

SITE SELECTION FOR NUCLEAR POWER PLANT IN MERSING, JOHOR

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Abstract. Nuclear power is considered as energy source option for future power generation in the National New Energy Policy 2010. The first nuclear power plant (NPP) construction is expected to start at 2017, and officially operated in 2025. This paper aims to propose possible candidate site areas for NPP in Mersing District, Johor. The evaluation uses the Atomic Energy Licensing Board (AELB) guideline documents as main reference, supported by regulation documents from International Atomic Energy Agency (IAEA). 4 safety parameters are used in the assessment – geological characteristic, air dispersion (meteorological) analysis, population data and safety characteristics. This study ranked 4 proposed areas possible candidate site area for NPP in Mersing district.

Keywords Nuclear power plant; candidate site area; Mersing District

1.0 INTRODUCTION

Due to the need for secured future energy supply, Malaysia has decided to include nuclear energy in the new energy policy 2010. Feasibility studies have started since then and commissioning steps had been undertaken slowly and carefully by related organization such as Tenaga Nasional Berhad (TNB), Atomic Energy Licensing Board (AELB) and Malaysian Nuclear Agency (MNA). The first nuclear power plant (NPP) construction is expected to start in 2017 and ready to operate by 2025.

Malaysia has no experience nuclear energy generation. Hence, the feasibility studies were prudently undertaken according to international regulation and standard. AELB, as a regulatory body for nuclear and radiation facilities and activities has been revising and upgrading related act to assist the commissioning process. In March 2011, AELB has published the nuclear power plant site selection guideline to determine a suitable site for NPP [1].

Since nuclear energy is new in Malaysia, various issues and challenges are inevitable, especially issues related to nuclear safety. Public sentiments are not supportive towards nuclear energy due to global nuclear events such as Chernobyl and Fukushima accident and other incidents related to nuclear reactors. Other reasons are basically fear and prejudice towards radioactive material safety issues, and limited information on nuclear related activities and its development in Malaysia. However, negative sentiments toward nuclear could possibly be changed with transparent and detailed information regarding the above matters [2].

One of preliminary steps in commissioning NPP is the proposal of candidate site. Selecting a site for nuclear power plant requires consideration in various aspects such as engineering features for the plant, transportation, safety management and emergency measurement [3]. Apart from the requirement for the power plant itself, other crucial consideration is the impact to the environment, economy and social at the surrounding area [3]. This paper tries to find candidate areas for NPP construction in accordance with safety requirements by AELB siting guideline and IAEA standards.

2.0 STUDY PARAMETERS

The main objective in NPP site selection is to achieve safety requirement regulated by IAEA. In AELB siting guideline, it stated that a candidate site is considered acceptable if the site characteristics are such that the consequences of potential accident would be at acceptable limits [1].

Based on the criteria stated in the guideline, we choose 4 safety characteristics as study parameters to propose a suitable site for NPP. The parameters are: geological and seismological characteristics, meteorological characteristics, population distribution and safety characteristics.

The safety characteristics consist of determination of safety zones and emergency infrastructure for NPP from estimated radioactive dispersion in a postulated nuclear accident. This study used 'selection-by-observation' method and simple safety analysis for the proposed candidate sites.

3.0 STUDY AREA

This study chooses Mersing district as study area for NPP site selection in Johor State. Mersing is located 136 km north east of the state capital Johor Bahru. The total area is 2,839 km² with total population of 70,894 in 2010 population census. The study area covers a distance of 10 km towards the inland from the beach along the coastline of the district. From the total area, 4 areas were chosen and labelled as possible candidate sites, and are illustrated in figure below:

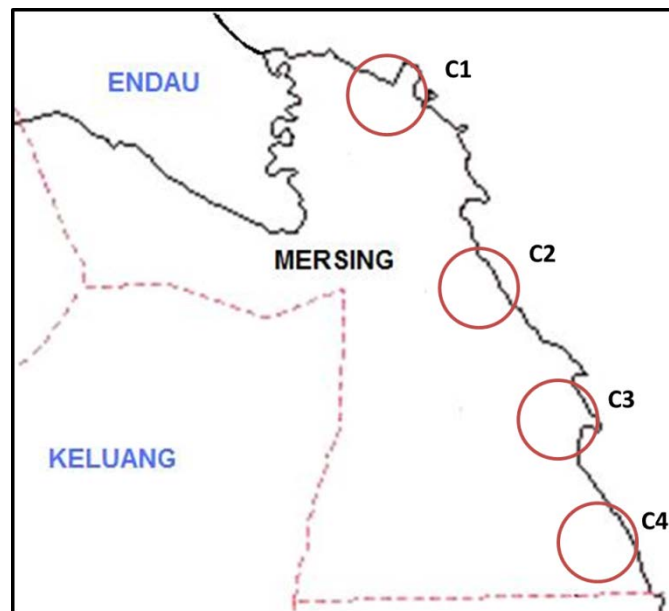


Figure 1 – Possible candidate sites

4.0 METHODOLOGY

In this study, general steps of site selection are as follows:

- i. Listing of mandatory and rejection criteria with reference to AELB guideline [1].
- ii. Marking the area of interest and possible candidate areas.
- iii. Determination of safety requirements and safety zones.
- iv. Data analysis and site mapping.
- v. Final selection of candidate sites.

Mandatory criteria and rejection criteria were listed and the areas are marked using MapInfo Professional software. Mandatory criteria for NPP in Malaysia were listed in a study by Tenaga Nasional Berhad (TNB), stating that the NPP sites must be located along coastal area, and next to large water body to meet the NPP cooling requirements [4]. Rejected area involves critical safety issues such as areas with high security risks, hazardous areas and densely populated areas. These areas are deemed unsuitable for NPP site as discussed in IAEA safety requirement for NPP [3]. Areas other than rejection areas are presumed as possible candidate areas. These areas were analyzed accordingly based on the above chosen study parameters.

For each study parameters, priority ranks were given to the sites based on observation of their fulfillment in safety requirements and deterrence from potential radiological risks. Higher rank will be given to the site that fulfills safety requirements or has low possible risks. Site with the highest priorities will be considered as the best candidate site for the chosen parameters in AELB guideline for NPP site selection. The priority ranking is as follows;

Table 4.1: Priority Ranking

Priority Rank	Details
1	Site fulfill safety requirements
2	Site have minimal safety risks
3	Site have high safety risks
4	Site cannot fulfill safety requirements

5.0 PARAMETER ANALYSIS AND OBSERVATION

Since the study area is limited to 1 district, there are no major differences in the physical comparison of seismic events, geological features, and meteorological behaviors between candidate sites. On the other hand, population distribution data and emergency support observation shows more significant difference between each candidate, which became the key point to differentiate their quality in the selection process.

In terms of seismic events, Mersing has low possibilities of earthquake since it did not lie on the Pacific Ring of Fire. However, certain places in Mersing did felt the effect from high magnitude earthquake from neighboring country, especially Indonesia. There are only several events recorded by Malaysian Meteorological Department stating felt earthquake events in Mersing as stated in their monthly report from the year 2007 [5]. This record depicts that risks from earthquake events are very small. However, the data must be updated regularly to ensure all possible risks from such events stays low and manageable throughout the NPP operation [2].

Meanwhile, geological formations at Mersing are mostly Quaternary and Jurassic, while granitic rocks could be found in the inner land. Areas with these formations are usually stable in

the flat ground areas and became more unstable towards higher grounds, depending on the type of soil in the area. Most areas in Mersing consist of some granite rocks and limestone's areas, peat soils areas, solid sand areas and mangrove swamps at the coastal lines. Although all candidate sites generally lie on stable ground, there are small relatively unstable areas in the undulating region which has soft soil buildup, which can cause surface faulting. Those areas are mostly marked as very unstable area or unstable area as stated in the surface stability map published by Malaysian Department of Geosciences and Mineral [6].

Meteorological behaviors in Mersing depend on the monsoon season throughout the year. According to wind speed report for the year 2009 until mid-2011 by Malaysian Meteorological Department [7], the average wind speed in Mersing is 1.6 to 3.3 m s⁻¹. The maximum wind speed occurs during Northeast Monsoon from November until March. During monsoon, the wind speed will increase to the ranges of 5.5 to 7.9 m s⁻¹. From this data, we did a simple analysis using HotSpot Software to observe radioactive dispersion from a postulated radiological event in the candidate area. Since the wind direction and speed changed with the monsoon throughout the year, the analysis is important to determine estimated dose for surrounding population in the area. The result will be discussed in the next part of this paper.

Consideration of population distribution and its density is one of safety requirement in NPP site selection. Population data is one of important indicator in safety and emergency planning. Present detailed map for population distribution in Malaysia was not yet published by Department of Statistics Malaysia from the 2010 population census. However, the distribution can be roughly predicted based on population trend in Malaysia, where most people concentrates in or surrounding area of main city, plantation area, and industrial area [2]. This study rejects the most populated area in the area of interest. According to a study from India, areas with more than 25,000 people are considered highly populated, hence rejected as suitable candidate area [8].

Safety support observation consists of dividing safety zones in the area of interests. Safety zones are the area around the candidate site, divided to several zones for safety purposes and emergency planning for the NPP sites. Basically, there are 4 zones in NPP site selection [8]:

- a. Exclusion zone where the NPP facilities are located. Settlements are prohibited in this area
- b. Sterilized zone or low population zone. Settlements are controlled with population less than 10,000 people
- c. Emergency planning zone. Emergency supports are best located in this zone with population less than 25,000 people.
- d. Outer zone.

For Malaysia, AELB suggested exclusion zone and low population zone as the basic requirement for safety zoning in a candidate site [1]. The zone size and boundary is not

specifically regulated by AELB, but refers to the sizing guidance provided by United States Nuclear Regulatory Commission (USNRC).

In this study, the size of exclusion zone is determined by the simulation of radioactive air dispersion during radiological incident. The distance is calculated based on AELB description of exclusion zone in, which it is an area of such size that an individual located at any point outside this zone within two hour immediately following the onset of the postulated fission product release shall not receive a total radiation dose to the whole body in excess of 250 mSv or total radiation dose in excess of 3 Sv to the thyroid from iodine exposure [1].

Meanwhile, the low population zone (LPZ) is the area immediately beyond the exclusion zone. In the guideline, AELB stated that simple determination of LPZ size is by fulfilling the requirement where distance to the boundary of the nearest densely populated center shall be one and one-third times the distance from the NPP to outer boundary of the low population zone [1]. The size of LPZ was calculated using this statement and the result is discussed later. Figure 5.1 below illustrates the dimension of LPZ according to the requirement [2].

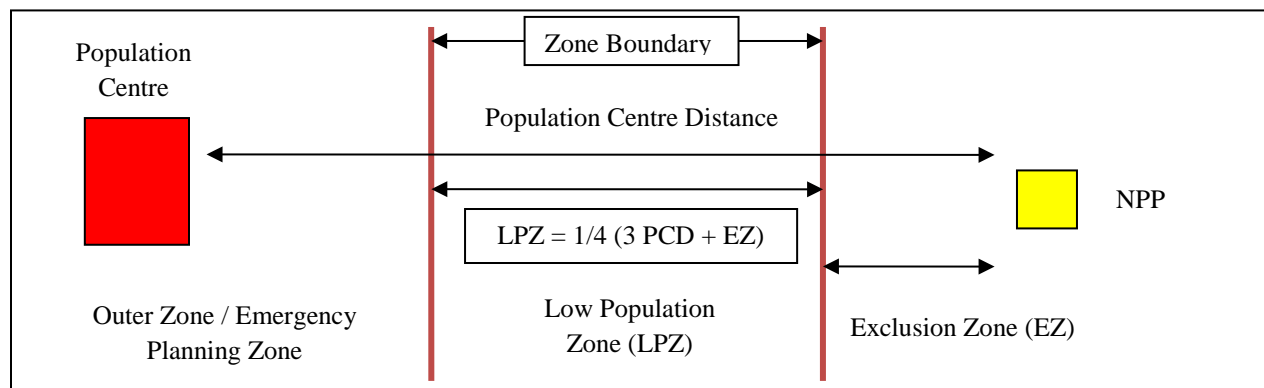


Figure 5.1: An Impression of Safety Zones Dimension and LPZ Calculation

Other than safety zones, infrastructures around the site is also observed as component of safety support and emergency planning for NPP. For example, hospital and fire station are important as emergency aid during radiological emergency. Military support can hasten evacuation, hence reduce fatalities and exposure to the public [8]. Other than that, transportation network, communication access, and electricity grid is also taken into consideration in the observation.

6.0 RESULT

6.1 Air Dispersion Simulation using Meteorological Data

Radioactive dispersion simulation is commonly used in probabilistic risk assessment to predict dose distribution in an emergency event. This kind of simulation is conducted in the site

selection phase with purpose of providing reference data during operation and to plan emergency measurement for the NPP and the surrounding area.

As stated in the above section, a simple simulation was conducted to observe radioactive dispersion from a postulated radiological event in the candidate area. Average minimum (2.0 m s^{-1}) and maximum wind speed (7.0 m s^{-1}) were used to simulate the contamination distance and the speed of radioactive material dispersion. The result is shown in the figures below.

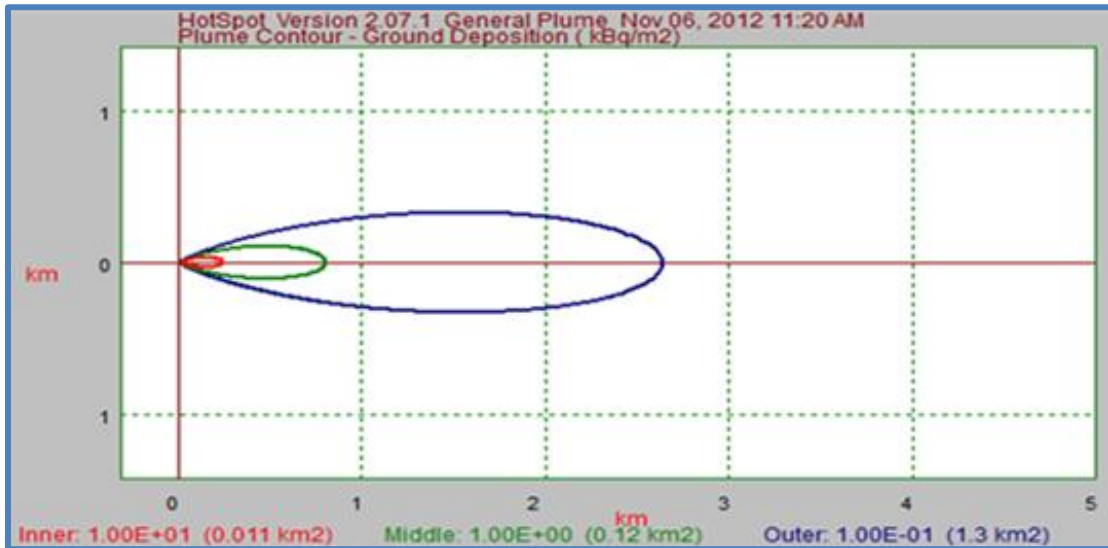


Figure 6.1: Ground deposition at minimum wind speed (2.0 m s^{-1})

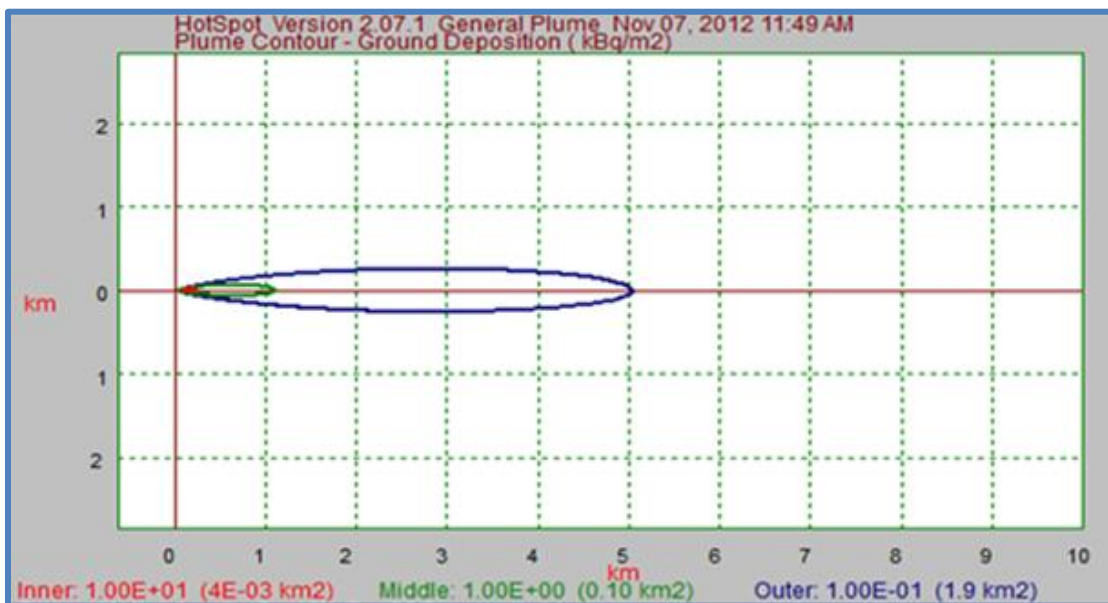


Figure 6.2: Ground deposition at minimum wind speed (7.0 m s^{-1})

The result shows that the area and distance of radioactive deposition is related to wind velocity. Higher value of wind speed results in a farther dispersion distance and larger contaminated area. In the simulation, the contaminated area spans to 80 km away from the plume's origin in less than 24 hours. At wind speed of 7.0 m s^{-1} , the dispersion arrived at about 80 km distance in 3 hours. However, at this distance, the estimated dose rates are smaller and did not exceed the dose limit regulated by IAEA.

6.2 Determination of Safety Zone

The simulation for the exclusion zone size refers to the radioactive release event equivalent to Fukushima incident in 2011. The size is measured from the dispersion origin to the point where the estimated effective dose is less than 0.25 Sv in 2 hours sampling time. The result of simulation in all candidate sites gave the range to be in between 0.7 to 1.0 km, depending on the non-monsoon and monsoon average wind speed in the area.

For LPZ calculation, the size differs with the distance of candidate sites with the nearest high population center, which is commonly the nearest town in the area. The nearest town is Mersing city with population number more than 30,000 people and population density of more than 300 people per kilometer square. Based on their distance from the town center, the LPZ was calculated using the formula stated in Figure 5.1. The result is shown in the table below.

Table 6.1: Low Population Zone

Candidate site	Estimated Coordinate	Distance from Mersing City (km)	LPZ size (km)
CS1	2°37'54'' N 103°44'18''E	24.6	18.7
CS2	2°21'56'' N 103°53'32''E	9.4	7.3
CS3	2°14'51'' N 103°57'14''E	23.6	18.0
CS4	2°10'05'' N 103°59'06''E	33.1	25.1

6.3 Site Ranking Result

The site evaluation process was done using priority ranking and are tabulated in Table 6.2;

Table 6.2: Candidate Site Ranking by Parameters

Parameters	Candidate Site Mark			
	CS1	CS2	CS3	CS4
Geology and Seismicity Characteristics	4	3	2	1
Meteorological Data and Atmospheric Dispersion Simulation	1*			
Population Consideration				
➤ Population number	3	4	2	1
➤ Distance from population center	2	4	3	1

Safety Zones

➤ Low Population Zone	2	4	3	1
➤ Infrastructure for Emergency Plan	2	1	3	4

*All sites is ranked as number 1 due to same meteorological behavior and simulation result

7.0 DISCUSSION

All sites chosen in this study has promising potential as NPP sites. However, they have different qualities in the safety characteristics / parameters as proposed in the AELB guideline for site selection in Malaysia. From the site evaluation, the sites were ranked and CS3 and CS4 are proposed as potential candidate site for NPP in Mersing district.

Site number CS3 and CS4 have nearly same characteristics in the ranking process. Both sites have 3,000 to 5,000 people and located far from population center, giving easier consideration for safety measurement and emergency planning. The only disadvantage of the area is the poor access to the main road and electricity grid because the area is far from the main city and has low population density.

Although both locations is slowly developed than other area, nearest safety supports such as hospital, fire station and military base still lies in a suitable distance for emergency planning. Hospital is essential emergency support to provide emergency aid to the NPP during radiological emergency. However, hospitals are also considered as avoidance entity in safety planning for NPP. Having a hospital close to NPP is risky, but is needed in emergency planning. Military bases are also important to be included in the site selection process. Military presence ensures security to the NPP facilities from events that may threaten nation's safety and security related to nuclear power plant. During radiological events, military support can hasten evacuation; hence reduce fatalities and exposure to the public [2]. However, since military base usually have weaponry and explosives, it is too risky to be placed nearby NPP to prevent catastrophic events such as explosions or sabotage to the NPP. Hence, it is suggested that the best location for a hospital and military base is close to outer boundary inside the low population zone, or at the boundary of emergency planning zone.

The only difference between CS3 and CS4 evaluation is in the safety evaluation. The location of emergency support infrastructure is the best in CS3, where the hospital, fire station and military base were located just outside the LPZ boundary. However, CS4 is also acceptable if the transportation route is upgraded to a level which emergency measurement can be executed without problem.

Site number CS1 and CS2 have several critical issues that may lead to it rejection as suitable candidate sites. CS1 lies on unstable area, where surface faulting event is likely occurred. Although CS1 is far from the nearby city and has acceptable LPZ size, the site itself

prone to cause safety risks to the NPP. Meanwhile, CS2 is too close to Mersing city, and the LPZ calculation shows that the size is unacceptable. Moreover, the area already has large number of population, which did not comply with low population zone requirements. Other issues are both sites are located close to hazardous areas and protected areas such as large fresh water reservoir which added to the list of safety risks from the environment to the NPP. If radiological emergency is to occur during NPP operation, large number of people will be affected at CS2, and protected area will be affected at CS1. An efficient emergency measurement is crucial to ensure risks from the NPP remained low to the surrounding population in this state.

Despite of the above problems, locating a site in both areas (CS1 and CS2) has its own advantage. Transportation routes and communication network is very good, and the electricity grid will be much closer to the plant. Since it closer to the nearby town, the infrastructure is better in comparison to the other areas (CS3 and CS4). Safety support such as hospital, military base and fire station can be included easily in the emergency plan. However, the location may be too close to the NPP, which has its own safety risks towards the NPP. Ultimately, we concluded that both CS1 and CS2 have high risks from the NPP to the surrounding area and vice versa. If the risks can be lowered, the sites can be reconsidered as possible candidate site for NPP.

8.0 CONCLUSION

We conclude that site number CS3 is the most suitable for NPP in Mersing district. The site has stable geological and seismological characteristics, which provide stable ground for NPP foundation. Simulation shows that the postulated radiological dispersion dose is acceptable when it reach Mersing after first 2 hour from the release time. CS3 also has the best safety support distance where the hospital, fire station and military base are located in the emergency planning zone, close to outer boundary of LPZ zone.

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