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MARSHALL ISLANDS RADIOLOGICAL SURVEILLANCE GROUP

BIKINI · ENEWETAK · RONGELAP · UTROK

MARSHALL ISLANDS MONITOR

Inside this issue

A note from the editor

The cover photo features the Enewetak Radiological Laboratory —a whole-body counting facility used to determine doses of radiation delivered to island residents as a consequence of the nuclear test program that took place in the northern Marshall Islands from 1946 to 1958.

In addition to Enewetak, Lawrence Livermore National Laboratory helped atoll governments establish whole-body counting facilities on Rongelap and Majuro islands with the total number of program volunteers engaged across the three facilities now exceeding 3,000 people. Marshallese technicians are primarily responsible for the day-to-day operations of these whole-body counting facilities while scientists from the Lawrence Livermore Laboratory provide training, system maintenance, facility upkeep, data quality assurance, and reporting.

Terry Hamilton, PhD
Editor in Chief

Feature Article

Is there any truth behind the secret Bravo map?

In a March 13, 2009, issue of *Marshall Islands Journal*, the authors discuss a map of the infinite dose contours (in Roentgens) from the initial U.S. Air Force aerial radiation survey conducted in the first few hours after the Bravo detonation on March 1, 1954. Reference was made to a newly declassified document that has actually been available for many years. Commentary was given on the magnitude and the geographical coverage of the Air Force dose contours relative to updated contour maps that appear in most of the scientific literature. The updated contour maps were generated after more detailed post-shot information became available after the Bravo event. The authors assert that: "What is significant about this Air Force fallout contour map, prepared shortly after the 1954 Bravo test, is that it shows a much wider fallout contamination than an official fallout map used in numerous reports about Bravo published since 1954."

The remainder of this article provides a discussion about why the various aerial contour maps are really quite similar and provides data that show that the extent of the Bravo fallout was well documented in the first five days after the Bravo detonation. All these data have been available for many years.

Background

Radioactive debris is an inherent characteristic of all nuclear detonations. It originates from the fission of the nuclear fuel and from interactions of the explosion with surrounding materials such as soil and water. Hundreds of different radioactive isotopes are formed during a nuclear detonation. These radioactive isotopes (also called radionuclides) are composed of about 35 different elements ranging in half-lives from fractions of a second to 17 million years. The energy released from a large near-surface detonation is sufficient to vaporize several hundred thousand tons of soil and associated materials. The amount of debris sucked into the atmosphere depends on the nature and altitude of the test. High temperature vaporization and condensation processes produce different types and sizes of radioactive particles that deposit as local or regional fallout or may be carried into the upper atmosphere and spread around the globe. Forecasting the intensity and depositional velocity of radioactive debris from large nuclear blasts is a very complex issue. It depends of the size of test, the type and quantity of materials consumed in the blast, localized wind patterns as well as upper atmospheric conditions. It is for this reason that initial high altitude aerial surveys were conducted immediately after major test events to confirm the general direction and intensity of the radiation field, and then to use ground-truth measurements (radiation detectors, gummed paper, or other) to more accurately define the fallout pattern on the ground. This is exactly the pattern of events that followed the Bravo test.

Characteristics of fallout from the Bravo test

Immediate Aerial Data

When viewing the different versions of the contour maps discussed below it is important to understand that different units are used to denote levels of radiation exposure and dose. Very careful consideration should be given to the radiation units because otherwise it is very easy to misinterpret data and, once in the public domain, this can lead to unnecessary public radiation hysteria. The Air Force map shown in the *Marshall Islands Journal* gives the radiation data in total "Roentgens (R) of infinity dose" whereas the Rand Corporation (Rand), Naval Radiological Defense Laboratory (NRDL), and a later version of the Air Force map, report the radiation levels as R per hour at 1 hour post detonation (H+1 hour). Consequently, there is a fundamental difference between these contour maps that has contributed to the confusion. Also, dose estimates to infinite time should not be confused with actual doses delivered to Marshallese exposed to radioactive debris from the Bravo test and later evacuated. Another radiation dose unit that will be used for some comparisons is the "Rem" that for the purpose of this discussion can be considered equivalent to the Roentgen. The other units used in this discussion will be the milliR (mR) and millirem (mrem) that are each 1000 times less than the rem and the R, respectively.

The Air Force map shown in the *Marshall Islands Journal* was generated in the first hours after the Bravo detonation. It was based on the first aircraft flyover of the potentially contaminated area once it was determined that the bulk of the debris cloud moved in an easterly direction. The purpose of the flight was to get a "general" perspective on the debris cloud direction, and provide initial estimates of radiation doses and the area encompassed by the deposition. Such actions formed part of a regulated military response to all major nuclear test denotations.

The Air Force developed a later version of the dose contour map after they had more time to evaluate data obtained during the initial flyover and ground truth data became available (AFSWP-895). This graph is given in mR per hour (as are most of the other contour maps), rather than infinite dose as was the case for the original Air Force map. This is the version that is more commonly seen (example shown in Figure 1) and used in various publications (AFSWP-895). It has an outside contour line of 25 R per hour at H+1 hour and of course encompasses very much less territory than the map in the *Marshall Islands Journal*. The map does show a small segment of the 1 R contour line going through Ailuk

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Secret Bravo map

Atoll. The outside dose rate contours on the commonly seen NRDL and Rand maps are 50 R per hour and 30 R per hour, respectively, and encompass less territory but do cover the most contaminated atolls in the Marshall Islands. These H+1 hour dose rates are decaying (declining) rapidly in the first hours, days, and weeks after the detonation at a rate inversely proportional to the time "t" after detonation ($1/t^{1.2}$).

The NRDL (Steton et al., 1956) and the Rand Corporation (Rand, 1955) both published revised versions of the initial Air Force flyover data that give the direction of the debris cloud and the radiation levels on the ground. These contour maps were supported by additional radiation data from aerial flyovers and ground truth radiation measurements at many atolls during the first few days after deposition, and wind data collected in the hours immediately after detonation by planes and ships.

All of these maps have been publicly available for many years. They are all a "general" description of the direction of cloud travel with estimates of the radiation levels on the ground and they all show radiation concentration contours as far northeast as Taongi and Bikar; east toward Ailuk, Utirik, Taka, Ailuk, Mejit; southeast toward Likiep, Wotje, and Erikub; and south toward Wotho. However, the focus of all these contour maps is confined to deposition in the Marshall Islands.

The outside contour line on all these maps represents the lowest radiation level shown. The only reason the map shown in the *Marshall Islands Journal* covers a greater area than other contour maps used over the years is because the two outside contour lines [0.5 R (500 mR) infinite dose and 1.0 R (1,000 mR) infinite dose] are very low doses that are essentially the same or only slightly greater than natural background dose in the Marshall Islands, U.S., and Europe (190 mrem, 300 mrem and 240 mrem, respectively) that populations receive every year. So, the two outside contour lines represent a total dose that is only slightly above one year of natural background dose. These doses are very low and are of no consequence as far as health issues are concerned but because they are so low the contours encompass a very, very large area.

In addition to the radiation data generated by the initial Air Force flyover there was a report from U.S. personnel at Enewetak Atoll on the night of March 5, 1954, of radiation levels of 3 to 4 mR per hour at Enewetak and Medren Islands with a reported maximum of 15 mR per hour (Castle Series, 1954).

Additional Gamma data from aircraft fly-over of atolls and islands (D to D+5 days)

The initial Air Force contour map and the subsequent NRDL and Rand versions of the cloud direction and estimated radiation deposition were initially useful to understand the scope of the problem. But much more detailed and precise data were generated in the first 5 days after the Bravo detonation to determine the actual radiation levels across the entire Marshall Islands and the Pacific region.

To better define the extent of the contamination and get better data in the Marshall Islands and other regions of the Pacific from the Bravo detonation various flights with radiation detectors on board were conducted between detonation day (D) and D + 5 days:

NYOO (New York Operations Office, Atomic Energy Commission) Kwajalein flight "Able" covered Lae, Wotho, Rongelap, Taongi, Utirik, Ailuk, Likiep, Ujae, Ailinginae, Rongerik, Bikar, Taka, and Jemo Atolls.

NYOO Kwajalein flight "Baker" covered Namu, Namorik, Kili, Mili, Majuro, Maleolap, Wotje, Aiglinglaplap, Ebon, Jaluit, Arno, Aur, and Erikub.

NYOO Kwajalein flight "Charlie" covered Kusai, Mokil, Ujlelang, Pingelap, and Ponape.

NYOO Guam flight "Easy" covered Guam, Truk, Losap, Lukunor, Pulap, Namonuito, Kuop, Namoluk, Satawan, and Guam (a second time).

NYOO Oahu flight "George" covered Kauai, Kaula, Necker Gardner Pinn., Laysan, Pearl-Hermes reef, Niihau, Nihoa, Fr. Frigate reef, Lisianski, and Midway.

NYOO Oahu flight "Item" covered Oahu, Hawaii, Molokai, Lanai, and Maui.

NYOO Oahu flight "Gilbert" covered Baru, Arorae, Onotoa, Aranka, Tarawa, Marakai, Nonouti, Nukunau, Tamana, Tabiteuea, Abemama, Abaiang, and Makin.

The radiation data from these flights were listed in mR per hour and published in reports that have been declassified for many years.

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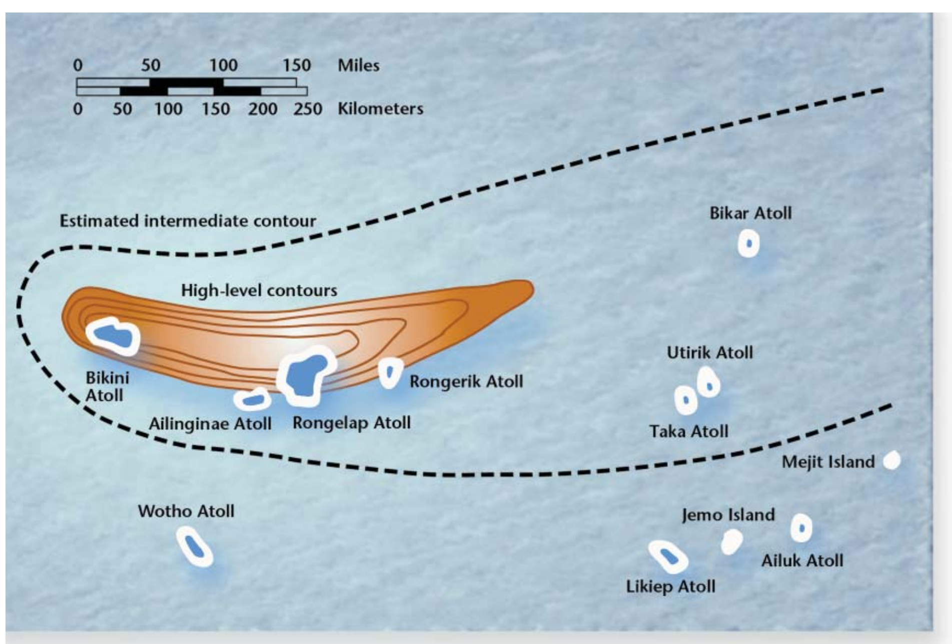

Figure1: A typical fallout pattern showing the extent and direction of the Bravo plume (it would be expected that the full extent of fallout from the Bravo test would extend beyond the intermediate contour line).

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Secret Bravo map

It is quite clear that the extent of the Bravo contamination was documented early on for the entire Marshall Islands, the Gilbert Islands, Hawaiian Islands, and elsewhere in the Pacific region (Joint Task Force Seven, Memo, 19 April, 1954).

Gamma data from ground measurements on the islands

In addition to the aerial data listed above a significant number of "ground-truth" gamma measurements were made in the days immediately following the Bravo detonation.

Trained personnel went ashore to directly measure the radiation exposure on islands with hand-held instruments. Measurements were made at Eniwetok Island, Rongelap Atoll; Utrik and Aon Islands, Utrik Atoll; Jemi Island, Ailuk Atoll; Mejit Island, Mejit Atoll; Ormed Island, Wotje Atoll; Erikub Island, Erikub Atoll; Kaven Island, Maleolap Atoll; Wotho Island, Wotho Atoll; Bikar Island, Bikar Atoll, and at several islands on Ailinginae Atoll (Joint Task Force Seven, Memos: 8 March, 1954; 18 March, 1954, and 19 April, 1954).

The data resulting from these surveys were made available to the Air Force, NRDL, and the Rand Corporation, all of whom developed updated radiation dose contours as discussed above.

About the Authors

Terry F. Hamilton, PhD

Dr. Hamilton received his doctorate from the University of Melbourne, Australia, in 1987 and earned undergraduate degrees in both chemistry and applied science. He served as a postdoctoral researcher at Flinders University of South Australia before joining the United Nations (1988-95) as a Group Leader in the International Atomic Energy Agency's Monaco Laboratory (IAEA-MEL).

In 1996, Dr. Hamilton joined the Lawrence Livermore National Laboratory and has held positions as the Deputy Director of the Marshall Islands Program, as Group Leader of Environmental Measurements and Characterization Group–Health and Ecological Assessments Division, and as Deputy Division Leader of the Environmental Science Division.

Dr. Hamilton is currently serving as the Scientific Director of the Marshall Islands Dose Assessment and Radioecology Program at the Lawrence Livermore National Laboratory.

William L. Robison, PhD

Dr. Robison received his masters degree in bioradiology and his PhD. in biophysics at the University of California, Berkeley. He joined Lawrence Livermore National Laboratory in 1965 as a biophysicist and has held positions as Section leader, Group Leader, and Division Leader (1993-1997) - Health and Ecological Assessment Division.

Dr. Robison's professional activities include Scientific Director of Marshall Islands Dose Assessment and Radioecology Program (1972 – 2000), Scientific Director of 1975 Radiological Survey of Bikini Atoll, and the 1978 Northern Marshall Island Radiological Survey.

He is also a member of National Council on Radiation Protection and Measurements: Subcommittee 64, Radionuclides in the Environment; Task group 3, Identification and Evaluation of Environmental Models for Estimating Dose from the Release

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Summary

Information on the extent and direction of the fallout cloud from the 1 March 1954 Bravo shot has been accurately portrayed in the public record for many years. The map shown in the *Marshall Islands Journal* is not new and in many ways is very misleading because the dose contours are given for infinite time (a convenient dose maximizing unit). We do recognize that there are uncertainties associated with initial mapping of fallout contamination from very large nuclear events such as Bravo but that is not to say that the existing program for cancer screening and environmental studies under the U.S. Department of Energy Marshall Islands Program is inadequate. Nor would the circumstances described in the *Marshall Islands Journal* effect any change in the way this work is conducted.

Dr. William Robison and Dr. Terry Hamilton, Lawrence Livermore National Laboratory

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Renewing hopes for full resettlement of Bikini, Enewetak and Rongelap

Cesium-137 is a long-lived fission product formed during nuclear weapons denotations, and is the largest contributor to the radiation dose that people receive from exposure to residual nuclear fallout contamination in the Marshall Islands (Robison et al., 1997). Elevated levels of Cesium-137 can still be found in coral soils, especially on islands and atolls in the northern Marshall Islands. Restrictions on the use of islands and atolls were originally formulated on the basis of predictive dose assessments based on the concentration of Cesium-137 in the soils and the amounts of Cesium-137 taken up into locally grown food products such as coconuts. However, these early dose predictions for resettlement did not account for the continual loss of Cesium-137 from soil to ground water by the action of rainfall. This environmental loss-rate of Cesium-137 is more important that radiological decay in controlling the long-term fate of Cesium-137 in coral soils (Robison, et al., 2003). Accounting for the effective loss-rate of Cesium-137 has very important implications on the future resettlement of the northern Marshall Islands, and may make early resettlement of islands and atolls much more plausible (Hamilton and Robison, 2004).

In previous dose assessments, it was shown that Cesium-137 accounts for about 98% of the total dose for returning residents (Robison et al., 1997). About 85 to 90% (depending on the atoll) is via consumption of locally grown foods containing Cesium-137 and about 10 to 15% is due to external exposure from Cesium-137 in the soil. These assessments were developed using the radiological half-life of Cesium-137 ($T_{1/2}$ = 30.1 years) but we now know that the effective half-life of Cesium-137 at the atolls is much lower. Cesium-137 is essentially disappearing at an accelerated rate through natural environmental processes. Incorporating the environmental loss of Cesium-137 from soil to ground water drastically reduces the half-life of Cesium-137 in vegetation at the atolls from 30.1 years to 8.5 years (Robison et al., 2003). This means that every 8.5 years there is a reduction on the amount of Cesium-137 in locally grown foods by about half, and because Cesium-137 is a major contributor to the dose, we would expect to see an equivalent reduction in the radiation dose.

We have also learned that treatment of coconut trees (and Pandanus and breadfruit trees) with potassium reduces the concentration of Cesium-137 in drinking coconut meat at Bikini Atoll to about 5% of the pretreatment level (Robison et al., 2006). The potassium treatment, together with removal of the top 15 cm of soil around houses and community buildings prior to construction to reduce external exposure where people spend most of their time, has been presented to atoll communities as a "combined option" remediation strategy. The effectiveness of the potassium treatment is

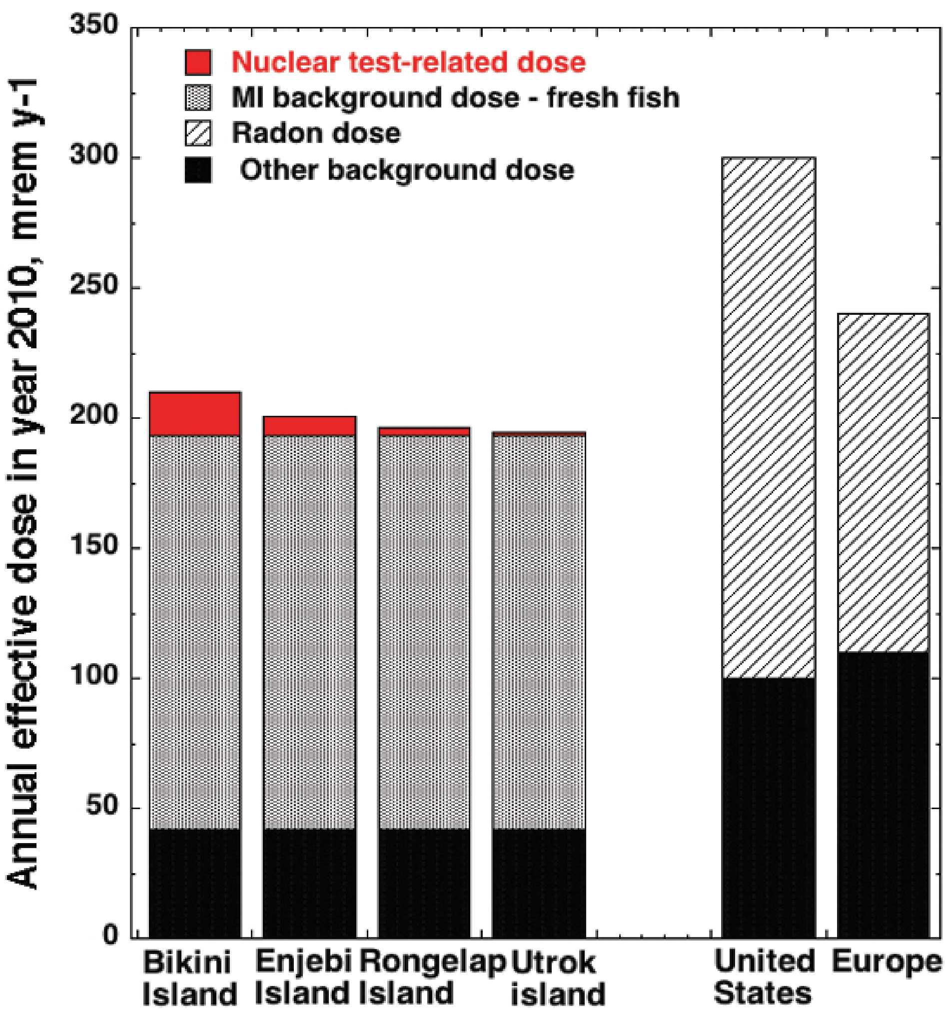

Figure 2: This graph depicts the sum of the natural background radiation dose in the Marshall Islands and the nuclear test-related radiation dose for Bikini, Enjebi, Rongelap, and Utrōk Islands on an annual basis [using the "combined option" remediation strategy (except for Utrōk Island) and the effective half-life of Cesium-137] compared with the natural background radiation dose in the United States and Europe.

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Hopes for full resettlement

dependent on the concentration of Cesium-137 in the soil so it is slightly less effective on Enjebi and Rongelap Islands than for Bikini Island. However, the use of potassium could be considered a best practice in support of ALARA (As Low As Reasonably Achievable) principles in radiological protection even where predicted doses satisfy basic safety standards. Such actions will be a compromise between the cost of remediation, and helping build confidence that resettlement programs can be accomplished in a sustainable, and environmentally and public health protective manner. The addition of potassium also has the added benefit of increasing the growth rate and productivity of some food crops with essentially no adverse environmental impact. Moreover, even a single application of potassium maintains its effectiveness for 10 years or more, reducing concerns about the cost of a long-term commitment to continually fertilize the land (Robison et al., 2006). A recent report explains the reason for this long-term reduction of Cesium-137 in food crops after application of potassium (Robison et al., 2009).

We have now completed an updated dose assessment for residence islands and atolls in the northern Marshall Islands incorporating the benefits of remediation of the soil using the combined option and the effective half-life of Cesium-137 at the atolls, and a diet of both imported and local foods. This new assessment indicates that the total dose from exposure to nuclear fallout contamination and naturally occurring radiation at Bikini, Enjebi, and Rongelap Islands is less for each of the islands than the average natural background dose most people experience in the U.S. and Europe (Figure 2). Details concerning this latest study will be published as the feature article in an upcoming issue of *Health Physics*.

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Whole-body counting technicians receive training in Livermore, California

Marshallese trainees Ms. Zhenya DeBrum, Mr. Helkena Anni and Mr. Junior Aisek successfully completed a month-long course of intensive training at the Lawrence Livermore National Laboratory this quarter. The trainees received a formal qualification as a Radiological Worker Level 1 as well as additional hands-on training in the operation of a whole body counter. All three trainees are expected to gain employment under the U.S. Department of Energy's Marshall Islands Program in support our Whole-Body Counting Program.

Awards Ceremony at LLNL (March 2009). Pictured left to right: Ms. Michelle Yamaguchi (POII), Mr. Steven Kehl (LLNL), Mr. Junior Aisek (Marshallese Trainee), Dr. Terry Hamilton (LLNL), Mr. William Jackson (DOE), Mr. Lance Yamaguchi (POII), Ms. Zhenya DeBrum (Marshallese Trainee), Dr. David Hickman (LLNL), and Mr. Helkena Anni (Marshallese Trainee).

DOE releases report on Runit Dome

The U.S. Department of Energy has released copies of a survey report of the Cactus Crater Storage Facility (Runit Dome) on Enewetak Atoll prepared by Doug Miller from National Security Technologies (NSTec) (DOE/NV/25946-569). The survey report describes the current conditions of the concrete structure overlying the dome based on a strictly visual inspection. A total of 357 concrete panels plus the center cap were inspected. A number of defects in the concrete were noted but the damage was categorized as non-structural in nature. Copies of the report are being made available on the Marshall Islands Program web site [http://marshallislands.llnl.gov/ (refer to the link, Field Survey of Cactus Crater Storage Facility (Runit Dome), Report A08, DOE/NV/25946-569)].

Did you know?

High Hopes for Obama in Russia

MOSCOW (Washington Post) - Hopes are rising that President Barack Obama's visit to Moscow in July will produce a breakthrough in talks on cutting U.S. and Russian nuclear weapons. Obama and President Dmitry Medvedev gave the go-ahead to talks on a new strategic arms treaty to replace START-1, which expires on December 5, when they met for the first time in London in April. Estimates of current nuclear stockpiles differ but according to the U.S.-based Bulletin of the Atomic Scientists at the start of 2009 the United States had around 2,200 operationally deployed strategic nuclear warheads and Russia around 2,790.

National Council on Radiation Protection & Measurement (NCRP) releases new report

(NCRP Report No. 159) - The National Council on Radiation Protection & Measurement (NCRP) released Report No. 159, Risk to the Thyroid from Ionizing Radiation. For the population at greatest risk (those people in the 0 to 14 year age group), NCRP Report No. 159 predicts a lifetime risk that is 1.5 times greater than in NCRP Report No. 80. However, the risk for the entire population is lower. This report is directly relevant to the Marshall Islands experience and is available from the NCRP Web Site (http://NCRPpublications.org), in both soft- and hard-copy formats.

Dutch water pyramids help Indonesia

INDONESIA (European-waternews.com) – On the Indonesian island Pomana, two huge Dutch water pyramids will start to provide clean sweet drinking water to the local population this summer. This sustainable invention, a large pyramid shaped silver colored balloon, 8 meters high and with a diameter of 30 meters is now aboard a ship from Rotterdam on its way to Indonesia. This innovative project is the result of collaboration between consulting and engineering firm MWH together with the producer, Aqua Aero Water Systems and the local NGO Yayasan Dian Desa.

Figure 3: Huge Dutch water pyramid on the Indonesian island Pomana produces around 1000 liters (about 260 U.S. gallons) of clean water per day.

In 2006, the water pyramid project received the innovation award of the World Bank. The installation produces around 1000 liters (about 260 U.S. gallons) of clean water per day and requires a minimum of energy: the fan that maintains the pressure in the tent and the water pumps run on solar energy (Figure 3).

Saline groundwater pumped into the pyramid, evaporates during the daytime when the temperature in the tent rises. Dirt and salt remain on the ground and the clean, sweet water drips along the inside of the canvas in a gutter collection system. The exterior of the tent is also used. When it rains, the water flows from the roof to a gutter into a reservoir where it is stored for drier times.

Survivor of both U.S. atomic bombings in Japan

TOKOYO (The Associated Press) – A 93-year-old Japanese man has become the first person certified as a survivor of both atomic bombings by the United States. The survivor, Tsutomu Yamaguchi, had already been a certified "hibakusha", or radiation survivor, of the bombing on Aug. 9, 1945, in Nagasaki, but he has now been confirmed as surviving the attack on Hiroshima three days earlier, in which he suffered serious burns to his upper body. Certification qualifies survivors for compensation, including monthly allowances, free medical checkups, and funeral costs.

Calendar of Events

MARSHALL ISLANDS PROGRAM

June 17-18, 2009

U.S. Department of Energy - Republic of the Marshall Islands Annual Program Meeting, Majuro Atoll, Republic of the Marshall Islands.

July 2009

Lawrence Livermore National Laboratory to conduct a mission to Rongelap Atoll to develop updated radiological data on pantry islands, and develop an experimental garden project to assess the uptake of fission products (Cesium-137 and Strontium-90) in leafy vegetables and other root crops.

October-November 2009

Lawrence Livermore National Laboratory to conduct a radiological survey mission to Utrōk Atoll to assess so-called *hot spot* locations, and develop an experimental garden project.

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About the Authors -- Dr. Robison

to the Atmosphere and Surface Waters; Scientific Committee 84-1 on Surface Soil Contamination; Scientific Committee 64-18 on Plutonium.

Member IAEA: Advisory Group for Evaluation of the Resettlement of Bikini Atoll; and Task Group A for the Study of the radiological situation of the atolls of Mururoa and Fangataufa.

Chairman of the IAEA coordinated Research Programs (CRP) – Radionuclide Transport and Uptake in Tropical and Subtropical Ecosystems, 1989-1994 (14 countries) and The Classification of Soil Systems on the Basis of Transfer Factors of Radionuclides from Soil to Reference Plants, 1994-1999 (14 countries).

Member of the American Association for the Advancement of Science (AAAS) and the Health Physics Society.

Dr. Robison has over 125 publications dealing with Radioecology, Dose Assessment, and other scientific endeavors.

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