LLWR) near the village of Drigg in Cumbria. A project risk was for the material to be consigned directly to the LLWR, then being rejected due to a non-conformity then being

returned to the place of origin. When the place of origin is the opposite side of the planet it was essential that this risk was substantially mitigated. A contract was placed with Safeguard International Ltd at Winfrith in Dorset to receive the LLW from Kiritimati Island and for them to consign the material to the LLWR. This significantly reduced a major project risk.

Upon notification to the Government of Kiribati that the hazardous wastes were destined for the United Kingdom, the Government of Kiribati submitted a Duly Motivated Request to the United Kingdom's competent authority [in accordance with Ref 15]. The competent authority for England & Wales is the Environment Agency. The Duly Motivated Request went through due process on more than one occasion as the project progressed due to the nature and volumes of wastes being encountered being different from that originally scoped for the clean up project.

Until the Duly Motivated Request had been approved, finalised arrangements for shipping the hazardous wastes could not be made.

Upon receipt of the signed Duly Motivated Request, it was then possible to start finalising the arrangements for transportation of the wastes and preparing the documentation for Transfrontier Shipment notification.

The class III and class IV wastes, were classified as general waste for shipping purposes as their radioactivity contents were less than the levels defined as being radioactive material for the purposes of radioactive material transport [16].

The importation of low level radioactive waste to the United Kingdom is normally subject to the requirements of the Transfrontier Shipment of Radioactive Waste Regulations 1993 [17], however as it was "Defence Related Radioactive Waste" an exemption was granted and accepted by the UK's Environment Agency.

The Control of Asbestos Regulations 2006 [18] specifically prohibits the importation of asbestos into the United Kingdom. From the clean up of Kiritimati Island, SEC had 383.4 metric tonnes of asbestos containing materials that needed to be imported to the United Kingdom. It was demonstrated to the UK's Health and Safety Executive that this material was of British origin and that there was a reasonable case for this asbestos to be imported for disposal. An exemption certificate was issued by the Health and Safety Executive for the import of the asbestos for disposal.

To transport material from Kiritimati Island to the United Kingdom, there are two shipping options. One is to take the material through the Suez Canal and the other is to take the material through the Panama Canal. The two options are approximately equidistant. To reduce costs associated with the project, it had been planned to transport the hazardous and the radioactive waste on the same vessel by the same route.

Discussions were held with both canal port authorities and permission was granted for all of the waste to pass through the Panama Canal however the radioactive material was not permitted to go through the Suez Canal. Therefore discussion took place with shippers to take the material east towards the United Kingdom through the Panama Canal.

Despite the organisation of shipping, exemption certificates, transfrontier shipment notifications, and disposal routes, at the eleventh hour the vessel scheduled to take the radioactive waste and the hazardous waste to the United Kingdom refused to accept the radioactive waste cargo. A decision was taken to load the hazardous and general wastes onto the vessel leaving one package of radioactive waste on Kiritimati Island. The scheduled vessels then proceeded through the Suez Canal instead of the Panama Canal. The



material arrived safely in the UK and was sent to either its disposal location or for recycling as appropriate.

In order to close out the project, the final package of waste had to be removed. Arrangements were put in place to air freight the material to the United Kingdom. A few months later, this material flew on a chartered aircraft (see figure 4) from Kiritimati Island to Honolulu then across the USA and arrived in London for road transportation to Safeguard International's facility at Winfrith. The air freight of the radioactive waste was about three times more expensive than the comparative cost for sea freight however if the radioactive material had been removed from the island as soon as it was ready for transportation then a number of complications associated with transporting hazardous and radioactive wastes on the same vessel would have been avoided and may have accelerated the completion of the project hence reducing the overall costs.



Fig. 4. Radioactive waste inside a B25 box being loaded into a cargo plane at Cassidy airport on Kiritimati Island.

## CONCLUSIONS

The environment on and around Kiritimati Island has been greatly improved by the remediation carried out to remove the United Kingdom's legacies. All of the wastes that were to be removed from the island were safely removed from the island for either disposal or recycling. The end point criteria were met for the remediation project [19]. The transportation and disposal of hazardous and radioactive wastes can be a project critical activity and needs to be planned well. Consideration should be given to removing radioactive material from a project site as soon as it is ready to be moved instead of combining it's transportation with other hazardous wastes.

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