Determination of radioactivity discharge limit to the atmosphere on Bandung nuclear area

J Chussetijowati and H Seno

Center for Applied Nuclear Science and Technology – National Nuclear Energy Agency of Indonesia (BATAN) Jl. Taman Sari No. 71, 40132, Bandung, Indonesia

E-mail: junic@batan.go.id

Abstract. The determination of radioactivity discharge limits to the atmosphere on Bandung Nuclear Area has been carried out. The purpose is that these values can be used to control the discharge of radioactivity from the TRIGA 2000 reactor stack and the labeled compounds and radiometry laboratory stack in the Area to the atmosphere. The determination method is using PC-CREAM software, assuming the discharge of radioactivity from the stack to the atmosphere occurs under normal conditions and occurs only once. The source terms discussed are radionuclides I-131 and Cs-137, while several the other source terms that were not discussed also contribute to this determination. The initial discharge limits of radioactivity I-131 and Cs-137 from the reactor stack of 4.46E-03 Bq/h and 1.26E+05 Bq/h respectively, while I-131 from the laboratory stack of 2.23E-02 Bq/h. The dose constraint for community members at a distance of 1000 m from the Area is set at 0.15 mSv/y. The parameter needed is source term, reactor building volume, the air flow rate in the reactor stack, stack height, angle and distance between the two stacks, meteorology, topographic roughness, and radionuclide pathway to the community. The result of the calculation obtained the discharge limits of radioactivity for I-131 and Cs-137 from the reactor stack of 7.07E-05 Bq/h and 2.00E+03 Bq/h respectively; and I-131 from the laboratory stack of 3.53E-04 Bq/h.

1. Introduction

Air is one of the important components and basic needs of human life. Without air, living creatures cannot breathe and will die. Air, among others, is used in the respiratory process, photosynthesis process, and energy sources.

The development of the human population also causes human activities to meet their daily needs. Science and technology also develop. Technology implementation activities, in addition to providing benefits for humans, also have an impact on the environment. Among these impacts are air, water or land pollution and waste.

Air pollution occurs because of the entry of pollutants into the air and contributes to reducing air quality. Elements from industrial fumes released without air filtering will have an effect on increasing the concentration of pollutants in the air.

Polluted air has the potential to endanger human health and the environment, especially those related to the respiratory system. Therefore, efforts are needed to prevent or to reduce the release of pollutants from their sources into the atmospheric. One way is to filter polluted air that will be released into the atmosphere through a stack equipped with an air filtering system. An air filtration system can be an air filter in which there are pollutant absorbent filters. It is expected that pollutants are filtered and retained in the filter and the air coming out of the stack is free of pollutants. However, the
potential release of pollutants into the atmosphere is still possible if the pollutants escape from the filter system filter.

Bandung Nuclear Area has 2 (two) stacks for release air (from the building) that has the potential to contain radioactivity into the atmosphere. The two stacks are the TRIGA 2000 reactor stack and the Labelled Compound and Radiometry laboratory (SBR laboratory) stack. Both stacks are equipped with an air filtering system before the air escapes into the atmosphere. While other stacks in this Area are used to release air that has the potential to not contain radioactive substances.

Areas that utilize nuclear power are basically no different from other industrial estates in general. All have the responsibility to ensure that the discharge of air from the Area does not have a negative impact on humans and the environment.

Radioactivity which is discharged from the nuclear area will become an artificial source of radioactivity. Therefore, if there is a release of radioactivity from the nuclear Area to the environment is needs to be controlled because it has the potential to increase the existing radioactivity in the environment. Control can be done by determining the discharge limits of radioactivity to the atmosphere (environment), so that the level of radioactivity in the atmosphere (environment) is recognized and reception dose of community members who live around the area does not exceed the dose limit value set by the Nuclear Energy Regulatory Agency (BAPETEN). In addition, a form of control can be carried out by direct monitoring (measurement) of radionuclide activity in the environment.

This paper discusses the determination of radioactivity discharge limits to the atmosphere in Bandung Nuclear Area, using PC-CREAM software. PC-CREAM software was developed based on the Gauss dispersion model [1]. The discharge limits of radioactivity discussed are the discharge limits of radioactivity from the TRIGA 2000 reactor stack and the SBR laboratory stack, assuming the discharge takes place under normal conditions (not an accident) and the discharge occurs only once.

Determination of radioactivity discharge into the environment is important, in addition to controlling the radioactivity discharged into the environment as well as for the protection of the health of community members and the environment especially if the radioactivity can enter the food chain. The control of the impact on the public and the environment in the nuclear industry is based on the radiological protection principles of justification, dose limitation and optimization [2].

In accordance with the Regulation of the Head of the Nuclear Energy Regulatory Agency (BAPETEN) that Nuclear Energy Utilization Permit Holders must determine the discharge limits of radioactivity to the environment (to the air and water bodies). The radioactivity discharge limits must be submitted to BAPETEN as part of the radiation protection and safety program for submitting construction, commissioning, and operation permits [3].

2. Theory

2.1. Radionuclide dispersion to the environment
One of the potential dangers of Nuclear Power Utilization is the release of radionuclides or radioactivity into the environment, either released into the atmosphere or water bodies (such as river water, seawater, or groundwater).

The release of radioactivity from the reactor stack into the atmosphere will be scattered and distributed in the atmosphere. Some of the radionuclides in the atmosphere fall to the surface of the earth, seep in the soil or water bodies or other components. Some are inhaled and stored in the respiratory system of the human body, animal or plant. Radionuclides that seep in the soil will be absorbed by plants, and those that enter the body of water will be absorbed by aquatic biota. Radionuclide contaminated soil and water are causing contamination of agricultural or aquatic products.

The released of radioactivity from the nuclear Area to the environment will be a source of artificial radioactivity, which has the potential to increase radioactivity in the environment. Being a major factor
that causes internal exposure and internal doses in the body, if living things are in a contaminated area or breathe air or consume food / drinks that are exposed to radioactive material.

The exposure pathways of radioactivity from the nuclear Area to human or environment: [4]

1. External radiation exposure due to
   - Radiation from the radioactive cloud
   - Radiation due to soil contamination
   - Radiation due to contamination of skin, clothing or objects
   - Direct radiation from the facility

2. Internal radiation exposure due to
   - Inhalation of airborne radioactive substances from the radioactive cloud
   - Ingestion of contaminated foodstuffs
   - Inhalation of stirred-up radionuclides that were previously deposited on the ground, objects or clothing

Quantitative calculation of the concentration of radioactivity in the atmosphere is necessary so that the radiological impact of the radionuclide release can be estimated. However, direct measurements are sometimes difficult to do and precise measurement values cannot be obtained. Therefore, we need a model for predicting the value of radioactivity concentration. This model was developed as an approach for matters relating to the release of radionuclides from the source point to the atmosphere, so that the value of radioactivity concentrations in the atmosphere at the specified point can be predicted. The developed model can be a mathematical or computer model.

2.2. Radiation protection fundamental

There are 3 (three) basic principles in protecting against radiation to protect humans, whether radiation Workers who are working using radioactive substances or to protect community members from radiation. The three principles of Radiation Protection are: [2, 5]

2.2.1. Justification. The activities of Nuclear Power Utilization are based on the principle of benefits, where the benefits must be greater than the risks posed to individuals or members of the community.

2.2.2. Limitation. The equivalent dose received by radiation workers or community members may not exceed the dose limit value (NBD) determined by BAPETEN.

2.2.3. Optimization. The activities of Nuclear Power Utilization must be planned and implemented properly so that the potential radiation exposure that occurs and the potential dose received by radiation workers or community members can be reduced to the lowest (As Low As Reasonably Achievable).

One of the implementations of the principle of “Optimization” is through setting the value of “Dose constraint” for radiation Workers and community members.

The dose constraint is the upper limit of the dose of the radiation Workers and members of the public who must not exceed the Dose Limit Value used in the optimization of Radiation Protection and Safety for each Nuclear Power Utilization [5].

2.3. PC-CREAM 08 software

PC-CREAM 08 software is software that can be used to carry out routine radiological impact assessments, the release of radioactivity from nuclear installations into the atmosphere and water bodies occurs continuously. In addition, PC-CREAM 08 software can also be used to determine the concentration of radioactivity released into the atmosphere and water bodies so that the estimated dose
of community members living around nuclear installations can be determined (individual and collective doses) [1]. In PC-CREAM 08 software, a radionuclide release model into the atmosphere was developed based on the Gauss dispersion model.

Radionuclide dispersion equations in the atmosphere are equations used to help predict the magnitude of radionuclide concentrations at a location in its removable path. By knowing the value of the concentration, it can be estimated the radiation dose received by community members and the radiological impact on the environment. In determining the discharge limits of radioactivity to the atmosphere here it is done in the opposite way, which is the first set of the site-specific dose constraint for the nuclear Area. Then by "try and error" input the value of the rate release of radioactivity source term from both stacks and parameters into PC-CREAM software until the dose value received by the receptor or community member at the specified location does not exceed the site-specific dose constraint.. Illustration of determination of the radioactivity discharge limit in here is almost the same as an illustration of the procedure for setting discharge limits in the IAEA-TECDOC-1638 [6].

3. Methodology
The stages of determining of discharge limits of radioactivity into the environment, both for radioactivity discharge into the air and into water bodies are as follows: [3]

- Establish the site-specific dose constraint
- Determine the source term and assumptions of the pathways from the installation to the community
- Calculates the discharge limits

In determining the discharge limits of radioactivity, the discharge of radioactivity from the stack to the atmosphere is assumed to take place in conditions (not accidents) and only once. Required parameters include:

- Source term data = in Table 1
- The reactor building volume = 6750 m³
- The airflow rate in the reactor stack = 2.03 m³/sec
- Filter paper efficiency = 60%
- Region topographic roughness = choose 1 ("default" program)
- Radionuclide pathway to community members = skin and inhalation
- Stack height = 23 m
- Distance between the two stacks = 35 m
- The position of the SBR laboratory stack from the reactor stack = 45° clockwise
- Meteorological data = Bandung city meteorological data, taken from the Meteorology, Climatology and Geophysics Agency (BMKG) Bandung

Meteorological data (wind direction and speed, solar radiation, and rainfall) are collected for 1 (one) year, with data obtained every hour. Meteorological data are used to determine atmospheric "stability", namely stability A, B, C, D, E, F, C rain, and D rain (Pasquill stability class). Furthermore, the stability data are grouped into 16 groups (according to the wind direction) and calculated "fractions" of each stability group A, B, C, D, E, F, C rain, and D rain for 1 year [1].

Pasquill classifies atmospheric turbulence into six stability classes named A, B, C, D, E and F with class A being the most unstable or most volatile class, and class F the most stable or least turbulent class [7].

By knowing the volume of the reactor hall, air filter efficiency, and airflow rate in the stack, it can be calculated the release rate of the radionuclide in the reactor stack (from inside the reactor hall), using equation (1) below:

\[ d = \left( \frac{A}{V} \right) x (1 - eff) x v \]  

(1)
which:
\[ d \] : discharge rate of the radionuclide in the reactor stack (Bq/s)
\[ A \] : activity of radionuclide inside the reactor hall (Bq)
\[ V \] : volume of the reactor hall (m³)
\[ v \] : air flow rate the reactor stack (m³/s)
\[ \text{eff} \] : efisiensi of filter paper

4. Result and discussion

4.1. Site-specific dose constraint
The site-specific dose constraint set by the Nuclear Power Utilization Permit Holder may not exceed the dose limit value of community members. The dose constraint for community members is determined by BAPETEN, which is not to exceed 0.3 mSv (three-tenths of a milli Sievert) annually [2].

The dose constraint for site-specific here is set at 0.15 mSv per year, with the consideration that the remaining 0.15 mSv per year is received from other sources not yet described here or from medical or natural radioactivity. With the determination of the site-specific dose constraint, it is expected that community members around the nuclear Area / installation will receive the lowest possible dose of radiation or not exceed the value of 0.3 mSv per year. The dose constraint applies to one region.

4.2. The source term and assumption of the pathways of radioactivity from the installation to the community members

4.2.1. Source term. The source term of the release of radioactivity into the atmosphere are all radionuclides which have the potential discharge from the stack of nuclear Area, both from the reactor stack and SBR laboratory stack. Radionuclides which are potentially released as fission products during routine operation of the reactor and/or inadvertent cases include I-131, Cs-137, Sr-90, and Kr-85. Radionuclides are usually fission products that can escape until they reach the reactor hall, namely radionuclides are gas (Krypton and Xenon) and volatile such as Iodine and Bromine. Meanwhile, the source term of the SBR laboratory stack is radionuclides which have the potential to discharge into the air of the laboratory building during the process of research / activities using radioactive materials in the laboratory building. For example is the process of making I-131.

The source terms / radionuclide are assumed to be a fission product released from the TRIGA 2000 reactor and inside the reactor hall, as shown in table 1.

| Nuclide | Activity in cladding (Bq) | Release to water coolant (Bq) | Release to reactor hall (Bq) |
|---------|--------------------------|------------------------------|----------------------------|
| Kr-83m  | 6.43 E+01                | 6.43 E+01                    | 6.43 E+01                  |
| Kr-85m  | 1.54 E+02                | 1.54 E+02                    | 1.54 E+02                  |
| Kr-87   | 3.12 E+02                | 3.12 E+02                    | 3.12 E+02                  |
| Kr-88   | 4.38 E+02                | 4.38 E+02                    | 4.38 E+02                  |
| Xe-133  | 8.21 E+02                | 8.21 E+02                    | 8.21 E+02                  |
| Xe-133m | 2.39 E+01                | 2.39 E+01                    | 2.39 E+01                  |
| Xe-135  | 4.14 E+02                | 4.14 E+02                    | 4.14 E+02                  |
| Xe-135m | 1.37 E+02                | 1.37 E+02                    | 1.37 E+02                  |
The source terms in Table 1 are assumed to be released from the reactor hall into the TRIGA 2000 reactor stack. Using equation (1), the discharge rate of the radionuclide/source term in the reactor stack can be calculated. The result of the calculation can be seen in Table 2.

**Table 2.** The discharge rate of radionuclide/source terms in the reactor stack.

| Nuclide | Release to reactor stack (Bq/y) | Release to reactor stack (Bq/h) |
|---------|---------------------------------|---------------------------------|
| Kr-83m  | 2.44E+05                        | 2.78 E+01                       |
| Kr-85m  | 5.84E+05                        | 6.67 E+01                       |
| Kr-87   | 1.18E+06                        | 1.35 E+02                       |
| Kr-88   | 1.66E+06                        | 1.90 E+02                       |
| Xe-133  | 3.11E+06                        | 3.56 E+02                       |
| Xe-133m | 9.07E+04                        | 1.04 E+01                       |
| Xe-135  | 1.57E+06                        | 1.79 E+02                       |
| Xe-135m | 5.20E+05                        | 5.93 E+01                       |
| Nuclide | Release to reactor stack (Bq/y) | Release to reactor stack (Bq/h) |
|---------|---------------------------------|---------------------------------|
| Xe-138  | 2.75.E+06                       | 3.14 E+02                       |
| I-131   | 3.91.E+01                       | 4.46 E-03                       |
| I-132   | 5.88.E+01                       | 6.71 E-03                       |
| I-133   | 9.33.E+01                       | 1.07 E-02                       |
| I-134   | 1.05.E+02                       | 1.20 E-02                       |
| I-135   | 8.73.E+01                       | 9.96 E-03                       |
| Rb-88   | 1.87.E+10                       | 2.14 E+06                       |
| Rb-89   | 2.44.E+10                       | 2.79 E+06                       |
| Te-127  | 2.25.E+07                       | 2.56 E+03                       |
| Te-129  | 1.07.E+08                       | 1.23 E+04                       |
| Te-129m | 1.62.E+07                       | 1.84 E+03                       |
| Te-131  | 4.32.E+08                       | 4.94 E+04                       |
| Te-131m | 6.18.E+07                       | 7.06 E+03                       |
| Te-132  | 7.21.E+08                       | 8.23 E+04                       |
| Te-133  | 6.37.E+08                       | 7.28 E+04                       |
| Te-133m | 5.12.E+08                       | 5.85 E+04                       |
| Te-134  | 1.13.E+09                       | 1.29 E+05                       |
| Cs-137  | 1.10.E+09                       | 1.26 E+05                       |
| Cs-138  | 3.45.E+10                       | 3.94 E+06                       |
| Ru-105  | 4.78.E-03                       | 5.46 E-07                       |
| Ru-106  | 1.24.E-03                       | 1.42 E-07                       |

The source term discharge from the SBR laboratory stack is assumed to be radionuclide I-131, with a discharge rate of 5 times greater than that of I-131 in the reactor stack.

4.2.2. Assuming the pathways of radioactivity from the nuclear Area / installation to community members. Bandung Nuclear Area is within the Municipality of Bandung, West Java Province. Food for consumption in the city of Bandung comes from outside the city of Bandung. Therefore, if there is a discharge of radioactivity from the Bandung Nuclear Area, then the pathways of radioactivity starting from the reactor stack and the SBR laboratory stack to the community members is through immersion, inhalation and exposure to contaminated soil (ground), moderate pathways through food are considered non-existent.

4.2.3. Calculation of dose constraint. By entering the initial discharge rate (Bq/y) data for each source term in Table 2 and from the SBR laboratory stack as well as other parameter data and the default data selected [1] into the PC-CREAM software, individual dose values are obtained at a distance of 100 m, 200 m, 500 m, 1000 m and 2000 m from the reactor stack (to the west). The dose of the initial discharge of the source term concerning an individual / community member can be seen in table 3, table 4, table 5, table 6 and table 7.

**Table 3.** Individual dose at a distance 100 m from reactor stack, for 1 year.
It could be seen from Table 3, Table 4, Table 5, Table 6 and Table 7 that the individual doses received by adults are greater than those of children or infants. This is probably related to the weight factor of body tissue, so that radiation exposure to the body and inhaled by adults is greater than children or infants. In PC-CREAM Software, the respiratory rate constant for adults of 8.10 E+03 m/y is determined; children of 5.60 E+03 m/y; and infant of 1.90 E+03 m/y. The value of this respiratory rate constant is almost the same as determined by UNSCEAR, namely adults (> 17 years) of 22.2 m/d; children (8-12 years) of 15.3 m/d; and infants (1-2 years) of 5.16 m/d [9]. While in the Safety Report Series number 19, the respiratory rate for adults of 8400 m/y and for infants of 1400 m/y [10].

The "Committed Effective Dose Coefficient for Inhalation (Sv/Bq)" for adults of 7.4 E-09 Sv/Bq smaller than infant of 7.2 E-08 Sv/Bq; and for Cs-137 "Committed Effective Dose Coefficient for Inhalation (Sv/Bq)" for adults of 4.6 E-09 Sv/Bq smaller than infant of 5.4 E-09 Sv/Bq [10].

## Table 4. Individual dose at a distance 200 m from reactor stack, for 1 year.

|          | Individual dose (µSv) | from reactor | from the SBR lab. | Total dose |
|----------|-----------------------|--------------|-------------------|------------|
| Adult    | 2.82 E-03             | 8.40 E-10    |                   | 2.82 E-03  |
| Children | 2.73 E-03             | 9.07 E-10    |                   | 2.73 E-03  |
| Infant   | 2.68 E-03             | 9.50 E-10    |                   | 2.68 E-03  |

## Table 5. Individual dose at a distance 500 m from reactor stack, for 1 year.

|          | Individual dose (µSv) | from reactor | from the SBR lab. | Total dose |
|----------|-----------------------|--------------|-------------------|------------|
| Adult    | 2.57 E-03             | 7.02 E-10    |                   | 2.57 E-03  |
| Children | 2.35 E-03             | 7.81 E-10    |                   | 2.35 E-03  |
| Infant   | 2.22 E-03             | 8.33 E-10    |                   | 2.22 E-03  |

## Table 6. Individual dose at a distance 1000 m from reactor stack, for 1 year.

|          | Individual dose (µSv) | from reactor | from the SBR lab. | Total dose |
|----------|-----------------------|--------------|-------------------|------------|
| Adult    | 1.14 E-03             | 4.00 E-10    |                   | 1.14 E-03  |
| Children | 1.04 E-03             | 4.49 E-10    |                   | 1.04 E-03  |
| Infant   | 9.82 E-04             | 4.81 E-10    |                   | 9.82 E-04  |

## Table 7. Individual dose at a distance 2000 m from reactor stack, for 1 year.

|          | Individual dose (µSv) | from reactor | from the SBR lab. | Total dose |
|----------|-----------------------|--------------|-------------------|------------|
| Adult    | 4.72 E-04             | 1.39 E-10    |                   | 4.72 E-04  |
| Children | 4.39 E-04             | 1.55 E-10    |                   | 4.39 E-04  |
| Infant   | 4.18 E-04             | 1.66 E-10    |                   | 4.18 E-04  |
According to UNSCEAR data, "Committed Effective Dose Coefficients for Inhalation (Sv/Bq)" for adults of 7.4 E-09 Sv/Bq, children 1.9 E-08 Sv/Bq, and infants of 7.2 E-08 Sv/Bq, while for Cs-137 "Committed Effective Dose Coefficients for Inhalation (Sv/Bq)" for adults of 4.6 E-09 Sv/Bq, children of 3.7 E-09 Sv/Bq, and infants of 5.4 E-09 Sv/Bq [9].

The farther the position of the individual from the reactor stack, the smaller the dose the individual receives. The Gauss dispersion equation model applied in PC-CREAM software was developed based on the distance function \[ d \]. The farther away from the stack (the point of discharge of radioactivity), the concentration of radioactivity is also reduced, whether it is reduced due to dilution or deposition of radioactivity or absorbed by components in the earth's surface.

Radionuclide Cs-137 has a half-life of 30.17 years so that its presence in the environment will be long because the activity decays a long time. While I-131 has a half-life of 8.02 days, if it is absorbed by the body it can settle to thyroid tissue and the activity decays more quickly so that its presence in the environment runs out. Therefore, we only discuss the reception of individual doses from the source I-131 and Cs-137, while several other source terms that were not discussed also contribute to this determination.

In determining the discharge limits of radioactivity here, the receptor is set at a distance of 1000 m from the reactor stack, parallel to the stack, westward from the stack. The receptors are in densely populated residential areas and are assumed to be continuously exposed to radioactivity for 8760 hours (1 year).

Based on the site-specific dose constraint that has been set at 0.15 mSv per year, the discharge limits of radioactivity source term from two stacks are calculated. The method is by "Try and Error" input value of the discharge rate of radioactivity from both stacks until the dose value received by the Receptor at a distance of 1000 m from the reactor stack does not exceed the value of the site-specific dose constraint. From the "Try and Error" value the discharge rate of radioactivity from the two stacks gives the results of the calculation of the dose, as shown in table 8.

| Receptor dose (µSv) from reactor | from the SBR lab. | Total dose |
|----------------------------------|------------------|-----------|
| Adult                            | 1.49 E+02        | 4.39 E-05 | 1.49 E+02 |
| Children                         | 1.39 E+02        | 4.92 E-05 | 1.39 E+02 |
| Infant                           | 1.32 E+02        | 5.26 E-05 | 1.32 E+02 |

From table 8 we can see that the total dose received by adult receptors approaches the site-specific dose constraint of 0.15 mSv per year (or 150 µSv per year). This means that the process of "Try and Error" input value of the discharge rate of radioactivity from both stacks is sufficient. The total dose received by the adult receptor comes from the discharge rate of radioactivity in the reactor stack for I-131 of 1.23 E+07 Bq/y and Cs-137 of 3.48 E+14 Bq/y; and I-131 from the SBR laboratory stack of 6.15 E+07 Bq/y. The other source terms in Table 1 also contribute to receiving the total dose at the Receptor and the results are shown in Table 9.

| Nuclide | Discharge limits of radioactivity (Bq/y) | (Bq/h) |
|---------|----------------------------------------|-------|
| Kr-83m  | 7.70 E+10                             | 8.79 E+06 |
| Kr-85m  | 1.84 E+11                             | 2.11 E+07 |
### Nuclide Discharge limits of radioactivity

| Nuclide | Discharge limits of radioactivity (Bq/y) | (Bq/h) |
|---------|-----------------------------------------|--------|
| Kr-87   | 3.74 E+11                               | 4.27 E+07 |
| Kr-88   | 5.25 E+11                               | 5.99 E+07 |
| Xe-133  | 9.83 E+11                               | 1.12 E+08 |
| Xe-133m | 2.86 E+10                               | 3.27 E+06 |
| Xe-135  | 4.96 E+11                               | 5.66 E+07 |
| Xe-135m | 1.64 E+11                               | 1.87 E+07 |
| Xe-138  | 8.68 E+11                               | 9.91 E+07 |
| I-131   | 1.23 E+07                               | 1.41 E+03 |
| I-132   | 1.86 E+07                               | 2.12 E+03 |
| I-133   | 2.95 E+07                               | 3.36 E+03 |
| I-134   | 3.32 E+07                               | 3.79 E+03 |
| I-135   | 2.75 E+07                               | 3.14 E+03 |
| Rb-88   | 5.90 E+15                               | 6.74 E+11 |
| Rb-89   | 7.71 E+15                               | 8.80 E+11 |
| Te-127  | 7.09 E+12                               | 8.09 E+08 |
| Te-129  | 3.39 E+13                               | 3.87 E+09 |
| Te-129m | 5.10 E+12                               | 5.82 E+08 |
| Te-131  | 1.37 E+14                               | 1.56 E+10 |
| Te-131m | 1.95 E+13                               | 2.23 E+09 |
| Te-132  | 2.28 E+14                               | 2.60 E+10 |
| Te-133  | 2.01 E+14                               | 2.30 E+10 |
| Te-133m | 1.62 E+14                               | 1.85 E+10 |
| Te-134  | 3.58 E+14                               | 4.09 E+10 |
| Cs-137  | 3.48 E+14                               | 3.98 E+10 |
| Cs-138  | 1.09 E+16                               | 1.24 E+12 |
| Ru-105  | 1.51 E+03                               | 1.72 E+01 |
| Ru-106  | 3.93 E+02                               | 4.48 E-02 |

The results of determining the discharge limit of radioactivity as in Table 9, gave a total dose to the adult receptor of 1.49 E+02 µSv. This means that the site-specific dose constraint of 0.15 mSv per year is fulfilled. However, the results of the calculations in Table 9 when compared with the value of the discharge limits of radioactivity into the environment for discharge into the air in the Head of BAPETEN Regulation number 7 of 2017 [3], it appears that the calculated value is fulfilling the BAPETEN provisions and some are not, especially for Cs-137. In Table 9 the Cs-137 discharge limits are 3.98 E+10 Bq/h, while the Cs-137 discharge limits in BAPETEN Head Regulation No. 7 of 2017 is 2.0 E+03 Bq/h.

Therefore, the "Trial & Error" process is inputted by the value of the discharge limits of radioactivity using PC-CREAM Software to meet the value of radioactivity discharge limits to the
environment for discharge into the air based on BAPETEN Head Regulation No. 7 of 2017. And the results of the calculation of the value of the discharge limits of radioactivity from the Bandung Nuclear Area stack to the atmosphere that meets the Head of BAPETEN Regulation No. 7 of 2017 can be seen in Table 10.

**Table 10.** The results of determining the discharge limit of radioactivity are based on the regulation of the head of BAPETEN.

| Nuclide | Calculation results that meet the regulation of the head of BAPETEN (Bq/h) |
|---------|-------------------------------------------------------------------------|
| Kr-83m  | 4.41 E-01                                                               |
| Kr-85m  | 1.06 E+00                                                               |
| Kr-87   | 2.14 E+00                                                               |
| Kr-88   | 3.01 E+00                                                               |
| Xe-133  | 5.63 E+00                                                               |
| Xe-133m | 1.64 E-01                                                               |
| Xe-135  | 2.84 E+00                                                               |
| Xe-135m | 9.40 E-01                                                               |
| Xe-138  | 4.98 E+00                                                               |
| I-131   | 7.07 E-05                                                               |
| I-132   | 1.06 E-04                                                               |
| I-133   | 1.69 E-04                                                               |
| I-134   | 1.90 E-04                                                               |
| I-135   | 1.58 E-04                                                               |
| Rb-88   | 3.38 E+04                                                               |
| Rb-89   | 4.42 E+04                                                               |
| Te-127  | 4.06 E+01                                                               |
| Te-129  | 1.94 E+02                                                               |
| Te-129m | 2.92 E+01                                                               |
| Te-131  | 7.82 E+02                                                               |
| Te-131m | 1.12 E+02                                                               |
| Te-132  | 1.30 E+03                                                               |
| Te-133  | 1.15 E+03                                                               |
| Te-133m | 9.27 E+02                                                               |
| Te-134  | 2.05 E+03                                                               |
| Cs-137  | 2.00 E+03                                                               |
| Cs-138  | 6.25 E+04                                                               |
| Ru-105  | 8.65 E-09                                                               |
| Ru-106  | 2.25 E-09                                                               |
The dose received by community members does not exceed the determined dose constraint and also the discharge of radioactivity from the stack of the nuclear area does not exceed the discharge limits of radioactivity into the environment according to the Head of BAPETEN Regulation number 7 years 2017 by using PC-CREAM software, the discharge limits of radioactivity I-131 and Cs-137 from the reactor stack of 7.07 E-05 Bq/h and 2.00 E+03 Bq/h respectively; and the discharge limits of radioactivity I-131 from SBR laboratory stack of 3.53 E-04 Bq/h. This means that radioactivity discharge from the stacks with a discharge rate of less or equal to the discharge limits calculated using PC-CREAM will provide an individual dose that is still safe (less than dose limit) for community members who live at a minimum distance of 1000 m from the Bandung Nuclear Area.

5. Conclusion
The determination of radioactivity discharge limits to the atmosphere on Bandung Nuclear Area has been carried out. The discharge of radioactivity comes from the source term from the reactor stack and the Labelled Compounds and Radiometry Laboratory stack. Discharge of radioactivity is assumed to take place normally (not an accident) and occurs only once. The site-specific dose constraint for community members living within 1000 m of the nuclear area and continuously exposed to radioactivity for 8760 hours (1 year) is set at 0.15 mSv per year. The radioactivity pathway from the Area to the community members is through the skin and breathing. So that the dose received by community members who live within a distance of 1000 m from the reactor stack (nuclear area) does not exceed the determined dose constraint and also so that the discharge of radioactivity from the stack of the nuclear area does not exceed the discharge limits of radioactivity into the environment according to the Head of BAPETEN Regulation number 7 years 2017 by using PC-CREAM software, the discharge limits of radioactivity I-131 and Cs-137 from the reactor stack of 7.07 E-05 Bq/h and of 2.00 E+03 Bq/h respectively; and the discharge limits of radioactivity I-131 from laboratory stack of 3.53 E-04 Bq/h.

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