ENVIRONMENTAL RADIOACTIVITY IN BANDUNG AREA

BY:

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Penulis bersama-sama anggota Group Health Physics jang sedang mendapat pendidikan dibawah pimpinan Health Physicist dari IAEA, R.E. Alexander, telah melakukan pekerdjaan survey disekitar kota Bandung. Survey ini adalah sebagai pendahuluan dari program survey jang kelak dilakukan setjara teratur, berhubung dengan akan didirikannja projek reaktor inti di ITB.

Maksud daripada survey pendahuluan ini ialah untuk mendapatkan data dari tingkat radioaktivita dalam air, tanah, tumbuh²an dan udara sebelum reaktor berdjalan, sehingga memungkinkan untuk mendapatkan perbandingan jang djelas djika kelak reaktor sudah berdjalan. Dengan alat² jang sangat terbatas jang terdapat di bagian Fisika dan di ITB pada dewasa ini, telah ditjoba untuk mendapatkan hasil jang se-baik²nja.

Introduction.

As was known, the institute of Technology Bandung (I.T.B.) nuclear energy facility would be established in Bandung. The TRIGA Mark II nuclear reactor (with the expected maximum power level of 250 KWT) will be the main point of activities. The location was near to the ITB campus (see fig. 1), and was decided by the committee appointed by the Government (Lembaga Tenaga Atom).

Among many works included in the Health Physics Division responsibility are the environmental survey program. Of prime importance was the task of determining what effects, if any, the operation of the reactor would have on the environment of the site. If was considered necessary, to prevent the possible hazards due to the reactor operation.

Of equal importance was the accumulation of data to evaluate ITB's position in the event of any legal action, in connection with the operation of this facility.

The Health Physics Group was assigned the responsibility for establishing and administering a program which would accomplish the above purposes and wich would be acceptable to local authorithies. (1) (3)

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Fig. 1. Map of Bandung Area

●. Vegetation & soil

O. Water

x. River mud

U. Rain. water

Fig. 1.

At present, members of the Health Physics Group at the Institute of Technology Bandung, who were undergoing training under the supervision of R.E. Alexander, health physicist, International Atomic Energy Agency, have conducted the pre-environmental survey program, as part of the environmental survey program being done regularly when the reactor goes into operation.

The pre-envitonmental survey makes the base line levels of radioactive content of the environment (air, soil, water and vegetation) were possibly established prior to the reactor operation.

It was aknowledged that the radioactive content of the samples would not be due entirely to natural causes, but would have been modified to some unknown extent due to fall-out from nuclear weapons test. (3)

It was decided however, that since there is no significant difference of radioactive content of the samples, the data collected prior to the reactor operation would be used as a baseline for comparison with the samples collected after the reactor goes into operation, whether there is any increase due to this operation or not.

All samples will be prepared and counted by this group, and the data will be analyzed for report and file.

Sampling points were determined around the site, and were chosen according to their location with respect to the site, population centres and accesibility. It was decided that the sampling point were in the radius of 200 m, 500 m, 1000 m and 5000 m from the site. The amount of the points for each distance were arbitrarily chosen.

Frequency of sampling was based on the value for detecting variations in radioactive content and ease of analysis. But it was advised, the samples should be collected several time during wet and several times during dry seasons.

Sampling procedures.

Water samples were collected in 1,5 liter polyethylene bottles which had been previously washed in tap water and rinsed in the subject water. Surface soil and river bed samples were collected in 300 cc plastic containers. Sub-surface soil samples were not taken during this program. An effort was made to obtain soil which was free of large rocks and organic materials. Radioactive contents of rocks are relatively high due to granite containing Uranium and Thorium.

Vegetation samples were also collected in 300 cc plastic container. Only new growth and the upper parts of the plants were taken for the purpose.

Air samples were not taken yet, due to lack in air sampler and suitable filters with known efficiency were not available at the ITB for this air samples collection. (")

Sample preparation for Counting.

All samples were prepared by members of the Health Physics Group for counting. The techniques we have adapted were recommended in some literatures.

A five hundreds milliliters portion of the water sample removed from the bottle into a six hundreds milliliter beaker, and was continuosly evaporated using the burners. In this case we could not control the temperature and the evaporation was too fast. Due to the limited equipments, we could not avoided fast evaporation, which might reduce the radioactive content of the samples; and this will be discussed later. When the water reduce to approximately 5 milliliters, we transfer in small increments, into a stainlessteel planchet. The water in the planchet was continuosly evaporated, at less than 100 degrees Celcius under the heat lamp until the entire 500 cc portion was evaporated and only the dissolved and suspended solids remained in the planchet. Precautions have to be taken throughout the entire procedure to avoid cross-contamination of the samples, and to guarantee that the solids, in the planchet were truly representative of the solids present in the water.

A portion of the soil was first shifted or screened to remove rocks and organic materials. The resultant soils was then pulverized further, with mortar and pestle and then screened. One gram of the screened soil was transferred to a planchet and stabilized with a small amount of distilled water. The resultant mud was allowed to dry at a moderate temperature (less than 100 degrees Celcius). The weight of these soils were determined by substracting the weight of the empty planchet from combined weight. The planchet was then stored in the planchet rack before counting. Similar as above, care has to be taken to avoid cross-contamination of samples and to prepare a representative sample.

(") Vacuum pump for the purpose of collecting air samples, and paper on the air monitoring have been prepared by Rustan for the Health Physics Group, but getting the trouble in determining the flow rate.

A portion of vegetation sample was washed in flowing tap water. Then it was dried in a moderate temperature in the porcelain crucible. And then ashed in a muffle furnace, at about 500 degrees Celcius, for 15 hours, until it was reduced to a fine white ash. This ash was transfered to a weighed planchet. About 0.2 grams of ash was obtained. Then it was stabilized with small amount of distilled water, and was allowed to dry under the heat lamp, stored until it will be counted.

All of those samples were counted and analyzed for gross beta activities. Some of them — taken from pre-determined sampling points — were prepared for gross alpha analysis. Soluble and unsoluble water samples were also prepared for gross beta analysis. The soluble water samples were prepared in the same manner as water, while the unsoluble water samples were preppared as a vegetation samples.

Counting procedure.

The samples were counted with Nuclear Chicago D-47 gas flow counter, operated in the proportional region, with 150 micrograms/square centimeter micromil window, using Nuclear Chicago PR-Gas. This counter was chosen because of its 2 Pi geometry (approximately), high detection efficiency and its ability to distinguish between α and β-γ radiation.

All samples were counted for 10 minutes. This counting time was chosen according to the reasonable work loads and the acceptable counting statistics. However the standard deviation due to the statistical errors are relatively high for this time of counting, which is not long enough for low level counting, and also caused by the relatively high background count rate with respect to the samples counts rate*). (5), (6), (7)

The reliability of the counter was checked before starting routine works. The operating voltage for β counting was about 2150 volts and 1200 volts for alpha counting.

Background measurements were made on counter before starting actual counting, (sw) and should be repeated frequently (5) after 4th or 5th counting time or repeated if there are any significant raise of activities. Background counting time was of the same lenght as sample counting time.

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*) The case could not be avoided, due to the limited in the equipments and manpower available at the ITB for the present.

Counter was standardized using source of known activity before starting counting and repeated frequently during the time of counting. The net count-rate obtained was converted into curie units of activity per unit volume or per unit weight of sample (concentration see Table 1 to 3).

Counter efficiency.

In order to provide a basis for correlation of the samples, it was necessary to choose isotopes to be used as standards. The Beta standard chosen was K-40 obtained from KCl. The K-40 isotope experiencies Beta decay of 1.33 mev (max), which approximates the effective energy of aged mixed fission products, which is expected from all samples.

To obtain wether there is any similarity in its behavior with the soil samples, we prepared a certain mixture of soil and Potassium Chloride as a standard source to obtain the counter efficiency. One gram of this mixture was transfered into a planchet, stabilized with distilled water, dried and then counted. Several such a sample were prepared to get the average efficiency.

Knowing the disintregation rate of potassium by calculation, we obtain the counter efficiency. (2)

According to the ref. (2), the true Beta emmision was obtained by:

$$T = 2.22 \times 10^6 \, (K_w/M_w) \, ASRW$$

where

T = True emmission, Beta/min.
K_w = Total atomic weight of potassium per mol.
M_w = Total molecular weight
A = Relative isotopic abundance = 1.19×10^{-4}.
S = K-40 specivic activity = 6.74 micro curie/gram = $\dfrac{3.59 \times 10^{11}}{TK}$
K = K-40 half life = 1.3×10^9 years
R = Beta decay relative to electron capture = 0.89
W = Compound weight, gram.

The K-40 Beta emission for KCl is $8.2 + 10^2$ beta/min.-gm.

In each gram of this mixture (soil $\div$ KCl) contains 10/75 grams KCl and 65/75 grams of soil. The efficiency of the counter was expected

approximately 25% or above. The radioactive content of the soil mixed was neglected.

The method of obtaining the counter efficiency was in order to avoid the necessity of correcting each sample for self absorption. All soil samples must be prepared with the same weight as standard source and the similar procedure for preparation should be maintained.

To evaluate efficiency for vegetation samples, we used only KCl with the same weight as vegetation samples. Prepared in the same manner as above.

Every sample should be weighed, and determined the thickness in term of mg/cm².

To obtain the counter efficiency for water samples, due to the variation in weight of the samples, we have to prepare standardization curve. This can be done by counting the various weight of KCl samples. Knowing the true emission of beta particles emitted by K-40, we obtain the efficiency for the various thickness (mg/cm²).

Alpha standard source was prepared by dissolving 1 gram $UO_2(NO_3)_2 \cdot 6H_2O$ into 100 cc distilled water. The total activity of this solution was calculated to be 7.15×10^3 alpha/min.//cc of solution. The total activity are being considered constant during 5 years since separation. Another alpha standard source was obtained from mobile isotope training laboratory, IAEA, using 1 mc RaDEF in 0.5 cc nitrate (only 50 Lambda was used).

Discussion.

Statistical errors due to background and sample fluctuation is inhaerent in radioactivity assays (5). The optimum distribution of counting times has to be determined.

The deviation (D) in the calculation shown in the 1 to 3 is the standard deviation. The standard deviation in the counting rate is $\sqrt{R/t}$, where R is the counting rate and t is the counting time.

Any counting is usually not free from the background rate. And the background rate is also subject to statistical fluctuation. What is the effect of the background to the accuracy? The following will make it clear:

$$D_b = (R_b/t_b)^{\frac{1}{2}} \qquad (1)$$ where D_b, the standard deviation in the background rate.

Similarly $$D_{s+b} = (R_{s+b}/t_{s+b})^{\frac{1}{2}} \qquad (2)$$ where D_{s+b}, the standard deviation in the sample plus background rate.

The total time involved in determination of a single sample count rate is

$$T = t_b + t_{sb} \tag{3}$$

Following the theory of propagation of error, the standard deviation in the sample count rate is given by:

$$D_s^2 = D_{s+b}^2 + D_b^2 \tag{4}$$

Substituting equations (1), (2) and (3) we get

$$D_s = \left[\frac{R_s + R_b}{T - t_b} + \frac{R_b}{t_b} \right]^{\frac{1}{2}} \tag{5}$$

For a given R_s, T and t_b equation (5) will becomes smaller for the smaller R_b.

To reduce the background rate, we have to have a well shielded detector or such a unit called "Low Level Counting Unit". In the case of not having such a unit we can reduce the deviation by chosing t if the program time T is given. By differentiating eq. (5) and equating to zero, we get

$$t_b = T \frac{\sqrt{a+1} - 1}{a}, \text{ where } a = R_s/R_b \tag{6}$$

and the we know t /T is the function of a (see fig. 2).

The minimum deviation was given by

$$(D_s)_{min} = \sqrt{\frac{R_b}{T}} \left\{ 1 + \sqrt{a+1} \right\} \tag{7}$$

And the percentage $(D_s)_{min}$:

$$S = \frac{100}{(R_b T)^{\frac{1}{2}}} \left\{ \frac{1 + \sqrt{a+1}}{a} \right\} \tag{8}$$

The ratio R/R should remain constant during this program time. Change in R due to decay is beyond the scope of this discussion.

Fig. 2.

From ref. (5) we know-when the counter is very stable, the background may be determined with such an accuracy that it can be considered known. In this case the counting procedure may be somewhat simplified and some counting time saved.
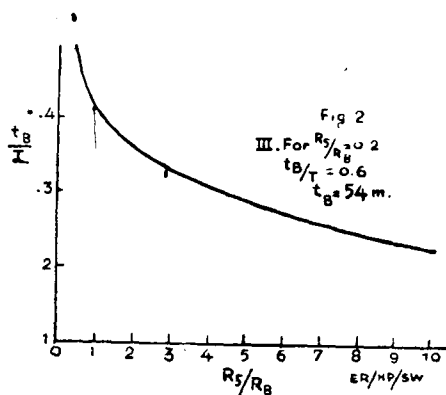
Counting proceduress tend to fall into two general classes, characterised either by constant or variable background can be determined independently of the sample. The background determination may then be made by intermittent checks distributed among many samples determinations. A variable background must necessarily be date mined separately for each assay. In this case the division of time between sample and background counts may be of critical interest (see eq. 6).
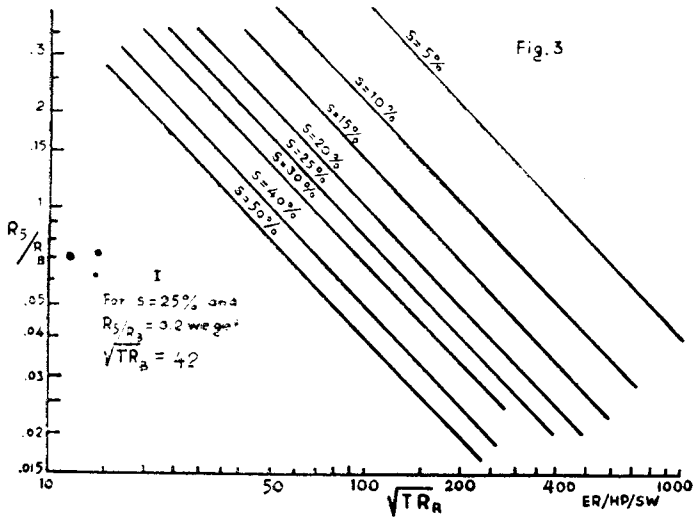

Fig. 3.

For using the 95% confidence level the deviation calculated should be multiplied by the factor 1.96.

One half of each sample collected is used for the activity determination, while the remaining one half is stored in the "Library" as a check sample which should be used when it is required by the authority or if there is any doubt in the result previously obtained.

Since the condition of counting are the same for every samples and standard source, the correction due to window thickness, backscatter, side scatter and air absorbtion are considered not necessary.

Eventhough the sampling points were chosen arbitrarily, its location with respect to the site, population centre and its accesibility was being considered. All the sampling points have their own number, according to which radius they belong. As an addition to the sampling points have been

previously determined (see fig. 1) some more sampling points were added to the program. According to the proposal for disposing the liquid waste into river Tjikapundung some points upstream and downstream should be controlled carefully. To make the authority and public for not being confused, river mud, river water of Tjikapundung near by to the Quinine Factory approximately 2000 meters S.S.W. from the site would be analyzed. The fresh quinine products would be also analyzed for its radioactivity.

Caused by some difficulties in getting a known standard source at the time of counting, the result of gross alpha activity was not shown in the present paper.

General conclusion.

Efforts have been made to get higher accuracy in background counting, but due to the lack of a representative "low level counting room" included a low level counting unit and man power, more accurate values could not be obtained. An average value of radioactivity and such a base line as discussed previously could not be drawn from those data, because many more

Fig. 4.

series should be needed. In comparing the results shown on tables *i* to 3 with the background activity values obtained at different Atomic Energy Establishments abroad (see Appendix) we can see that the results are comparable and of the same order, although absolute conclusions cannot be made from these comparisons.
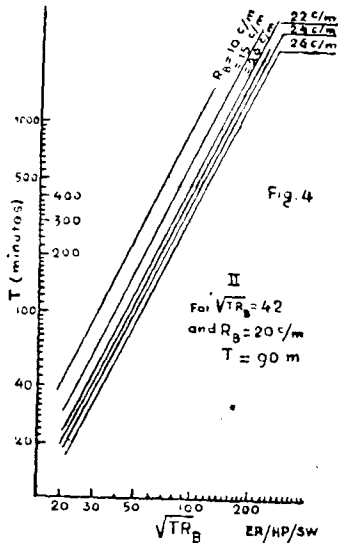
Augustus 1961

Aknowledgements.

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Table 1. Gross Beta Activity in soils (uc/gm soil $\times$ 10^{-6})

Station No.	Series I January 31, 1961	Series II April 27, 1961
200-1	2.4 ± 1	4.4 ± 1.1
200-2	9.3 ± 1.1	4.2 ± 1
200-3	1.5 ± 1	1.5 ± 1
200-3'	0.2 ± 1	1.8 ± 1
200-4	0.4 ± 1	2.2 ± 1
500-1	5.6 ± 1	0
500-2	8.6 ± 1.1	4.7 ± 1
500-3	0	2.2 ± 1
500-4	5.5 ± 1	2.7 ± 1
1000-1	10 ± 1	6.5 ± 1

Continuation of tabel 1

Station No.	Series I January 31, 1961	Series II April 27, 1961
1000-2	7.1 ± 1	8.2 ± 1
1000-3	8.2 ± 1.1	4.7 ± 1
1000-4	8.4 ± 1.1	1.8 ± 1
1000-5	2.9 ± 1	1.1 ± 1
1000-6	9.1 ± 1.1	6.8 ± 1
5000-1	2.7 ± 1	5.9 ± 1
5000-2	4.5 ± 1	6.2 ± 1.1
5000-1'	6.6 ± 1	0.2 ± 1
5000-3	4.9 ± 1	0.9 ± 1
5000-4	2.6 ± 1	9 ± 1
R-1'	0	4.2 ± 1.1
R-2'	6.7 ± 1	7.4 ± 1

Table 2. Gross Beta Activity in Vegetation (uc/gm ash $\times$ 10^{-6})

Station No.	Series I January 31, 1961	Series II April 27, 1961
200-1	75 ± 6	126.9 ± 6
200-2	0	45.7 ± 5
200-3	28 ± 5	46.4 ± 5
200-4	72.3 ± 6	65.5 ± 6
500-1	60.8 ± 5	84.3 ± 5
500-2	8.2 ± 5	135.5 ± 6
500-3	36.1 ± 5	50.3 ± 5
500-4	73 ± 6	70 ± 5
1000-1	313.3 ± 4"	64.5 ± 6
1000-2	34.3 ± 5	43.4 ± 5
1000-4	133 ± 4"	97.5 ± 6
1000-3	71.6 ± 6	62.5 ± 6
1000-5	64.8 ± 6	83 ± 5
1000-6	36.1 ± 5	67.8 ± 5
5000-1	77.8 ± 6	no sample
5000-2	42.3 ± 5	82.3 ± 5
5000-3	86.8 ± 6	120.3 ± 5
5000-4	78.5 ± 6	72.3 ± 5

' river mud treated as soils
" Counted with end window G-M counter

Table 3. Gross Beta Activity in Water (uc/cc $\times 10^{-8}$)

Station No.	Series I January 31, 1961	Series II April 27, 1961
R-1	—	1 ± 0.2
R-2	—	0.1 ± 0.2
SW-1	—	0.2 ± 0.2
ITB	—	no sample
SW-L	0	0.1 ± 0.2
5000-1	—	1 ± 0.2
5000-2	—	1.4 ± 0.2
5000-4	—	0.6 ± 0.2

APPENDIX

PRE — OPERATIONAL BACKGROUND VALUES AT DIFFERENT ATOMIC ENERGY ESTABLISHMENT ABROAD *)

Sample	AEET India	Windscale U.K.	Dounreay U.K.	Ohio U.S.A.	Handford-Columbia River — U.S.A
Fish					
Alpha-uc/gm	3×10^{-7}	—	9×10^{-8}	$0\text{-}31 \times 10^{-6}$	—
Beta- uc/gm	1×10^{-6}	—	2.4×10^{-6}	$110\text{-}260 \times 10^{-6}$	20×10^{-7}
Salt					
Alpha-uc/gm	1×10^{-9}	—	—	—	—
Beta-uc/gm	—	—	—	—	—
Soil					
Alpha-uc/gm	3.6×10^{-7}	1×10^{-5}	—	—	1.8×10^{-7}
Beta-uc/gm	2×10^{-5}	2.4×10^{-5}	—	$50\text{-}200 \times 10^{-6}$	1.1×10^{-6}
Sea water					
Alpha-uc/cc	4.5×10^{-10}	—	6×10^{-10} uc/gm of sea weed	—	1×10^{-6} uc/gm of plankton
Beta-uc/cc	$1\text{-}5 \times 10^{-8}$	—	7×10^{-6} uc/gm of sea weed	$40 \times 5100 \times 10^{-6}$ uc/gm plankton	1×10^{-8}
Vegetation					
Alpha-uc/gm	1×10^{-8}	3×10^{-7}	1×10^{-7}	—	—
Beta -uc/gm	1.3×10^{-7}	3.1×10^{-7}	4.6×10^{-5}	$120\text{---}1500 \times 10^{-6}$	4.6×10^{-6}

*) *Taken from Ref. 3*