Population Mapping in the West Kalimantan Nuclear Emergency Planning Zone

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Abstract: This study aims to map the socio-economic conditions of the population of the 10-15 km radius area from the PLTN site point in Gosong Beach, Bengkayang Regency, West Kalimantan Province. This radius was chosen because it is included in the Urgent Protective action planning Zone (UPZ) area. The data collection method was carried out using the census method. This is to collect all the community's population, social and economic information in the research area. The research objects totaled 5,017 family heads and 15 Village Heads in the 10-15km radius area from the NPP site. The total population data collected was 18,690 people. The mapping results show that the 10-15 km radius area is 179.88 km^2, and the population density is 104 people/km^2. The densest population is in the northeast direction, accounting for 36.2% of the total population. Population characteristics: 67.8% of the population is more than 20 years old, males outnumber females in 9 villages, 41.8% are unemployed, 44% of the total population has a primary school degree, and 98.7% of the population has never had a severe illness. One hundred four building points can accommodate people if a nuclear emergency occurs. Increasing nuclear safety and security at a radius of 10-15 km from the point of the nuclear power plant can be done by increasing the population's education level, maintaining the population's health, increasing employment opportunities, and preparing good public service buildings.

Key-Words: population mapping, nuclear emergency planning zone, demography

1 Introduction

The plan to build a nuclear power plant (PLTN) in West Kalimantan to increase the supply of electrical energy is currently being studied, and the site location being considered is. The feasibility study related to the plan to build a prototype nuclear power plant in West Kalimantan is one of the tasks given by the government to BATAN. The feasibility study includes site and non-site studies. Regarding the site study, the coastal area of West Kalimantan has been assessed for its potential as a candidate for a nuclear power plant site. The inland coastal area includes the administrative area of the sub-district in the coastal area. Based on the collaboration that has been carried out by the Center for Nuclear Energy System Studies (PKSEN) BATAN and the West Kalimantan Provincial Government Number 298.3/SEN/RN01.01/12/2016 and 01/PK-BAPPEDA/2016 concerning the Study of Nuclear Power Plant, a candidate site has been obtained at Gosong Beach, Sungai Raya Village, Sungai Raya District, Bengkayang Regency.

Related to the nuclear power plant plan to be built in West Kalimantan is the Small Medium Reactor (SMR) type, the radius of the nuclear emergency planning zone is 5-25 km from the nuclear power plant site reference point. The planning zone is a preparation area for sheltering, environmental monitoring and implementation of immediate protective measures based on the monitoring results for several hours after the release. A nuclear emergency plan is needed to anticipate in the event of a nuclear accident. Nuclear emergency planning includes preparedness and countermeasure programmes. Nuclear preparedness is a systematic and planned activity to anticipate nuclear emergencies by providing infrastructure and capabilities for nuclear emergency response quickly,

precisely, effectively, and efficiently. Nuclear emergency countermeasures are a series of activities carried out immediately in the event of a nuclear emergency to minimise the impact on humans, property and the environment. In addition to nuclear emergencies, natural disasters such as earthquakes and floods, as well as man-made disasters such as fires that occur in the NPP site area can cause mass evacuation and or relocation, [1]. In addition, data collection is costly and time consuming, making it a less favourable indicator for safety outcomes, [2].

Therefore, one of the main requirements of the International Atomic Energy Agency (IAEA) in the establishment of nuclear power plants is to conduct a comprehensive study, especially related to safety and non-safety aspects, which endanger nuclear installations or workers, residents and the surrounding environment. Therefore, as in the construction of other nuclear power plants, the protection of the public and the environment from the impact of radioactive releases under normal operating conditions and accidents is the main target of site evaluation for the construction of Prototype NPP in West Kalimantan. The results of the study can later be used as a database in the plan to avoid or minimise unwanted things. This is part of nuclear preparedness and emergency response that is important to be carried out in the planning of nuclear power plant construction. Demographic aspect which is one of the safety aspects considered. This is related to the impact of nuclear power plants on society and the environment. Population demographics are used for risk evaluation of the surrounding community and the feasibility of implementing nuclear preparedness for the protection and health of the affected community, in the event of a nuclear accident. According to Sung et al. (2022) socio-demographic conditions are fundamental information needed to understand risk perceptions among the population so as to facilitate effective communication in tackling risks. When an accident occurs at a nuclear power plant, there will be a potential risk of radioactive release, which is distributed to the population and the environment around the nuclear power plant site. Some of the demographic data needed is related to safety behaviour, such as age, gender, education [3]–[7], marital status, poverty and employment status [5], job division and age work experience, [6]. Demographic data using age and education level is because younger age subgroups have higher levels of general response awareness and behaviour than older age subgroups regarding nuclear safety awareness, [4].

In the research of Alimah et al. (2021) has conducted demographic mapping of the population in the 0-5 km radius of the West Kalimantan NPP site. The results showed that the population density in the 5

km radius area was 177 people/km2. In 2018, the total population was 5,199 people. The percentage of male population is 50.3%, and the female population is 49.7%. The population aged ≥20 years was 63.4%, aged 5-19 years 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, emergency response considers vulnerable populations. This research aims to map the socio-economic conditions of the population in the radius of 10-15 km from the PLTN site. This radius was chosen because it is included in the Urgent Protective action planning Zone (UPZ) area. According to Kubanyi et al. (2008), the UPZ area for Reactors > 100 - 1000MW (th) is at a radius of 5-25 km.

2 Methodology

This research uses a quantitative approach. The methodology used is through literature and secondary data review, primary data collection and verification, mapping and data analysis. The research location is located in the 10-15 km radius area from the PLTN site, as shown in Fig 1.

Fig. 1. Research Location Radius 10-15 km from the NPP Site reference point

Areas included in the radius of 10 - 15 km, namely: Pagmilang, Sagatani, Sedau and Sijangkung villages in South Singkawang sub-district, Singkawang City; Sungai Jaga A, Sungai Jaga B, Sungai Pangkalan I, Sungai Pangkalan II villages in Sungai Raya sub-district, Bengkayang Regency; Capkala, Mandor and Pawangi villages in Capkala sub-district, Bengkayang Regency; Karimunting, Pulau Lemukutan, Rukma Jaya and Sungai Raya villages in Sungai Raya Islands sub-district, Bengkayang Regency.

The data collection method was conducted using the census method. This was to collect all population, social and economic information on the community in the research area. The research objects totalled 5,017 family heads and 15 Village Heads in the 10-15km radius area of the NPP site. The total population data collected was 18,690 people. The information

No	Village	Total Population (people)	Area (km²)	Population Density (people/km²)
	Kecamatan Capkala, Kabupaten Bengkayang			
1	Pawangi	843	18.00	47
2	Mandor	0	7.96	0
3	Capkala	0	0.15	0
	TOTAL	843	26.11	32
	Kecamatan Sungai Raya, Kabupaten Bengkayang			
1	Sungai Jaga A	1,040	3.09	336
2	Sungai Jaga B	1,287	3.81	338
3	Sungai Pangkalan I	1,540	6.36	242
4	Sungai Pangkalan II	3,199	11.46	279
	TOTAL	7,066	24.72	286
	Kecamatan Sungai Raya Kepulauan, Kabupaten Bengkayang			
1	Karimunting	2,156	20.19	107
2	Pulau Lemukutan	0	3.45	0
3	Rukma Jaya	0	30.50	0
4	Sungai Raya	0	9.39	0
	TOTAL	2,156	63.53	34
	Kecamatan Singkawang Selatan, Kota Singkawang			
1	Kelurahan Pangmilang	373	12.06	31
2	Kelurahan Sagatani	127	5.42	23
3	Kelurahan Sedau	7,682	31.86	241
4	Kelurahan Sijangkung	443	16.17	27
	TOTAL	**8,625**	**65.51**	**132**
	TOTAL AMOUNT	**18,690**	**179.88**	**104**

collected is population data related to: 1) population size and density; 2) population size based on radial (every 1 km radius) and sectoral (16 cardinal directions); 3) population size by age group (0-4 years, 5-19 years, and ≥ 20 years); 4) population size by sex and sex ratio; 5) population size based on livelihood, education level, and health (including facilities); 6) maximum population size in activity centres (population with special conditions) in schools, hospitals, prisons, places of worship and others. Based on the population data collected, the distribution pattern of population settlements will be determined.

3 Results and Discussion

Population data is one of the indicators in safety and security planning related to the release of nuclear power plant radioactivity into the environment, [9]. Kyne (2015) provides a warning for all relevant parties to look carefully at the problems associated with the increasing population accidentally exposed to disasters caused by nuclear power plants. For this reason, the government needs preliminary mapping data related to the population and socio-economic conditions of its population to anticipate if unwanted things happen due to the existence of nuclear power plants. Based on the survey results, the number and density of the

population in the 10-15 km radius were obtained (can be seen in table I).

Table I. Number and Density of Residents within 10-15 km Radius

The total area of the 15 villages in the 10-15 km radius is 179.88 km2 with a population of 18,690,
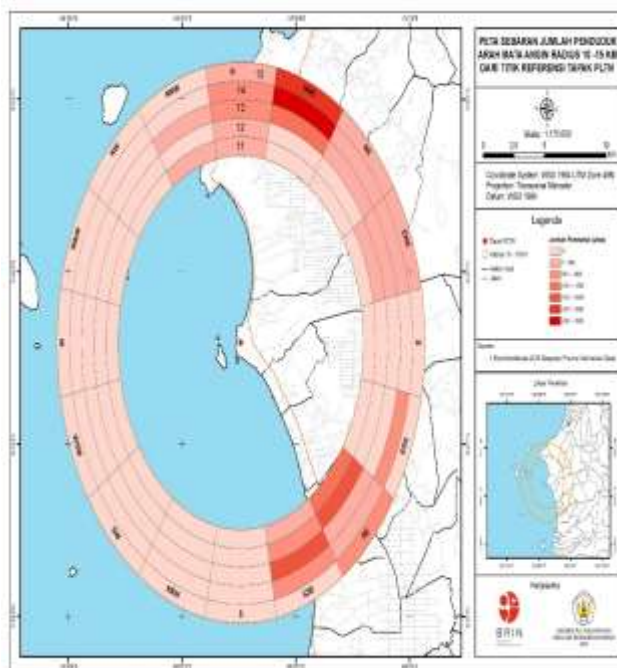
resulting in a population density of 104 people/km2. The villages of Mandor, Capkala, Pulau Lemukutan, Rukma Jaya and Sungai Raya are included in the 10-15 km radius but are not populated. The highest population density is in Sungau Raya Sub-district, Bengkayang Regency. According to Basri & Ramli (2012), densely populated areas provide better services and easier access to public facilities such as hospitals and fire brigades, transport lines, communications and electricity networks, which are considered supporting characteristics of nuclear power plants. However, densely populated areas will increase radiological risks, which will require more complicated safety measurements and emergency planning.

Fig. 2. presents a map of the population distribution of the 10-15 km radius area based on the cardinal directions. It can be seen that the densest population is located in 4 cardinal directions, namely (1) north-northeast (NNE) with 36.2% of the total population (6,759 people), (2) southeast (SE) with 21.1% of the total population (3,952 people), (3) south-southeast (SSE) with 18.2% of the total population (3,403 people), and (4) north (N) with 14.7% of the total population (2,749 people). This population data is broken down by a 1 km radius and 16 cardinal directions to illustrate density (table II).

This is useful for designing anticipatory measures if a nuclear emergency occurs.

Fig. 2. Map of Population Distribution Based on the Cardinal Direction of Radius 10-15km from the NPP Site

Table II. Population by Radius and Cardinal Direction

No	Radius (km)	N	NNE	NE	ENE	E	ESE	SE	SSE
1	11	328	0	0	0	0	0	563	0
2	12	490	0	0	5	0	0	1,481	8
3	13	919	1,413	256	12	0	0	1,662	965
4	14	692	3,270	318	255	0	0	235	1,549
5	15	320	2,076	51	108	0	554	11	881
	Total	2,749	6,759	625	380	0	554	3,952	3,403

No	Radius (km)	S	SSW	SW	WSW	W	WNW	NW	NNW
1	11	0	0	0	0	0	0	0	231
2	12	0	0	0	0	0	0	0	0
3	13	0	0	0	0	0	0	0	37
4	14	0	0	0	0	0	0	0	0
5	15	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	268

The next population mapping is related to the number of residents by age group. Based on Table 3, the population of the 10-15km radius area based on age consists of 67.8% of residents aged more than equal to 20 years, 27.4% of residents aged 5-19 years, and 4.8% of residents aged 0-4 years. Mapping the population by age and gender is necessary to determine evacuation behaviour in the event of a nuclear emergency. Based on research by Morita et al. (2018), demographic factors that choose to stay when there is a nuclear disaster are male, 40-64 years old, living with parents, and living alone, while people who are ready to voluntarily evacuate are female, less than 20 years old, and live with children. Furthermore, Miyawaki & Sasaoka (2017) states that women feel more anxious than men about potential nuclear accidents. Overall, women also have higher risk perceptions regarding radiation exposure, food consumption, and medication for their children [12].

Table III. Population by Age Group at 10-15 km Radius

No	Village	Total Population (people)			
		0-4	5-19	≥20	Total
Kecamatan Capkala, Kabupaten Bengkayang					
1	Pawangi	91	267	485	843
	TOTAL	91	267	485	843
Kecamatan Sungai Raya, Kabupaten Bengkayang					
1	Sungai Jaga A	76	321	643	1.040
2	Sungai Jaga B	65	377	845	1,287
3	Sungai Pangkalan I	89	426	1,025	1,540
4	Sungai Pangkalan II	181	845	2,173	3,199
	TOTAL	411	1,969	4,686	7,066
Kecamatan Sungai Raya Kepulauan, Kabupaten Bengkayang					
1	Karimunting	167	611	1,378	2,156
	TOTAL	167	611	1,378	2,156
Kecamatan Singkawang Selatan, Kota Singkawang					

1	Kelurahan Pangmilang	17	119	237	373
2	Kelurahan Sagatani	7	42	78	127
3	Kelurahan Sedau	184	1,978	5,520	7,682
4	Kelurahan Sijangkung	27	136	280	443
	TOTAL	235	2,275	6,115	8,625
	TOTAL AMOUNT	904	5,122	12,664	18,690

In Fig. 3, we can see the total population by sex. The sex ratio is the ratio of the male population to the female population of an area and at a certain time, usually expressed as the number of male residents per 100 female residents [13]. In Figure 3, it is evident that 9 villages in the 10-15 km radius area have a sex ratio value above 100, meaning that the male population outnumbers the female population. These villages are Pawangi, Sungai Jaga A, Sungai Pangkalan I, Sungai Pangkalan II, Karimunting, Kelurahan Pangmilang, Kelurahan Sagatani, Kelurahan Sedau, Kelurahan Sijangkung. The sex ratio for Sungai Jaga B village is 95, meaning that the female population is greater than the male population.
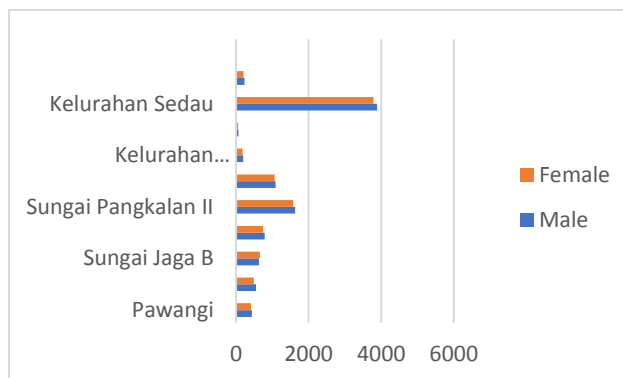

Fig. 3. Total Population by Sex and Sex Ratio in the Radius Area 10-15 km from the NPP Site

The next mapping of the population is based on the type of occupation where the occupation of the population is categorised into eleven (11), namely: 1. civil servant/TNI/POLRI; 2. civil servant/TNI/POLRI retiree; 3. honorary worker; 4. private employee; 5. self-employed; 6. farmer; 7. fisherman; 8. labourer; 9. Other; 10. Not working; 11. taking care of the household. The mapping results illustrate that the occupations of residents within a radius of 10-15 km from the PLTN site are 23.8% self-employed, 21% taking care of households, 6% farmers, 2.1% labourers, 1.8% private employees, 1.4% civil servants / TNI / Police, 1.1% fishermen, 0.4% others, 0.3% retired civil servants / TNI / Police, 0.3% honorary workers. Based on the results of the census, 41.8% were unemployed. The large number of people in this category is due to the fact that the population is still of school age, elderly, and unemployed. According to Lei et al. (2013), people who do not

work in public services, low income, have a bachelor's degree or higher and who live closer to nuclear power plants are more sensitive groups, whereas employees or self-employed people are more vulnerable groups when an accident disaster occurs. In the case of the Spanish Nuclear Power Plants (SNPP), unequal labour conditions in terms of contract stability, wages or the nature of the work performed can also determine differences in perceptions of safety culture, [15].
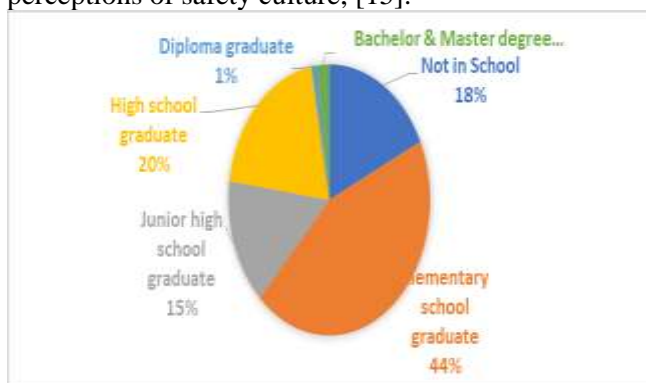

Fig. 4. Total Population by Education Level

Table IV. Total Population by Type of Occupation

No	Village	Type of Occupation											
		1	2	3	4	5	6	7	8	9	10	11	People
	Kecamatan Capkala, Kabupaten Bengkayang												
1	Pawangi	8	4	3	29	50	118	4	98	6	387	136	843
	TOTAL	8	4	3	29	50	118	4	98	6	387	136	843
	Kecamatan Sungai Raya, Kabupaten Bengkayang												
1	Sungai Jaga A	7	3	6	22	73	106	42	97	1	498	185	1,040
2	Sungai Jaga B	29	9	9	14	252	85	30	6	3	580	270	1,287
3	Sungai Pangkalan I	47	4	3	12	316	168	23	12	6	650	299	1,540
4	Sungai Pangkalan II	47	10	9	62	719	236	47	29	10	1,354	676	3,199
	TOTAL	130	26	27	110	1,360	595	142	144	20	3,082	1,430	7,066
	Kecamatan Sungai Raya Kepulauan, Kabupaten Bengkayang												
1	Karimunting	14	3	6	9	644	93	24	16	6	906	435	2,156
	TOTAL	14	3	6	9	644	93	24	16	6	906	435	2,156
	Kecamatan Singkawang Selatan, Kota Singkawang												
1	Kelurahan Pangmilang	2	0	0	1	58	54	4	1	1	167	85	373
2	Kelurahan Sagatani	0	0	1	9	14	12	0	1	0	60	30	127
3	Kelurahan Sedau	100	14	12	175	2,256	217	8	118	30	3,033	1,719	7,682
4	Kelurahan Sijangkung	5	0	0	3	63	35	27	19	12	185	94	443
	TOTAL	107	14	13	188	2,391	318	39	139	43	3,445	1,928	8,625
	TOTAL AMOUNT	259	47	49	336	4,445	1,124	209	397	75	7,820	3,929	18,690

In Fig. 4, the population is mapped based on the level of education. According to Yan & Lu (2018), the higher the level of education is a good basis for evaluating the sense of nuclear safety and security in society. Based on the results of the census conducted, in the 10-15 km radius area from the nuclear power plant point, the number of residents who graduated from the diploma level was around 1% of the total population of 170 people. Residents who get bachelor and master degrees are around 2% of the population or around 359 people. The largest

population education is elementary school graduates at 44% of the total population or around 8,263 people, while the population with junior high school education is only 15% and high school level 20%.

Further mapping of the population based on the type of disease suffered by the population and health facilities is important. Safety in nuclear power plants is closely related to public health, [17]. According to Morita et al. (2018), mass evacuation may also adversely affect the functioning of the health system in the local community or people in the affected area (e.g. disruption in the delivery of healthcare and other public health services), which in turn may expose those who remain in place to other disease risks. There are other aspects that need to be considered to evaluate the risk to public health, namely that not all people exposed to radiation are affected equally and radiation from internal emitters is in a sense different from external beam radiation, where external beam radiation only exists as long as the radiation source exists, [18].

The condition of health facilities in the 10-15 km radius area from the nuclear power plant point consists of Puskesmas in Sedau Village, Nani Maryani Clinic in Sungai Pangkalan II Village, Posyandu in Sungai Pangkalan II Village, and Puskesmas Pembantu in Sungai Pangkalan II Village. The top 10 diseases suffered by the population are high blood pressure (45 people), diabetes (38 people), cholesterol (20 people), stroke (19 people), asthma (16 people), heart disease (15 people), ulcer (14 people), rheumatism (11 people), gout (8 people), and complications (6 people). The condition of public health in the 10-15 km radius area from the PLTN point can be said to be good because 98.7% of the population (18,437 people out of a total population of 18,690 people) are in good health and have never suffered from serious illnesses.
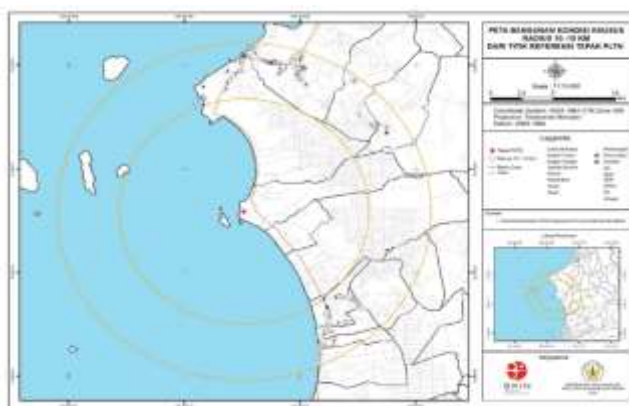

Figure 5: Map of Special Condition Buildings 10-15 km Radius from the NPP Site

This study also mapped the maximum number of residents that can be accommodated at the population

activity centre. This mapping is important to ensure places that can be used as temporary places for evacuation in the event of a nuclear emergency. Based on the census results, there are 104 building points that can accommodate the community with details of 36 Muslim places of worship, 4 Christian places of worship, 12 Chinese places of worship, 11 tourist attractions, 13 offices, 3 PAUD / TK, 14 elementary schools, 5 junior high schools, 1 vocational school, 1 Islamic boarding school, and 4 health service centres. The distribution of these building locations can be seen in Fig. 5.

4 Conclusion

Improving nuclear safety and security at a radius of 10-15 km from the PLTN point can be done by increasing the education level of the population, maintaining the health of the population, increasing employment opportunities, and preparing good public service buildings. The education level of the population needs to be increased because it will affect the mindset related to safety and help the evacuation process. A well-educated population also increases the absorption of the population to work or create jobs. Improvements in the world of work make it easier for the population to be evacuated in the event of a nuclear emergency. Evacuation centres also need to be prepared both in terms of building structure and infrastructure access to public services. This is an anticipation that can be done for nuclear emergency planning.

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