Analysis of how earthquakes in California can affect nuclear power plants which can affect the population in the region

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ABSTRACT

California is one of the most earthquake-prone regions in the US. The region has several fault lines that may cause earthquakes. Initially, California had six working nuclear reactors-Diablo Canyon Nuclear Power Plant, Humboldt Bay Nuclear Power Plant, The San Onofre Nuclear Generating Station, The Rancho Seco Nuclear Power Plant, The Vallecitos Nuclear Power Plant and the other one: The Santa Susana Sodium Reactor was just an experimental reactor to perform initial experiments (considered US's first nuclear reactor) to generate nuclear power, out of which only one is currently in use[1]. Five nuclear reactors have been shut down of which The San Onofre Nuclear Generating Station was recently shut down. Currently, only one nuclear plant is functional- Diablo Canyon. So my research is on Diablo Canyon Nuclear Power Plant. This can be dangerous if it lies in a fault line region and causes huge catastrophes like the one that happened in the Fukushima plant in 2011 killing hundreds of people after a powerful earthquake that struck the place and destroyed the nuclear power plant that led to the release of radioactive substance into the atmosphere.

KEYWORDS

Bay area, Earthquakes, Nuclear Plants, Spatial Analysis

1 Goals(s) and Objective(s)

The main goal of this project is a) do a case study reports on Fukushima and Chernobyl nuclear disasters and understand how it affected people close the plant b) to determine if the nuclear plant is located in any of California's fault line region, c) to determine how the population of that region can be affected, for example- in terms of population involving more of the younger generation(ages between 15 and 35), nuclear materials might affect their DNA(causing repair) and might affect future generations as well [2]. In terms of population involving elderly people (ages between 70 to 85 years or over), evacuation might get a little difficult if a lot of older people live within the affected radius. d) What are the other effects of radioactive radiation and what measures could be taken in such a situation? Additionally, I will be analyzing Chernobyl nuclear disaster dataset to determine the distance up to which the radiation spread in Chernobyl's case to show how far radiation might spread during a nuclear disaster.

2 Peer-reviewed Literature

The Great East Japan earthquake that occurred in 2011 was estimated to be a 9.0 magnitude earthquake that caused damage to the electric supplied in Fukushima nuclear site which in turn resulted in a failure of cooling agents present in a reactor. This caused a rupture of the plant releasing a huge amount of radioactive substances into the atmosphere, thus killing more than 15000 people [3]. There were about 30000 people within 272 sq. km area (closer to the plants) in Fukushima and about 52000 people within 495 sq. km area [4]. This was the case in a small town in Japan and Japan has a population less than that of the USA. Moreover, the radiation has a long-term effect as it contaminates the soil for many years like the contamination in Chernobyl [4].

3 Methodology

3.1 Objective 1: I conducted a case study on the Chernobyl and Fukushima nuclear disaster reports in order to get a detailed idea about the aftermath of a nuclear disaster.

The dangerous materials let out during a nuclear disaster are- Plutonium and Cesium that can affect a human body and alter its DNA. Moreover, the effects are so severe that it might cause different types of cancer and different type of diseases. The Chernobyl incident happened in 1986 and even now generations have been suffering from limb misplacement, handicapped, etc. The radiation effect was so worse that Chernobyl is inhabitable even today. The radiation still exists around the place even today after 34 years since the disaster occurred. The effect on the population after the incident until now has been severe and includes: deformation of legs, eye; unnatural growing of eyes; hydrocephalus(deformation of the head, face, hands, and legs); negative effect of brain development (abnormal mental condition); and growth rate of plants was decreased [5]. About 100,000 people were evacuated 30 km away from the plant.

On the other hand, the effects and damage made by the Fukushima nuclear disaster are much smaller than the damage made by the Chernobyl nuclear plant. During the time of the explosion, the evacuation radius was only 2 km from the plant. But as things started getting worse and as the plant kept releasing nuclear radiations the evacuation zone was extended to 10 km and later to 20 km for safety purposes. Infants exposed to these radiations are expected to have a 7% increase in chances to have Leukemia and a 6% chance to develop breast cancer in the future. The worst part is, the chances to develop thyroid cancer were 70(increased chances after the incident) more for females exposed as children [6].

So I chose the Fukushima incident as it was the effects of the aftermath of an earthquake and tsunami and I chose the Chernobyl incident to show the worst effects of a nuclear disaster. There is now an idea of what a nuclear disaster can do to the people around it.

URL: https://link.springer.com/chapter/10.1007/978-981-13-8218-5_20

URL: https://archive-ouverte.unige.ch/unige:122532

3.2 Objective 2: I used California's fault line shape dataset to determine if the Diablo Canyon nuclear power plant lies in any of California's fault line regions to make sure if the research is fair to be conducted.

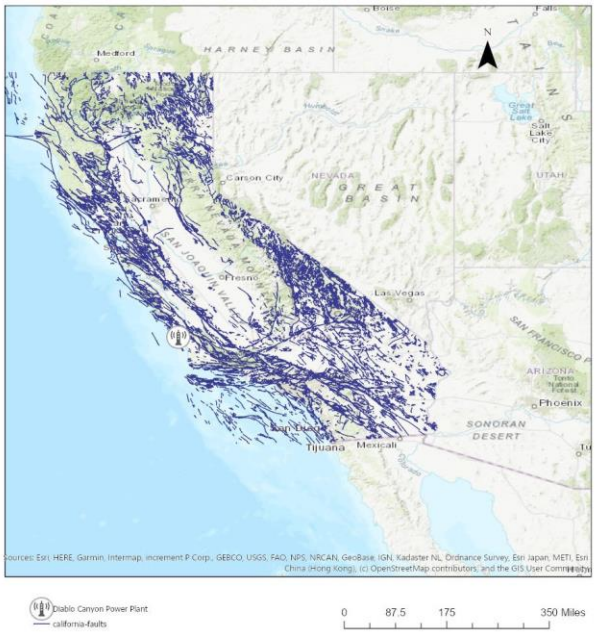

Figure 1: Fault lines of California

After analyzing the fault line data set it was clear that the Diablo Canyon plant lies near the fault lines of California. As you can see in Figure 1, the nuclear plant lies in the fault line region. This means this region is prone to an earthquake and the aftermath can be dangerous. Although the plant has survived an earthquake of magnitude 7.2 recently [7], we never know what might happen tomorrow and the plant hasn't seen an earthquake like the one in Fukushima (magnitude: 9).

3.3 Objective 3: Now that it is clear from Figure 1 that the plant lies in the fault line region of California, it will be useful to proceed with the research. In order to determine how the population in this region can be affected, I acquired and analyzed data from different sources.

URL: https://data.census.gov/cedsci/

URL:https://www.arcgis.com/home/item.html?id=062d4ea518174021b3520b88dd4270d7

The data did not have the total population for ages 5 or less and ages between 5 and 10 or less but the data had populations of ages 5 or less and population for ages between 5 and 10 for males and females separately. So I used the custom field in symbolization and I used the sum function to calculate the population that I needed(between 5 and 34).

3.4 Objective 4: I used the Buffer tool to create an evacuation zone- a 20 km radius away from the plant. This distance is based on the case study on the Fukushima incident as the people were evacuated 20 km away from the plant. Again, this distance is just based on the case history and the disaster was a level 7 nuclear disaster.

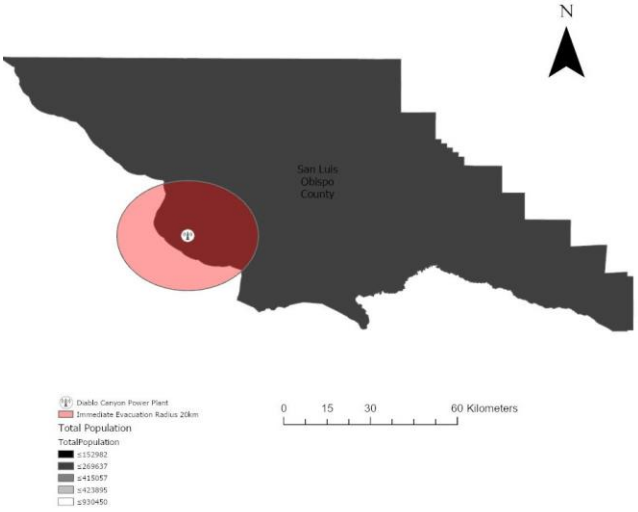

Figure 2: Evacuation Zone

I used a 'distance band from neighbor count' tool to calculate the extent to which the radiation might spread. To approximately calculate this I used the Chernobyl radiation spread data and used the distance tool to calculate how far the radiation spread after the Chernobyl incident. It was clear that dangerous materials like Plutonium and Cesium had spread across 300 km away from the plant. However, other less dangerous chemicals had also spread across a distance of 20000 sq. km. across Ukraine.

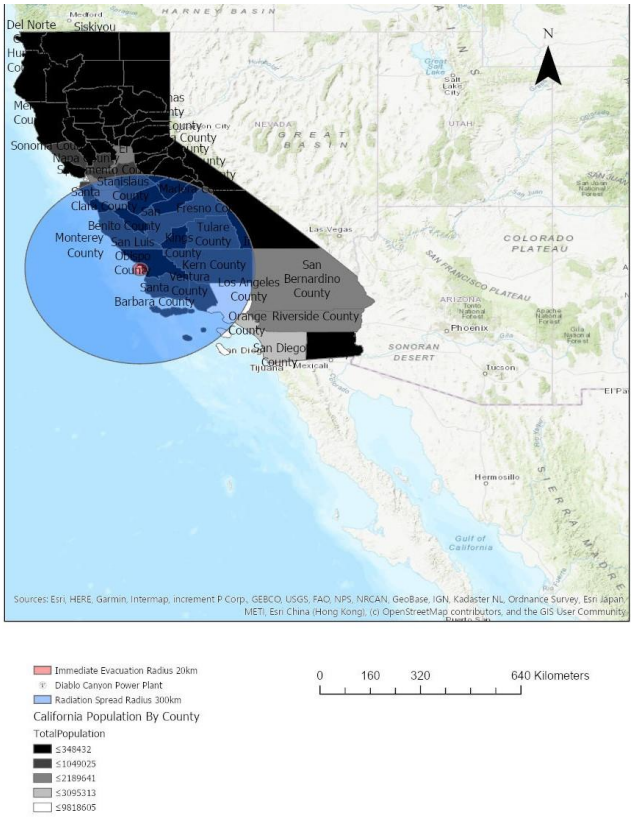

Figure 3: Radiation Spread across the state

URL:https://data-package.ceh.ac.uk/data/782ec845-2135-4698-8881-b38823e533bf.zip

4 Final Results

As we have seen in the case study, the Chernobyl incident had a large effect on the population around the place. The radiations have short term effects and long term effects based on the level of radiation the body is exposed to. Short terms effects can be the development of a tumor and long term effects can be the ones affecting different generations with abnormality or diseases.

4.1 Population group of ages between 5 years and 34 years: I am analyzing the population of ages between 5 and 34 as this part of the population includes a lot of the younger generation and their exposure to the nuclear radiations might affect generations after generations as the radiations are harmful on a long term

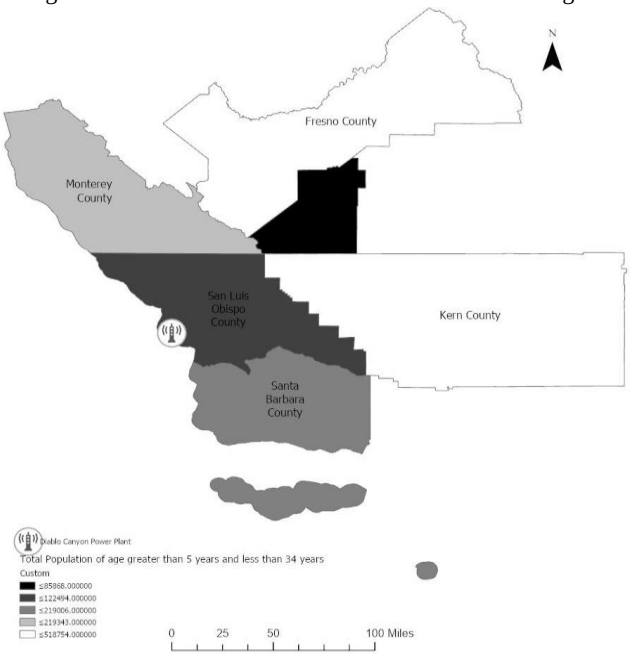

Figure 4: Population spread of ages between 5 and 34

basis. This group of population covers approximately 34% of the whole population in San Luis Obispo County where the nuclear plant is located. There are approximately 122,000 people between 5 years and 34 years in this location. This number is huge and if so many people are affected, the future generations would be born with a defect in their DNA and even the future generations after that might be affected. Also, the radiation might even spread to nearby counties like Santa Barbara, Kern, Monterey, Fresno and Kings counties having populations of approximately 220,000; 520,000; 220,000; 520,000; and 85,000 respectively. There are a number of people in this category in San Barbara county. So if the radiation spreads to this county, the effect on the younger generation might be more. The spread of radiation might depend on the wind which is a factor too. So if the wind blows towards the south, then this region will also be affected as the plan is present south of San Luis Obispo County near Santa Barbara county. This shows how the younger generation can be affected if they are exposed to radiation after a nuclear aftermath.

4.2 Population group of ages greater than 65: I analyzed the population of ages greater than 65 in the region to determine how harder it would be for evacuation. It would be difficult to evacuate older people as it might take time to move them away from the affected area especially the older people who are bedridden and unable to walk.

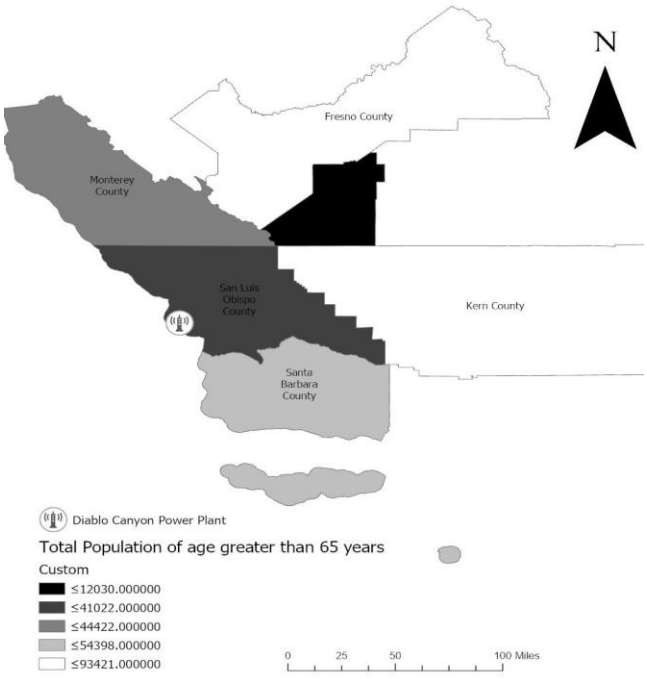

Figure 5: Population spread of ages between 5 and 34

The population of age greater than 65 years makes up 11% of the whole population in San Luis Obispo County. Though the percentage seems small, the count is approximately 41,000. Moving 41,000 people during an emergency situation becomes a harder task. Also, the radiation might even spread to nearby counties like Santa Barbara, Kern, Monterey, Fresno and Kings counties having populations of approximately 54,000; 93,000; 44,000; 93,000; and 12,000 respectively. As we can see in Figure 4, the neighboring county- Kern county has a population density of 93,000 under this category. In this case, during an emergency when the radiation has spread across San Luis Obispo County, the neighboring counties will be the hotspots for hospitals, camps, etc and if the hospitals are occupied by a lot of older people, it would be difficult during evacuation. So, in this case, the other counties must be considered during an evacuation.

5 Summary

As we see in the results, an earthquake causing a nuclear catastrophe can do great damage to the people in the region. The younger generation living around the region is high especially in the counties near San Luis Obispo County. This can be supporting the claim of a lot of people around the region to shut the plant down. However, we need nuclear power plants to provide energy. This research shows that a lot of younger people can be affected and this can affect a lot of forthcoming generations as well as the radiations are very harmful. The aftermath of an earthquake could create any one of the two types of disasters: the smaller one like the one that happened in Fukushima and the larger one like the one that happened in Chernobyl. Both the catastrophe did damage to the population around the plant. So, a nuclear disaster, big or small, will affect the population on a large scale. As we see in Figure 3, the spread of radiation could be so much like the one in Chernobyl. Again, the spread of the radiation could depend on the wind. The direction of the wind would determine the direction of the spread of the radiation, in case of a disaster. Moreover, the damage of nuclear plants in Fukushima worsened after a Tsunami struck the plant. Since the Diablo Canyon plant is present in the coastal region, this would also be a point in consideration. There can be emergency services like hospitals and camps set up after the 20 km radius. There must be a number of fire stations near the plant.

6 Conclusion

In the big picture, a nuclear disaster will definitely cause more damage than the earthquake itself. It is about the scale of damage, i.e., how the population gets affected. The power plant has been withstanding earthquakes until today, but nobody knows what might happen tomorrow. After the population analysis, it is clear that a lot of younger generations would be affected during such a disaster. On a large scale, a nuclear disaster could affect a large population especially in a state like California which is a business hub and a large number of people reside. The government should make sure that the plant is safe even during an earthquake and the officials working there must check the plant for failures on a regular basis. There must be a sufficient amount of equipment to tackle a nuclear disaster. This could avoid the spread of radiation and the number of people getting exposed could be reduced.

7 Future Work

Machine learning technologies can be used to predict the aftermath of a nuclear disaster, based on the data of other nuclear disasters, so that necessary steps could be taken in advance before the disaster actually happens. Wind data around the region could be analyzed to determine the direction of the radiation spread. This could help in the planning of evacuation of the right zones that could be affected.

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