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FALLOUT IN KYUSYU FROM THE ACCIDENT OF CHERNOBYL NUCLEAR PLANT

By

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Abstract

The accident of Chernobyl nuclear power plant contaminated all over the world. It was the most tragic nuclear accident mankind has ever experienced. However we have no assurance such a miserable accident never happens again in near future.

The study to know how the radioactive material from Chernobyl fell and contaminated our environment, is one of the most urgent theme. Our study is done about Kyusyu island in Japan.

In Europe, fallout density from Chernobyl was not continuous among the districts nearby. Simplified diffusion equation couldn't explain such a phenomenon. The place so called "hot spot" has extraordinary high level of radioactivity compared to the other districts nearby. We observed the resemble phenomenon in Kyusyu.

1. Theory¹⁾

Nuclide which emits gamma ray has it's own energy spectrum and abundance. We are able to know the quantity of the radioactive material by analyzing energy spectrum and net counts of the peak. The following formula gives the quantity.

$$Q = N / (T \cdot A \cdot EF) \quad (1)$$

Where Q is quantity of radioactive material in becquerel, N is net counts, T is counting time in second, A is abundance, EF is count efficiency of the detector determined from energy and geometrical form of the sample.

2. System²⁾

Ge (Li) multi channel analyzer EG & G ORTEC 7040 was used for our survey. Ge (Li) semiconductor detector transduces gamma ray to electrical pulse in a definite efficiency determined from the energy and geometrical form. The height of the pulse is proportional to energy. Detector is kept on liquid nitrogen temperature and suppressed in bias voltage at 1700 V during counting period. To prevent the external environmental radioactivity, detector and sample are closed in a shield box made of about 10 cm thick iron block and lead plate. The pulse from the detector is amplified by preamplifier and linear amplifier.

Analogue Digital Converter transduces the pulse into 12 bits digital signal. The signal is accumulated in 4096 memory block. After the counting, the data in memory block is transferred to computer system through RS232C cable by operating control board.

The computer system with a softwear developed from the auther, analyzes the data and print out the result. Fig. 1 shows the block diagram of the system.

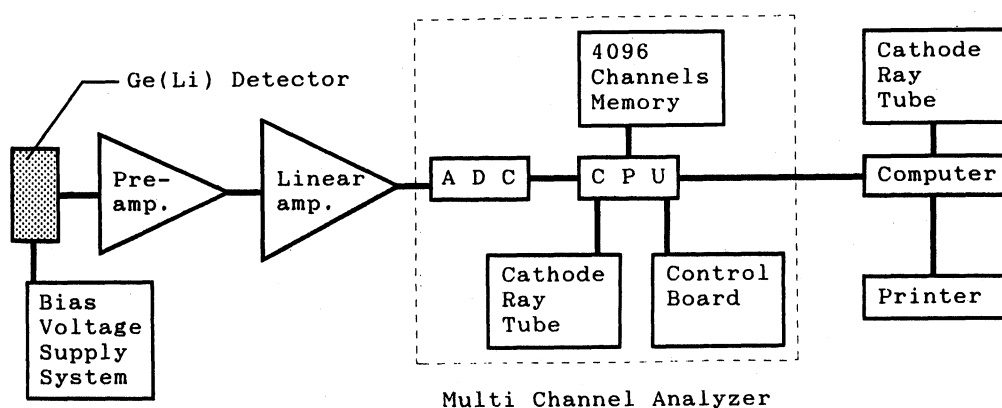


Fig. 1. Block diagram of total system.

3. Calibration

Calibration to know the relation between energy and channel, was carried out using well known nuclide such as K-40 or annihilation peak of pair created electrons. Using a least squares method, following relation was gotten from our system.

$$EV = 0.4994 \cdot CH + 6.31 \cdot 10^{-8} \cdot CH^2 + 0.5615 \quad (2)$$

where EV is energy in kev, CH is channel number. The coefficient of linear term of formula (2) is set near to $1/2$ by adjusting the gain of the linear amplifier.

It's well known that Ge (Li) detector has following relation between count efficiency and energy above 200 kev.

$$\text{LOG} (EF) = a \cdot \text{LOG} (EV) + b \quad (3)$$

Where a and b are definite constants.

Relation curve below 200 kev is approximated as follows

$$\text{LOG} (EF) = c \cdot (\text{LOG} (EV))^2 + d \cdot \text{LOG} (EV) + e \quad (4)$$

where c, d and e are determined so as to have maximum at 120 kev and connect smoothly to formula (3) at 200 kev.

$Ac-228$ was used to know constant a . Granite produced in Ohsumu district contains lot of $Ac-228$ than any other kinds of rocks. It was smashed to pieces around 0.5 cm. Fig.2 shows the relation between energy and $ONET/ENET$. where $ONET$ is net counts observed from our system, $ENET$ is expected net counts if count efficiency was independent to energy. $ONET/ENET$ is normalized to 1 at the peak of 911.2 kev. From Fig. 2 we got $a = -0.97$.

Ratio of *K-39* and radioactive *K-40* is constant in natural Kalium. The ratio *K-40/K-39* is 0.0118%. So quantity of *K-40* is easily calculated from the weight of *KCl* reagent. *K-40* has only one peak at 1460.75 keV with abundance of 10.67%. Count efficiency of the detector at 1460.75 keV is found out from the quantity of *K-40* and net counts of the peak.

KCl reagent mixed with flower filled in malineli beaker was used for the purpose. So as to deduct self absorption effect, density of *K-40* was set to 0.1 times compared to the density filled only with *KCl* reagent.

Fig. 3 shows the form of malineli beaker filled with flower diluted *KCl* reagent to a definite height from the bottom. Fig. 4 shows the relation between the height *H* in cm and count efficiency *KEF*. The relation is approximated as follows.

$$KEF = 0.5556 - 0.032567 \cdot H + 0.0003072 \cdot H^2 \tag{5}$$

From formula (1), (3) and (5) *b* is determined.

$$b = 0.4343 \cdot \text{Log}(KEF) + 3.0697 \tag{6}$$

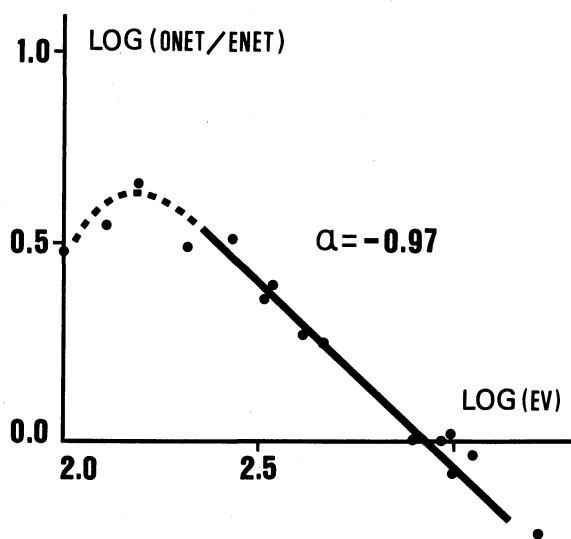


Fig. 2. Relation between energy EV and ratio of observed net per expected net ONET/ENET. An inclination of linear part (above 200keV) is equal to constant a.

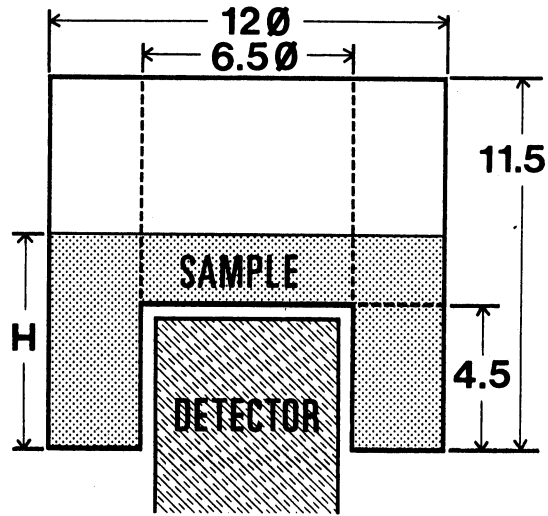


Fig. 3. Malineli beaker filled with sample. Efficiency depends on height from bottom H.

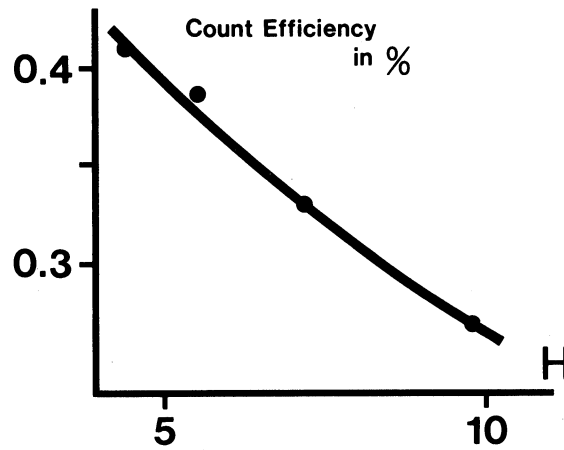


Fig. 4. Count efficiency of K-40 depends on H. The unit of H is expressed in cm.

4. Results of survey

The results are shown in table 1, 2 and 3. Their sampling points are dotted on a map in Fig. 5.

Table 1. Cesium in sweet potatoes. Harvested in 1986, measured in 1987.

Sweet potato

Sample No.	CS-137 (Bq)	CS-134 (Bq)	Counting time (min)	Measured date
1	0.287±0.128	ND	2880	1/22
2	0.238±0.091	ND	2932	3/12
3	0.266±0.089	ND	4320	4/20
4	0.485±0.126	ND	2648	4/22
5	1.12±0.13	ND	2666	3/28
6	ND	ND	3248	4/15
7	ND	ND	3331	4/3
8	ND	ND	3094	3/30
9	ND	ND	3977	6/15
10	ND	ND	2880	1/29
11	0.351±0.108	0.130±0.062	2436	4/1
12	0.807±0.108	ND	2880	1/14
13	11.1±0.2	1.33±0.10	3997	2/16
14	0.544±0.111	ND	2880	1/9
15	0.952±0.122	0.363±0.092	3103	2/23
16	1.34±0.28	ND	1423	2/21
17	1.90±0.13	0.47±0.09	2829	2/8
18	2.24±0.14	ND	2880	1/16
19	1.39±0.13	ND	2863	1/24
20	0.407±0.094	ND	2880	2/4
21	0.422±0.089	ND	2459	2/26
22	2.41±0.17	ND	1391	2/28
23	0.313±0.111	ND	1651	3/10
24	0.241±0.077	ND	4399	3/23
25	1.97±0.17	ND	1974	2/3

Table 2. AG-110m in Oyster. Landed date is close to measured date.

Oyster

Sample No.	AG-110m (Bq)	Counting time (min)	Measured date
O-1	2.21±0.09	5445	12/22 1986
O-2	0.433±0.056	2880	12/24 1986
O-3	0.0826±0.0142	8301	2/2 1987
O-4	ND	1534	4/9 1987

Table 3. Cesium and AG-110m in soil. Unit is Bq/m². Samples are collected on Feb. 1987. Amount of AG-110m in S-1 is data from surface to 1 cm depth. Counting time of the part is 4383 min. The other part of S-1 and other samples were counted around 60 min.

Soil

Sample No.	CS-137	CSs-134	AG-110m	Measured date
S-1	3039±23	618±10	6.3±1.4	4/27 1987
S-2	2934±117	653±40	ND	4/16 1987
S-3	644±60	ND	ND	6/12 1987
S-4	740±67	20±8	ND	6/19 1987

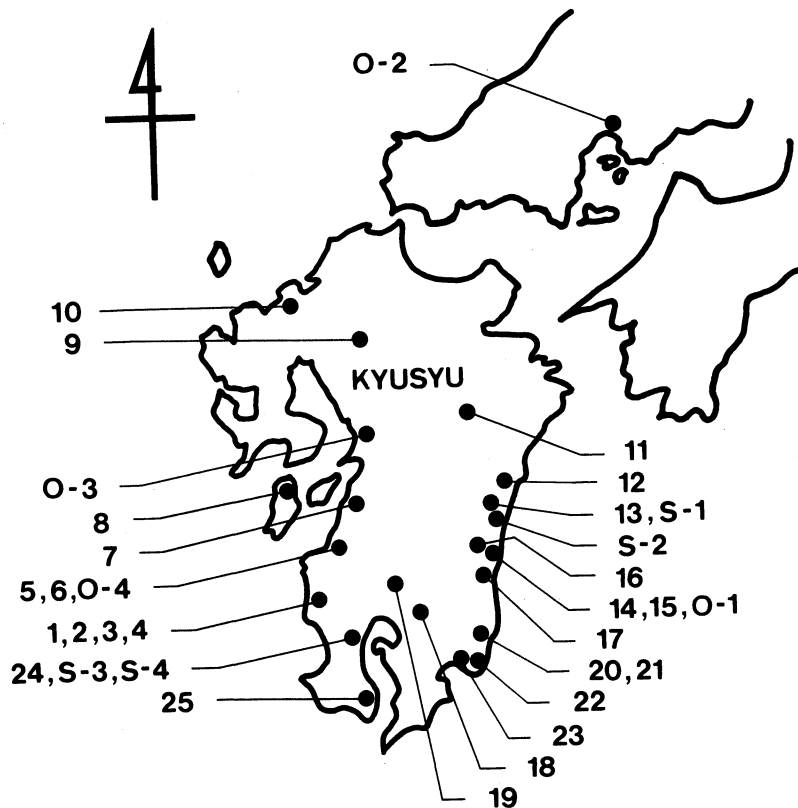


Fig. 5. Sampling points are dotted on the map of Kyusyu island Japan.

5. Discussion

About sweet potatoes, $Cs-137$ was found much more in east coast of Kyusyu than west coast, especially in northern part of Miyazaki prefecture. $Cs-134$ which is produced only by nuclear plant, was found only in the west coast, and not to be able to find in east coast.

The ratio of $Cs-137$ and $Cs-134$ discharged from Chernobyl plant is about 2.5. This is from the analysis of air dust just after the accident and from heavily contaminated foods in Europe. On the case of sample No 1, distribution of $Cs-137$ from Chernobyl plant can be considered to 3.33 Bq, and the rest part of 7.78 Bq is due to the nuclear explosion experiments. As the experiments have been carried out for many years, we can regard that the distribution of fallout from them might have no big differences among the districts³⁾. However quantity of $Cs-137$ in sample of sweet potatoes from west coast were very small or not able to find. It's difficult to explain.

We are surprised to $Ag-110m$ in oyster. The ratio of nuclear fission products by thermal neutron of $Ag-110m$ is in order of 0.01% while the ratio of $Cs-137$ is 6.15%. So we didn't quite expected to find $Ag-110m$ in our samples.

Detection of $Ag-110m$ is reported by G. D. Jones from Welsh beef and lam liver in England,⁴⁾ and also by H. van Dan in Netherland.⁵⁾ Their reports discuss about mechanism

why such unexpected amount of *Ag-110m* was produced.

However the mollusca has high accumulation efficiency for Silver amount to 7100 times.⁶⁾ As shown in table 1, *Ag-110m* was found in soil. Though the value is very small, it is enough to detect significantly if it has been accumulated through the body of oyster. We can explain it is only from fission product.

Acknowledgements

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