TRANSPORTATION OF LOW LEVEL RADIOACTIVE WASTE IN TAIWAN, REPUBLIC OF CHINA

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ABSTRACT

There are three nuclear power stations with six units in operation in Taiwan, R.O.C. The nuclear power stations generate about 95% of the total wastes. Pursuant to the present regulations on radwaste management, the solidified low level waste encapsulated into 200 - liter steel drums is only allowed to be transported to Lan-Yu for interim storage before final disposal of its kind is planned to be implemented.

From May 1982 to the end of 1985, 102 radwaste shipments, each carrying 288 drums in six exclusive and specilly designed steel casks, have been completed safely, and the receiving of waste drums also have been smoothly operated at the National Lan-Yr Storage Site. This storage site can house 100,000 drums in 23 near surface concrete trenches currently and can be further expanded as required.

The operation of radwaste shipment, including land and marine transportations, and its related works are described. The radiation impact on the general public and workers are also assessed by using the modified computer code Radship 2.

INTRODUCTION

Although Taiwan's economy has enjoyed a high growth rate over the past two decades, its economic structure is still tender for lask of natural resources. Taiwan needs to import most of the energies. In order to keep economy ever-growing, the top priority is to diversify the energy dependency. The government, therefore, launched its nuclear power program as early as 1968. In 1978, the first nuclear power reactor started its commercial operation. Today there are three nuclear power Stations with six units in operation totalling the output of 5145.6 MWe. More and more radioactive wastes are inevitably produced. As Taiwan is densely populated (525 persons/Km^2 as of 1985), the radwaste could be a serious hazard if it is not properly handled. Through a series of evaluations and investigations, Lan-Yu, among several candidate sites, was chosen as the interim storage site for low-level radioactive waste before the final disposal is planned to be implemented.

Currently, wastes from hospitals, industries and institutions are sent to the Institute of Nuclear Energy Research (INER) for treatment. The INER only generates about 5% (including waste produced by itself and other) of total wastes in Taiwan. Nuclear power stations are dominant in waste generation. The generation rate of each of the three stations is summarized in Table I. According to the regulations on radwaste management, solidified waste encapsulated into a 200-liter drum only is allowed to transport to the Lan-Yu National Storage Site, operated by the Radwaste Administration (RWA).

The status of LLW transportation for the first nuclear power station may be taken as an example because it involves land and marine transportations with a longer distance (Fig. 1.). Typically, transportation of LLW and its related works consists of five steps. They are: 1) application for storage, 2) waste drum examination and loading, 3) land transportation, 4) marine transportation, 5) receiving at Lan-Yu. Detailed descriptions are given below. In addition, the radiation impact on the general public and workers during the whole process is also assessed by using the Radship 2 computer code which was rewritten according to another code RADTRAN with some modifications.

DETAILED DESCRIPTION OF LLW TRANSPORTATION AND ITS RELATED WORK

Application for Storage

The waste producer, in most cases the nuclear power station of Taiwan Power Company, must submit the shipping documents to the RWA for approval. The contents in the drum, the activity, the solidification date and the surface dose rate should be well written in these documents. Only after the RWA approves this application, may the waste producer proceed to the second step.

Waste Drum Examination and Loading

In this step, drum conditions and waste form shall be examined to comply with the requirements stipulated by the RWA.

Drum Conditions:

- No pit holes are found on the drum,
- The distorted drum is acceptable only if it cannot affect the vertical stability when three drums, including this distorted one, are piled end to end.
- The stripped varnish layer should be repainted after de-rusting and drying.

Waste Form in the Drum:

- Waste should be completely solidified,
- No free standing water appears on the surface of the waste form, and the free water content in the waste should be less than 0.5% of the waste volume,
- The solidified waste should at least occupy 90% of the drum volume.

A sampling program for examining the waste form and drum condition is undertaken in order to reduce

TABLE I

The Annual Generation Rate of LLW for Each of Three Nuclear Power Stations

Unit: drum (200 liters)

Year / Station	Before the end of 1979	1980	1981	1982	1983	1984	1985
CHIN-SHAN 1st	4,000	4,034	3,416	4,141	6,622	4,088	3,315
KUOSHENG 2nd	0	0	691	4,643	5,904	6,769	5,460
MAANSHAN 3rd	0	0	0	0	0	145	627
Total	4,000	4,034	4,107	8,784	12,526	11,002	9,402
Cumulative Total	4,000	8,034	12,141	20,925	33,451	44,453	53,855

radiation exposure for the inspectors. The Average Outgoing Quality Limit (AOQL) is set at 3% temporarily. If more than 2 of 40 sampled drums are found not to be arranged in an optimum way in a cask to meet the requirements.

The computer code RADSHIP 2, which is a modified version for domestic need from RADTRAN, is used to evaluate the exposure rate for the workers and general public due to the transportation of radioactive material. The Transportation Index (TI) at 1 m away from the surface of cask and its corresponding maximum activity for each package are listed in Table II. The basic data about radwaste transportation are also tabulated (see Table III). Other parameters input to RADSHIP 2 are conservatively taken with respect to local conditions.

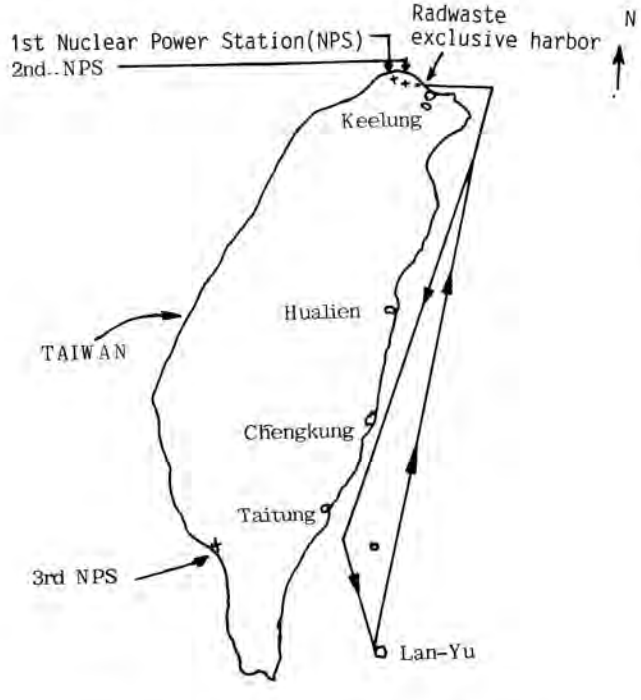

Fig. 1. Transportation Route of LLW.

The evaluation is performed under normal and abnormal conditions respectively. Normally, the annual maximum individual radiation exposure for workers and total man-rem for the general public in a year are shown in Table IV and V. Under normal conditions, the transportation index 13 may be an ideal case in light of its low radiation exposure for personnel. Abnormal conditions are, of course, an accident.

Marine transportation accidents may be classified as follows:

Flooding -
- Heavy seas
- Collision

TABLE II

The Transportation Index and its Corresponding Activity Per Shipping Package

TI (mR/h)	13	14	15	16	17	18	19	20	21	22
Ci/PKG (Max.)	4.64	5.12	5.60	5.36	4.48	4.28	3.40	2.78	2.04	1.46

TABLE III

The Basic Data of Low Level Radwaste Transportation

Parameters	Descriptions
Cask capacity	48 drums
Marine transportation vehicle	Cargo ship
No. of casks for each shipment	6
Shipments in a year	50
Distance of land transportation	20 km
Distance of marine transportation	350 km
The average velocity of truck	30 km/h
The average velocity of ship	15 km/h

TABLE IV

The Annual Maximum Individual Exposure for the Workers under Normal Operation

Unit: rem/y

$TI/_{PKG}$	$CI/_{PKG}$	Land Transporation			Loading at the harbor	Marine ransportatio
		Escort HP personel	Driver	Traffic Controller	Crewmen	Crewmen on the ship
13	4.64	0.0697	0.5117	2.633E-4	1.0231	2.1708
14	5.12	0.0751	0.5511	2.835E-4	1.1023	2.3377
15	5.60	0.0804	0.5904	3.038E-4	1.1808	2.5046
16	5.36	0.0858	0.6298	3.240E-4	1.2592	2.6715
17	4.48	0.0912	0.6691	3.443E-4	1.3385	2.8385
18	4.28	0.0965	0.7085	3.645E-4	1.4169	3.0062
19	3.40	0.1019	0.7479	3.848E-4	1.4950	3.1731
20	2.78	0.1072	0.7872	4.050E-4	1.5746	3.3400
21	2.04	0.1126	0.8266	4.253E-4	1.6531	3.5069
22	1.46	0.1180	0.8659	4.455E-4	1.7315	3.6738

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The Total Man-rem for General Public Under Normal Operation in a Year

Unit: rem/y

$TI/_{PKG}$	$CI/_{PKG}$	Land Transportation			Loading at the harbor	Total
		Residents	People moving at the opposite direction	People moving at the same direction	Residents	
13	4.64	0.2612	0.0077	0.0111	0.0687	0.3487
14	5.12	0.2813	0.0083	0.0119	0.0740	0.3755
15	5.60	0.3014	0.0089	0.0128	0.0793	0.4024
16	5.36	0.3215	0.0095	0.0136	0.0846	0.4292
17	4.48	0.3416	0.0101	0.0145	0.0899	0.4561
18	4.28	0.3617	0.0107	0.0153	0.0952	0.4829
19	3.40	0.3818	0.0113	0.0162	0.1005	0.5098
20	2.78	0.4019	0.0119	0.0170	0.1057	0.5365
21	2.04	0.4219	0.0124	0.0179	0.1110	0.5632
22	1.46	0.4420	0.0130	0.0187	0.1163	0.5900

Loss of propulsion -
- Fire
- Mechanical failure
- Grounding

Unplanned harboring -
- Severe weather
- Unforseen event

Land transportation accident may cause a breakdown of a vehicle -
- Mechanical failure
- Fire
- Unforseen event

Overturned trucks or casks -
- Lossening of buckle
- Excessive speed
- Pitfall of road or collapse of bridge
- Crash

Major accidents are defined as any event which involves a release of radioactive material, while the minor accidents include those events without a release of radioactive material.

The annual maximum individual radiation exposure for workers in case of accidents without a release of radioactive material is computed and shown in Table VI. The relationship between the latent cancer fatality (LCF) for the general public and transportation Index (TI) is depicted in Fig. 2. Furthermore, in case of accidents with a release of radioactive material, the annual LCF is, however, proportional to the activity in that accidental package. (See Fig. 3)

Under normal conditions, the radiation impact on the general public and workers would be minimum at Transportation Index 13, while in case of accidents with a release of radioactive material, the environmental impact on the general public at TI 22 (because of its lowest activity per package correspondingly) is lower than at other conditions (TI 13 to 21). However, operations at TI 22 would result in the maximun radiation exposure to the general public and may require the necessary radiation protection measures to reduce both drivers' and crewmen's exposure. Still, the probability of an accident is very low in light of the present operating procedures. Thus, to suggested that radwaste shipments be performed at the Transportation Index 13 from this study.

The waste drums each weighing about 350Kg, can be loaded into a specially designed cask. The drum with high surface exposure rate are given priority to position either at the lower layer or at the center of the upper layer in each cask to reduce the exposure rate outside the waste cask. Steel plates in the casks have a thickness of 3.8 cm to attenuate both the integrity and energy of above line gamma rays from the waste. A fully loaded cask, having 24 LLW drums in each of the two layers, weighs about 40 tons.

Land Transportation

Once deciding to do an exercise of waste transportation (this country regards radwaste shipment as an exercise), six of these LLW casks are placed on trailers which in turn are dragged by tractors to waiting zone in the nuclear power station after strict check-ups with emphasis on mechanical and radiological safety by quality control and health physics personnel. Lead blankets will be covered on the outside of the casks if the exposed rate at 2 m away from the surface of the cask exceeds 10 mR/h, which is maximum permissible exposure rate imposed by the RWA's regulations for LLW transportation.

The cask team, followed by the emergency vehicle which carries personnel and necessary devices for accidents, is escorted by the local safety guard and policemen during transportation. Meanwhile, traffic routes are appropriately

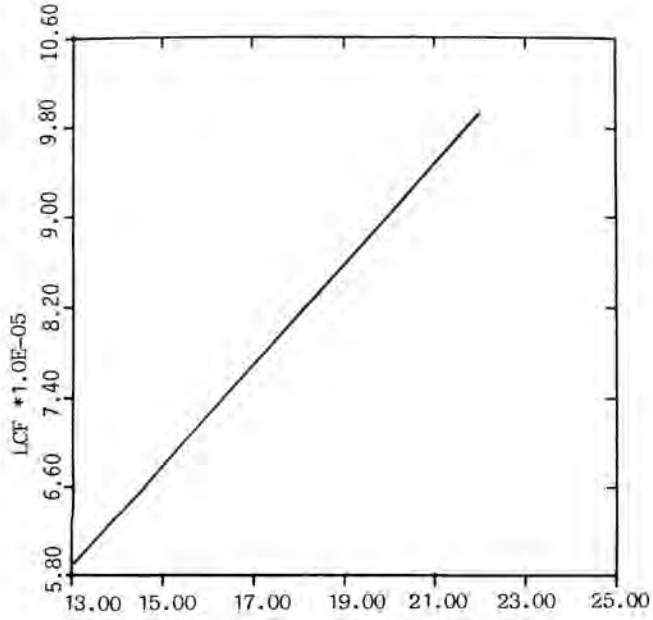

Fig. 2. The Relationship of Latent Cancer Fatality (LCF) for General Public and Transportation Index (TI) in Case of the Accidents Without a Release of Radioactive Material.

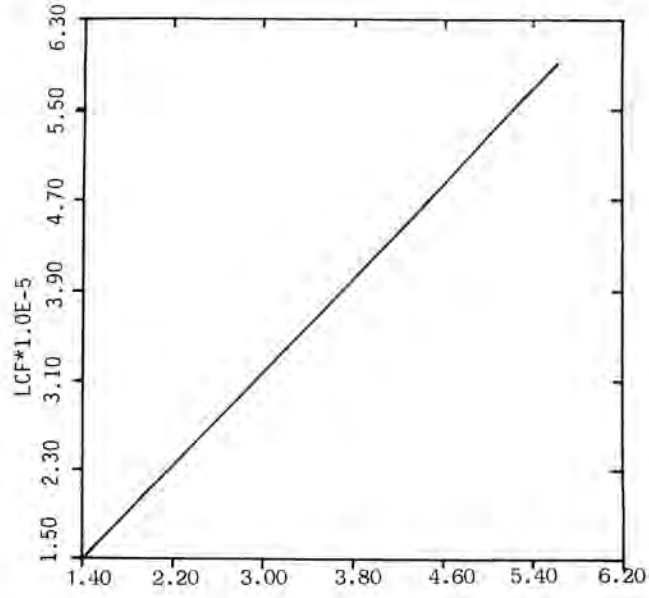

Fig. 3. The Relationship of Annual Latent Cancer Fatality (LCF) for General Public and the Activity per Package in Case of Accidents with a Release of Radioactive Material.

TABLE VI

The Annual Max Individual Radiation Exposure for Workers in Case of Accidents Without a Release of Radioactive Material

Unit: rem/y

$TI/_{PKG}$	$CI/_{PKG}$	Land Transportation			Loading at the harbor				Marine Transportation	
					Falling down on the ship or land	Falling down in the sea		Stranded	Ship accident	Unplanned pocking
		Escort HP people	Driver	Traffic Controller	Lift handler	Lift handler	Salvage worker	Cremen on the ship	Crewmen on the ship	Crewmen on the ship
13	4.64	4.1783E-3	3.067E-2	8.365E-3	4.77E-6	4.77E-7	1.25E-14	2.679E-4	5.582E-4	0.134
14	5.12	4.4983E-3	3.030E-2	9.008E-3	5.13E-6	5.13E-7	1.35E-14	2.885E-4	6.012E-4	0.144
15	5.60	4.8200E-3	3.539E-2	9.653E-3	5.50E-6	5.50E-7	1.44E-14	3.092E-4	6.441E-4	0.155
16	5.36	5.1417E-3	3.775E-2	1.0295E-2	5.87E-6	5.87E-7	1.54E-14	3.298E-4	6.870E-4	0.165
17	4.48	5.4633E-3	4.011E-2	1.0938E-2	6.24E-6	6.24E-7	1.64E-14	3.504E-4	7.300E-4	0.175
18	4.29	5.7850E-3	4.247E-2	1.1583E-2	6.60E-6	6.60E-7	1.73E-14	3.710E-4	8.500E-4	0.185
19	3.40	6.1067E-3	4.483E-2	1.2225E-2	6.97E-6	6.97E-7	1.83E-14	3.916E-4	8.162E-4	0.196
20	2.78	6.4267E-3	4.719E-2	1.287E-2	7.34E-6	7.34E-7	1.92E-14	4.122E-4	8.585E-4	0.206
21	2.04	6.7483E-3	4.955E-2	1.3513E-2	7.70E-6	7.70E-7	2.02E-14	4.328E-4	9.015E-4	0.216
22	1.46	7.0700E-3	5.190E-2	1.4155E-2	8.07E-6	8.07E-7	2.12E-14	4.535E-4	9.446E-4	0.227

Marine Transportation

Only if the weather and sea conditions along the east coast of Taiwan are favorable in two consecutive days after the projected departure time, then, the cargo ship may be granted a permission to leave the exclusive harbor near the second nuclear power station. The RWA, from the safety point of view, specifies the navigable condition in terms of wind speed and wave height as follows:

> The average wind speed must be lower than Scale 7 (13.9-17.1 m/sec or so-called near Gale), while the instaneous wind speed may be up to Scale 8 (17.2-20.7 m/sec, namely Gale).
>
> The average wave height must be lower than Scale 5 (2.5-4.0 m, i.e., near rough seas), while the instaneous wave height may reach Scale 6 (4.0-6.0 m is equivalent to rough seas in meterological terms).

Upon leaving the harbor, the ship must radio its position every 4 hours to the nearest monitoring station in one of four harbors located in the eastern Taiwan. The distance to Lan-Yu, which is situated 75 km from the southern tip of Taiwan in the Pacific Ocean, is about 350 km. The voyage in the sea takes 24 to 26 hours with a speed of 9 knots. The cargo ship must change its course immediately to any of the harbors indicated in Fig. 1, should the severe weather conditions be encountered en route. The armed forces search/rescue center is on alert until the ship arrives at the destination safely.

Receiving at Lan-Yu

When the cargo ship is approaching to Lan-Yu, the National Storage Site will be informed of its arrival two hours before it navigates into the exclusive pier located about 1 km from the storage site. Therefore, the storage site personnel will contact the related authority and personnel for the waste receiving. As soon as the ship is locked at the pier, the safety guard can quickly implement the regular check-up. If this check-up is usual as expected, workers of the National Storage Site start to unload the casks to the waiting zone at the pier. From there, LLW casks are to be sent to the inspection center to check if the waste drums are damaged during the voyage. Only as the waste drums are assured to be in good condition, may they be allowed to store in the concrete trenches of the site.

CONCLUSION

Transportation of low level radioactive waste to Lan-Yu for interim storage is carried out under strict control by the Radwaste Administration. There has not been an accident so far. Nevertheless, we still need to conduct a series of researches and, hopefully, to reach the safety goal for transportation.

Besides, standard model to compute the environmental impact on the general public and workers during transportation has just been established. Through these efforts the radwaste management should be more safely handled, and the nuclear energy program can thus be developed more widely in this country.

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