DEMOGRAPHIC CHARACTERISTICS OF SITE VICINITY AREA FOR PREPARATION IN WEST KALIMANTAN NPP SITE

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ABSTRACT

The potential risk of radioactive release to the environment and surrounding population can occur when there is a nuclear emergency, and nuclear preparedness planning is required for disaster mitigation. In preparedness planning, data is needed, one of which is demographic characteristics. Demographic information in site preparation can produce appropriate and efficient policy formulations because the number and density of the population, as well as the susceptible population, are known. The method used is secondary data collection, data verification, data processing, mapping, and analysis. This study aims to determine the demographic characteristics of the site vicinity. The study results show that the population density in 5 km radius area is 177 people/km^2. In 2018, the total population was 5,199 people, the percentage of the male population was 50.3%, and the female population was 49.7%. The population aged ≥20 years was 63.4%, 5-19 years old was 29.7%, and aged 0-4 was 6.9%. The projected population in 2047 is 6,523 people. The assumption is that in the event of a nuclear emergency, the emergency response considers the susceptible population. Evacuation of residents related to the emergency response can be carried out through 2 routes, namely through the South Singkawang District to the West Singkawang area, which is about 30 km from the site or through the Sungai Raya District to the Sungai Kunyit area, which is of about 26 km from the site.

Keywords: demographic; site vicinity; nuclear emergency; evacuation
Received: 2021-05-18; Revised: 2021-07-28; Accepted: 2021-08-02

INTRODUCTION

The results of the site study in the West Kalimantan area have obtained potential locations for nuclear power plant sites, namely Gosong Beach and Semesa Island in Sungai Raya Village, Bengkayang Regency [1]. In analyzing the sources of events affecting the safety of nuclear installations, the demographic characteristics of the area around the site are also considered. In addition to the benefits of the nuclear power plant (NPP), the surrounding communities will also be at risk in the event of a nuclear emergency. When there is a nuclear emergency, there will be a potential risk of radioactive release, which is distributed to the population and the environment around the site. Demographic characteristics in site preparation are used for risk evaluation of the surrounding community and preparedness in the event of a nuclear emergency for the protection and health of the people who will be affected.

The nuclear emergency area includes the on-site area, which is limited by certain markings and the off-site area. In the off-site area, there are areas for emergency response measures, namely the precautionary action zone (PAZ) and the urgent protective action planning zone (UPZ), as well as the food control zone [2]. The food control zone is outside the UPZ, an area where the consumption of local agricultural and livestock products is prohibited because the area has been contaminated [3].

The NPP planned to be built in West Kalimantan is the SMR (Small Medium Reactor) type. It has a potential hazard when a radioactive release occurs, which can have a severe deterministic effect outside the site, with a UPZ radius of 5-25 km. In the planning of urgent protective actions, information such as demographic characteristics is required, and in this study, it will be analyzed up to a radius of 5 km.

Actions taken within the UPZ in the event of a nuclear emergency can include

evacuation, individual decontamination, respiratory protection, distribution of iodine, prohibiting the consumption of potentially contaminated foodstuffs, and appropriate refugee camps [4]. The distribution of iodine is prioritized for susceptible populations such as infants, children, and pregnant women. Appropriate refugee camps are that it has no potential for health during evacuation (especially for patients and the elderly). The action in the UPZ is effective radiation protection for the public in an emergency. The evacuation process will run smoothly if countermeasures are taken properly to minimize casualties, health risks, and traffic accidents. Patients and the elderly in evacuation facilities will not suffer serious life-threatening conditions due to worsening medical problems due to improper treatment. Traffic congestion can prolong the evacuation time; with the right countermeasures, increased exposure to radiation dose can be minimized [5]. With information on demographic characteristics, efforts can be made to plan an appropriate and efficient preparedness to minimize the risk of fatalities and public health.

The study aims to determine the demographic characteristics of the site vicinity (radius 5 km from the NPP site) and the main evacuation route in the event of a nuclear emergency. The demographic characteristics referred to are data on the total population and population density, as well as population-based on gender and age. The age and sex of individuals exposed to radiation have different radiosensitivity. Age is one of the important factors regulating the carcinogenesis of radiation. At comparable doses, the radiosensitivity of females was higher than that of males [6].

METHODS

Data Collection, Data Processing, Mapping, and Analysis

The method used in the study is secondary data collection, data verification, data processing, mapping, and analysis. Secondary data used is population data of Sungai Raya Kepulauan District, which has been verified by the Statistics Agency of West Kalimantan Province. Secondary data are from statistical data and processed by using Microsoft Excel. Calculation of population projections using the exponential method. Meanwhile, the radius of the study location was made with the help of ArcGIS software using the polygon buffer facility on the 1: 50,000 scale Administration Map. Determination of evacuation routes based on the nearest transportation route from the settlement directed to the main road.

The study location is a radius of 5 km from the NPP site, which is the zone around the site (site vicinity) with an area of 29.4 km^2 covering Sungai Raya, Sungai Keran, and Karimunting Villages (**Figure 1**).

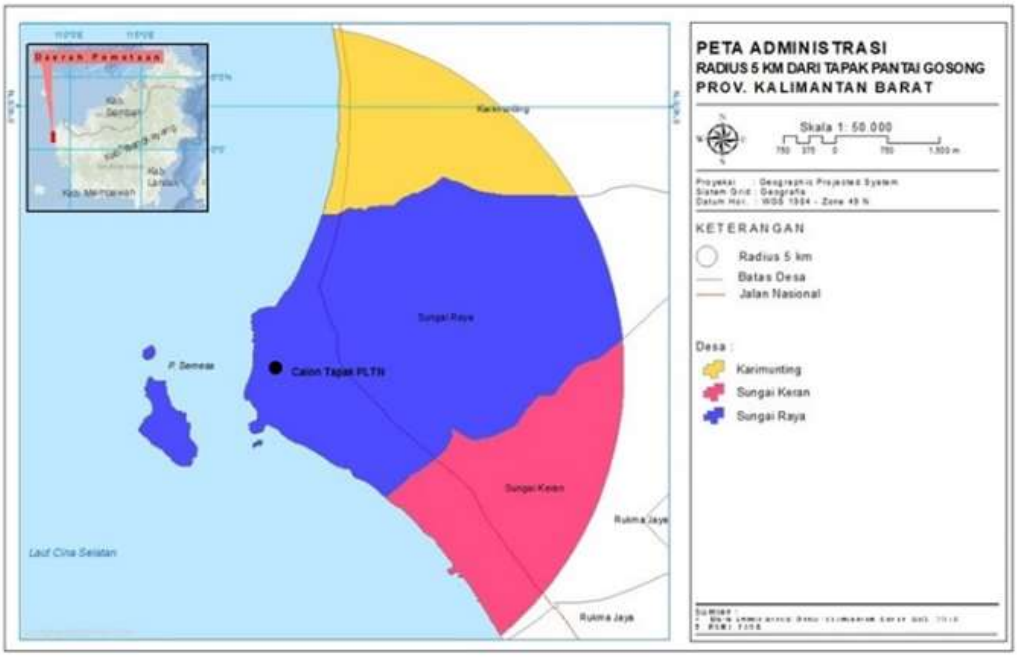

Figure 1. The area on a 5 km radius of the NPP site.

The NPP site is located in Sungai Raya Village, Sungai Raya Kepulauan District, Bengkayang Regency, West Kalimantan Province. The boundary area of the site are 108º51'30"BT – 108º53'20"BT and 0º43'48"LU – 0º42'10"LU.

DEMOGRAPHIC CHARACTERISTICS FOR NUCLEAR PREPAREDNESS

Analysis of population distribution such as total population and population density, population by age, and sex is required for the evaluation of community risk and nuclear preparedness. Preparedness is a planned and systematic activity to anticipate nuclear emergencies. The ability for reliable emergency response requires appropriate, effective, and efficient preparedness planning [7]. Besides requiring demographic data, this preparedness planning policy also involves various experts in other fields [8].

A nuclear emergency is a state of hazard that threatens human safety and loss or damage to the environment due to nuclear accidents. The direct threat from nuclear power plant accidents is the ionizing radiation that escapes from the reactor core. In nuclear power plant operation, when a nuclear accident occurs, low-level ionizing radiation emissions can be exposed to workers and the community around the facility, which in the long run can cause health effects [9]. The health effects of radiation exposure are determined by the type and quality of radiation. Therefore, when a nuclear power plant operates, environmental monitoring is always carried out to find out whether there is radiation exposure to the environment, workers, or the community.

The regulations require that the dose limit for radiation exposure of public members does not exceed one mSv/year. In special circumstances, the effective dose received in one year should not be more than five mSv, but the average dose over five consecutive years should not exceed one mSv/year [10]. Low radiation exposure more than the dose-limit value does not cause immediate health effects but is a small contributor to cancer risk. The International Agency for Research on Cancer (IARC) has categorized all types of ionizing radiation as carcinogenic to humans [11].

Radionuclides that cause radiation exposure to the environment consist of air emissions and liquid effluent. Examples of the types of radionuclides produced by NPP include krypton-85, xenon-133, argon-41, uranium-235, tritium, carbon-14, strontium-90, cesium-137 and iodine-131 [12]. Exposure to humans can be internal through food and drink (ingestion) or inhalation (inhalation). While externally, it is absorbed through the skin. Externally exposed individuals can also be exposed internally. There are several radioactive substances that are easily absorbed by the body and survive, such as iodine which is absorbed by the thyroid gland, strontium and radium in bone [13], plutonium in the lungs, and cesium in soft tissues [14].

Urgent protective measures in nuclear emergencies aim to prevent deterministic effects and minimize stochastic effects [15]. This action plan will ensure the protection of reactor personnel, emergency workers, and the surrounding communities. Deterministic effects are effects due to radiation exposure whose severity depends on the radiation dose so that below the threshold, no adverse effects are seen [16]. In a deterministic effect, damage or death of cells due to exposure to radiation at a sufficiently high dose [17]. Physical effects will occur if the death of the cells is large enough to cause damage to tissues or organs, such as skin erythema, cataracts, infertility, acute radiation syndrome, or fetal death. Tissue damage is the result of exposure that exceeds the dose limit value, such as erythema that occurs after 1 to 24 hours of exposure to 2 Sv [18]. Acute radiation syndrome is a symptom of nausea and vomiting within hours and can sometimes cause death in the following days or weeks due to very high levels of exposure in a short period [19]. The probability of a stochastic effect need not be a threshold dose, and as a function of the radiation dose causing the effect [20], so the risk of the effect increases linearly with increasing dose. Some examples of stochastic effects are cancer, congenital defects (decreased syndrome), effects on the gastrointestinal, haematological and lymphoreticular, reproductive, central nervous system, respiratory, and others.

In preparedness planning, demographic information regarding the sex and age of individuals when exposed to radiation is needed because individuals have different radiosensitivity. When receiving the same dose, the female sex has a higher radiosensitivity than men. Women are at greater risk of suffering and dying from radiation exposure that causes cancer than men.

Studies related to radiation carcinogenesis in different age groups have shown that exposure to radiation during infancy and childhood has a greater risk of cancer than exposure to older ages [21].

Radiation exposure to infants, children, and fetuses will cause cells to divide rapidly, so radiation has many opportunities to disrupt the process and cause damage to cells. Radiosensitivity in infants and children is very high and decreases in adulthood.

In preparedness planning, besides demographic information, infrastructure must also be prepared. Plans for long-term shelter facilities with suitable structures need to consider the suitability of the available resources (water, food, electricity, etc.). Evacuation must take into account the route, means of transport, and location of the destination, taking into account the special needs of different groups of refugees (infants, children, pregnant women, patients, and others). Availability of iodine supplements needs to be planned as well as including storage, distribution and administration methods. With reliable planning, immediate protective measures in the event of a nuclear emergency can be implemented precisely and efficiently.

RESULT AND DISCUSSION

When planning the policy formulation on nuclear preparedness, it is important to know data on total population, population density, population composition according to age and sex because each population group has different handling needs. In preparing the NPP site, the more precise demographic information is the formulation of policies that will be taken regarding infrastructure, and emergency response when an emergency occurs will be more efficiently determined because the susceptible population has been well calculated. In this study, the accuracy of the data was carried out by verifying the population data to the Central Bureau of Statistics of West Kalimantan Province.

Based on population data for 2018, the data processing and analysis results of the total population at a radius of 5 km were 5,199 people, with the largest population in Sungai Raya Village, amounting to 3,473 people and the least being Karimunting Village with 769 people. The overall population density in that radius, which is the ratio of the population to the area of the radius, is 177 people/km^2. Obtained the percentage of population male is 50.3%, and female is 49.7%. The graph of the total population by sex in 2018 in each village is shown in **Figure 2**. As seen in **Figure 2**, the number of the male population in all villages is greater than the female population, except Sungai Raya.

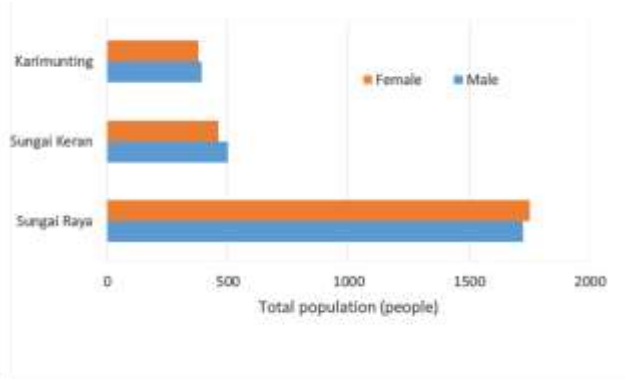

Figure 2. Total population by gender in 2018 at a radius of 5 km.

In this study, the total population by age group was divided into three groups, namely ages 0-4 years, 5-19 years, and ≥ 20 years. In 2018, based on the analysis results, it is known that the percentage of the total population by age group is dominated by the age group ≥ 20 years, which is 63.4%. Meanwhile, 29.7% are the population aged 5-19 years, and 6.9% are the population aged 0-4 years. The graph of the population by age group in each village with a radius of 5 km is shown in **Figure 3**.

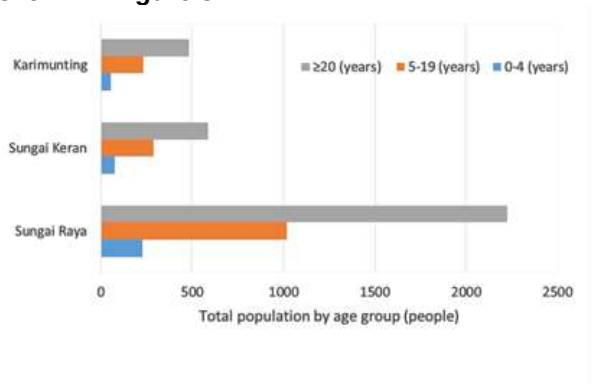

Figure 3. Total population by age group in 2018 at a radius of 5 km.

When the 20-year reactor operates in 2047 (assuming it will start operating in 2027), the projected population at a radius of 5 km is 6,523 people, in order of the largest population, namely Sungai Raya Village 4,357 people, Sungai Keran Village 1,201 people, and Karimunting Village 965 people. If it is assumed that a nuclear emergency has occurred, then the emergency response will be carried out by prioritizing susceptible populations such as infants, children, pregnant women, and patients. Evacuation of residents when there is an emergency can be done through 2 main routes, as shown in **Figure 4**.

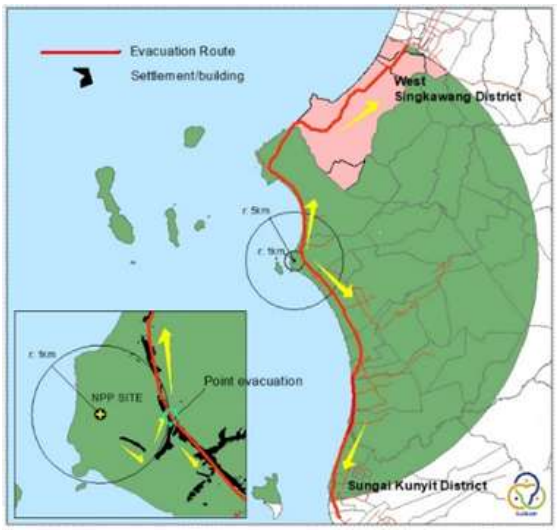

Figure 4. The main route for evacuation to sheltering.

The first route is through the South Singkawang District to the West Singkawang area, about 30 km from the NPP site, and the second route can go through the Sungai Raya District to the Sungai Kunyit area, which has a distance of about 26 km from the NPP site. This evacuation route is the national road of Singkawang City - Sei Duri, which connects Pontianak City with Singkawang City. Under normal conditions, this distance can be travelled in 45 minutes. Residents within a radius of 1 km from the NPP site can be directed to the evacuation gathering point at the meeting point between the road of Pantai Gosong and the road of Singkawang City - Sei Duri.

Sungai Raya Village, with the largest population in 2047, namely projected around 4,357 people, really needs to be concerned with the provision of bus vehicle facilities in sufficient numbers for evacuation. This is because the NPP site is in the area with the largest population density compared to the other two villages in a 5 km radius.

Various protective measures and emergency response actions to reduce stochastic effects can be [22]:

- Giving iodine tablet in the first seven days if the thyroid equivalent dose due to radioiodine exposure exceeds 50 mSv.
- Sheltering, evacuation, avoiding ingestion by limiting food, milk, drinking water, food chain, water supply, and other food commodities, contamination control, decontamination, and community assurance if the effective dose and in the fetus exceed 100 mSv in the first seven days.

CONCLUSION

Demographic information in site preparation can produce appropriate and efficient policy formulations for nuclear emergency preparedness plans because the total population and population density, as well as the susceptible population, are known. The area of the zone with a radius of 5 km is 29.4 km^2, covering the Villages of Sungai Raya, Sungai Keran, and Karimunting in Sungai Raya Kepulauan District. In 2018, the population in that radius was 5,199 people, with the largest population in Sungai Raya Village, amounting to 3,473 people and the least being Karimunting Village with 769 people. The overall population density is 177 people/km^2. The percentage of the male population is 50.3%, and female is 49.7%. The percentage of population aged ≥20 years was 63.4%, 5-19 years old was 29.7%, and aged 0-4 was 6.9%.

The projected population of a radius of 5 km in 2047 (assuming the reactor will operate in 2027) is 6,523 people. In the event of a nuclear emergency, emergency response will be implemented, prioritizing susceptible populations such as infants, children, pregnant women, and patients. Evacuation of residents can be carried out through 2 main routes, namely through the South Singkawang District to the West Singkawang area, which is about 30 km from the site and through the Sungai Raya District to the Kunyit River area, which has a distance of about 26 km from the site.

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First Author and Second Author are the main contributors who have contributed equally to this study. The third, fourth, and fifth authors are member contributors who were revising and finishing the paper.

ACKNOWLEDGMENTS

The author would like to thank the Head of Center for Nuclear Energy Systems Assessment - BATAN for providing the opportunity to conduct this research.

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