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Dispersion Simulation of Cesium-137 Released From a Hypothetical Accident at the Bushehr Nuclear Power Plant in Persian Gulf

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ABSTRACT

The nuclear disasters in Chernobyl and Fukushima have shown that such nuclear incidents are causing serious and undesirable long-term damage to the environment and the health of living beings, including humans. So that they should be taken very seriously. Considering the importance of the subject, in this paper, the simulation of the transmission and emission of cesium 137 nuclear abandoned from the contingency incident of Bushehr Power Plant in the Persian Gulf using the CROM (Código de cRiba para evaluaciÓn de iMpacto) code has been discussed. We assumed that the incident took place on July 1, 2018, and the most dangerous and an important nucleus of the abandoned is cesium 137. The simulation results show that the Cs-137 released from the incident is moved to the west and northwest of Persian Gulf and approach the head of the Persian Gulf after fifteen days. Then driven by the discharge of the Arvandrood River to the south coast and center of the Gulf moves forward and leads to the bottom. About two months later (late August) it will leave the Strait of Hormuz and will advance the Oman Sea and the Indian Ocean. Now, if this happens on January 1, after about 30 days, cesium 137 reaches the head of the Persian Gulf, and four months later (late March) will leave the Strait of Hormuz. The results of this study can be used under the same conditions in the nuclear emergency of Bushehr Power Plant.

1. Introduction

Nuclear power plants are designed and built according to high standards. But the occurrence of natural disasters and the possible dangers of wars and ... can cause serious damage to them and cause the release of nuclear pollutants in the environment. The release of nuclear material in atmosphere and oceans is a major threat to the health of living creatures. Many researchers from different parts of the world, after two major Chernobyl events in Ukraine in 1986, and Fukushima in Japan in 2011 have been using numerical simulation models to try to predict the risks of releasing radioactive substances and their impact on the environment after assumptions in different nuclear power plants. So each has gained some interesting results.

After the Fukushima accident, the horizontal distribution of cesium 137 and sea surface current is simulated using several different models, like CRIEPI, JAEA, JCOPET, Sirocco, NOAA models. What the results of the models show is that coastal currents lead the pollutants to the south, after that to the east, and wherever currents become stronger, the movement of pollutants also accelerates [6]. The horizontal distribution of the sea surface concentration, in different season, obtained by a coastal model from Tokyo Electric Power Company (TEPCO), common feature for each season is the high concentration in the area close to F1NPP, which gradually decreases with distance from the F1NPP, and the relatively high-concentration plume dispersion along the shores. The contaminated water migrates eastward with the Kuroshio Extension; however, the Kuroshio Extension's position and current speed varies seasonally because of the change in the water mass balance of the Oyashio and Kuroshio currents [3].

The ROMS model shows external effective dose rate of radionuclides originated from F1NPP. In the beginning of the discharge, the external effective dose rate could peak to 10-6 Sv/hour. The effective dose originated from intake of sea food was assessed to about 1.7×10-6 Sv/year. This means immersing in the coastal water for hours would accept the equal effective dose from intake sea food for a whole year. The effective dose rate decreased quickly and became less than 10-8 Sv/hour from May [5]. In this research, we show that if this happens for the Bushehr nuclear power plant, one of the most important and most dangerous nuclear radiculocytes, called cesium 137, with a half-life of about thirty years, extends to the Persian Gulf. This nuclear pollutant is not naturally found in the environment and only enters the environment through nuclear activities and fission of uranium 235, which can affect the surface even to the depths of the water.

2. Research Method

It is assumed that a major accident at Bushehr nuclear power plant, would release large amounts of radioactive nuclei into the environment, including the Cesium 137. Because of the greater importance of Cs-137, this radioactive nucleus is used in simulation. We assume the inventory of the Bushehr reactor core at the time of the incident and the percentage of that released in the environment on the basis of the Chernobyl accident [2], that is, we consider that the reactor core at the time of the incident is 1.7×10^{17} Bq [7], of which about thirty percent is entering the environment of these, ten percent enters the water. We consider that the release of radioactive substances into the environment takes place within three days, after which time the incident is inhibited and their release into the environment is stopped. The release of the Cs-137 nucleus differs from these three days. But it is assumed, on average, that each day, 5×10^{15} Bq (5 PBq) will enter the water from the cesium 137 [8].

The currents and physical conditions of the Persian Gulf are different for each day. For this purpose, it is necessary to consider the environmental conditions of that particular day to study the emission of nuclear pollutants. In this paper, for example, the first day of July is considered, and the average surface water flow is lowered on average for the summer, because the Shamal winds (Northwest winds) that inflate the Gulf and affect the flow of waters in the area, and water currents can reach the Gulf, so that the flow of water in the Gulf is generally more regular than in other seasons [9-10].

The development of marine and ocean emission models is needed to investigate and predict the release of nuclear materials. One of these models is the CROM code. The CROM (Código de cRiba para evaluaciÓn de iMpacto) software tool was designed by the "Information Technology Laboratory (LABI)" at the Polytechnic University of Madrid's School of Industrial Engineers in collaboration with the CIEMAT Department of Environmental Impact of Energy under the Environmental Radiation Impact Program. It is based on the SRS19, but with some improvements based on the EUR 15760. The models implemented in CROM have been published by the CIEMAT. The CROM software application is designed to automate calculation of the concentrations of radionuclides in different environments. We use here from version 8 of the CROM code , by which we examine the transfer and accumulation of Cs-137 pollutants after a hypothetical incident at the Bushehr Power Plant for the Persian Gulf on a spatial scale, and then with We use a series of simple physical calculations to make them scalable. The method of calculating the CROM model is using the exponential method and Gaussian function, which is widely used to simulate the spread of marine pollutants. The exponential function has a density function (Equation 1):

$$f(x) = \frac{1}{\lambda} e^{\frac{-1}{\lambda} x} \quad \text{for } x \geq 0 \qquad (1)$$

Lambda (λ) is decay constant. In the exponential distribution, the user cannot truncate the distribution below it, because it does not tend to infinite to the left. The lower limit is controlled by displacing the distribution. As in the rest of the modules, certain parameters must be provided to be able to make the calculations. We find some stations in Persian Gulf and put their physical parameters in the CROM code. Export data of the code are radionuclide's concentration (C) (Equation 2) [1]:

$$C = \left(\frac{962 U^{0.17} Q_i}{D x^{1.17}}\right) \left[exp \frac{(-7.28 \times 10^5) U^{2.34} y_0^2}{x^{2.34}}\right] \left[exp\left(-\frac{\lambda_i x}{U}\right)\right] \quad (2)$$

(2)

The primary data for simulating the emission of pollutants in this model is the horizontal distance between the studied stations relative to the coastline and the discharge point (x) and their vertical distance (y), the water depth at those points (D), the velocity and direction of the coastal current (U), The vertical distance of the point of discharge to the station (y_0) and the dispersion coefficient perpendicular to the coast (E_y). In addition, data on the rate of radioactive activity at discharge time (Qi) and (λi) is radioactive decay constant of pollutants are important and necessary. As a default, the initial activity of 137 cesium was calculated to be 6×10^{10} Bq/s (5×10^{15} Bq/day) [2] and we estimated the x,y,y_0 values for each station using the guide map. E_y is various in different parts, which we used in our default software. We set the water level to about one meter (at the surface). And we set the flow rate according to Figure 9 for each station. λ_i is 7.322×10^{-10} /s for Cs-137.

3. Results and discussion

It is assumed that the incident of the Bushehr reactor took place on the first day of July 2018. Dispersion simulation of cesium 137 in the Persian Gulf indicates that due to the currents and flow of water in this basin, radionuclides tend to head to the Gulf and very simply, given the velocity and time relation (v = x / t), we can estimate the time to reach the head of the Gulf and from there to the other points. It takes about 50 days to infect the whole surface of the Persian Gulf. Of course, parts from the southern shores of the United Arab Emirates and small areas in the center of the Gulf remain contaminated (Fig. 1).

On this day, surface currents reach the basin at speeds of about 0.6 m/s from the Strait of Hormuz and pass through the northern coasts (Iran) and slow down at the head of the Gulf at 0.1 m/s and then move to the south coasts. They move very slowly and enter the bed near the Strait of Hormuz. The simulation results show that after the accident, the Cs-137 is released in the west and northwest direction of the Power Plant and then begins to move toward the head of the Gulf and reaches the head of the Gulf after almost fifteen days. There , the Arvandrood crater directs it towards the center and the southern coasts, and it takes about 50 days to cover the entire gulf with regard to the speed of the surface currents, and again it is observed that the severity of pollution in the south and center of the Gulf is far less or it is even free of contaminants, and because of the direction of the surface currents in the Strait of Hormuz, it flows into the Gulf, the cesium 137 contaminates the Strait to the bed and then enters the Oman Sea and the Indian Ocean. Now, if this happens on January 1, given that the speed of the currents from the Strait of Hormuz to the Persian Gulf is about half the speed of them in the summer, and the Shamal Winds that blow from the northwest in the winter will not allow the streams to reach head of the Gulf and complete a full cycle [9]. As a result, cesium 137, as shown in Figure (2), is released at surface of the Gulf, it takes about one month to reach the head of the Persian Gulf, and from there it moves very slowly towards the south latitude. Advances to the center of the Gulf, then enters the bottom and about 4 months after that, leaves the Strait of Hormuz. Also for other radionuclides, the intensity of the radiation is similar to that in Figures 3 to 10.

To ensure the results, we compared them with some of the simulations that came from other models after the Fukushima incident. Including CRIEPI [6], JAEA [6], JCOPET [6], Sirocco [6], NOAA [6], POM [4], ROMS [5], models, and considering that the Persian Gulf is a semi-enclosed basin and that the surface water flow is more varied and more complex than the Pacific coast, so it seems to be possible to confirm the results of the CROM model to a high degree.

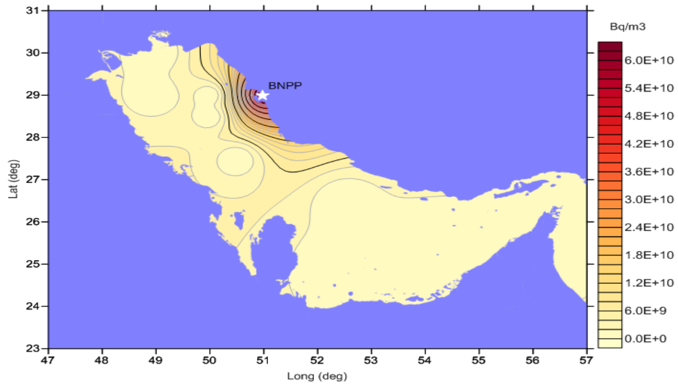

Fig 1. Dispersion Cs-137 in the Persian Gulf (summer)

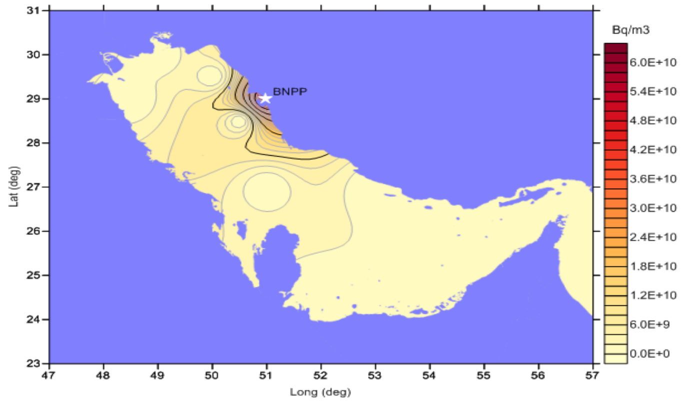

Fig 2. Dispersion Cs-137 in the Persian Gulf (winter)

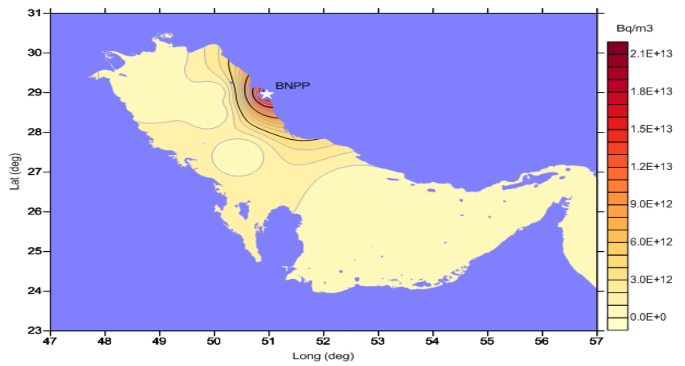

Fig 3. Dispersion I-131 in the Persian Gulf (summer)

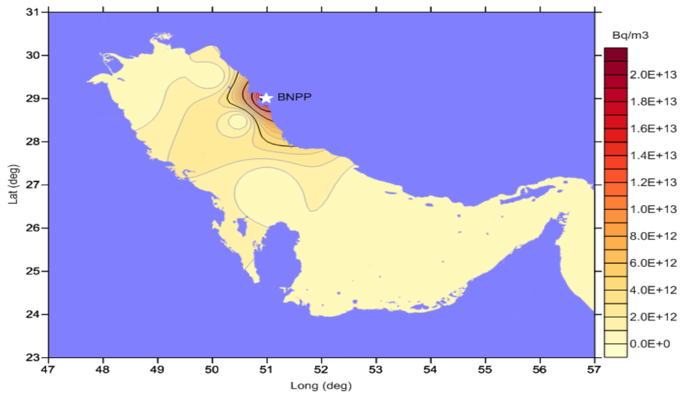

Fig 4. Dispersion I-131 in the Persian Gulf (winter)

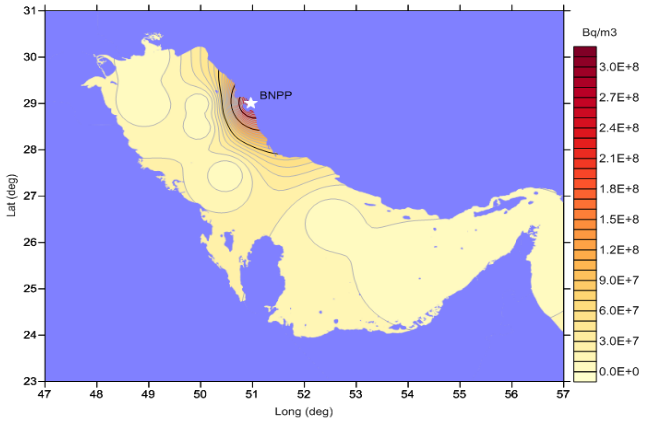

Fig 5. Dispersion Pu-239 in the Persian Gulf (summer)

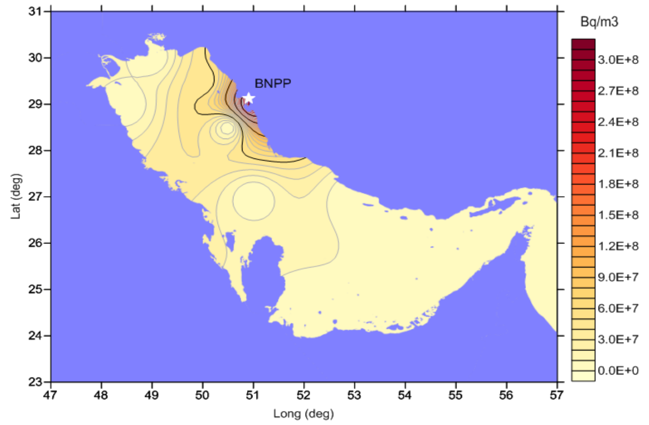

Fig 6. Dispersion Pu-239 in the Persian Gulf (winter)

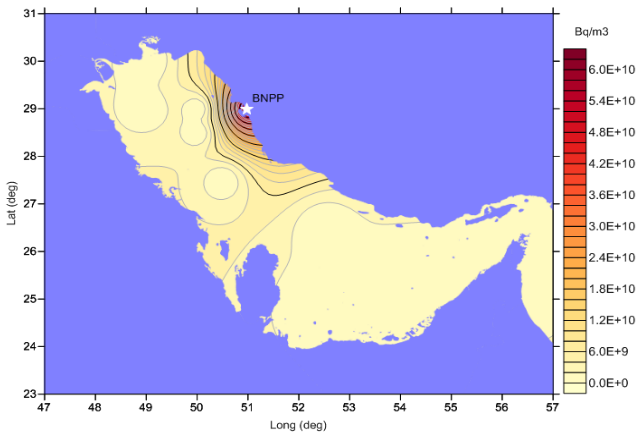

Fig 7. Dispersion Sr-90 in the Persian Gulf (summer)

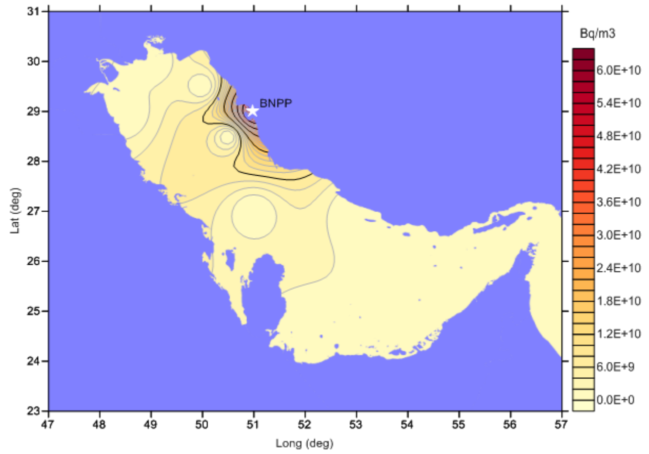

Fig 8. Dispersion Sr-90 in the Persian Gulf (winter)

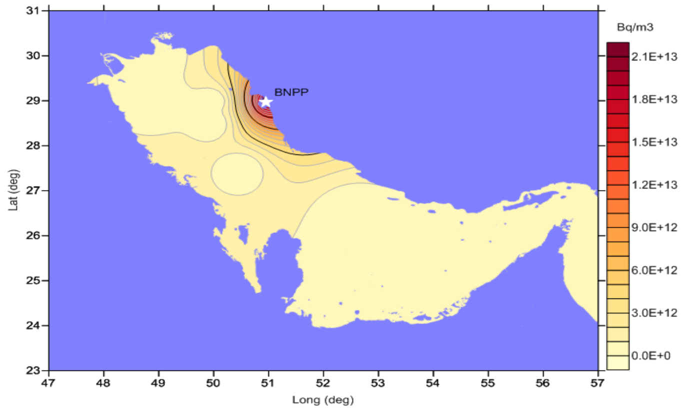

Fig 9. Dispersion Te-132 in the Persian Gulf (summer)

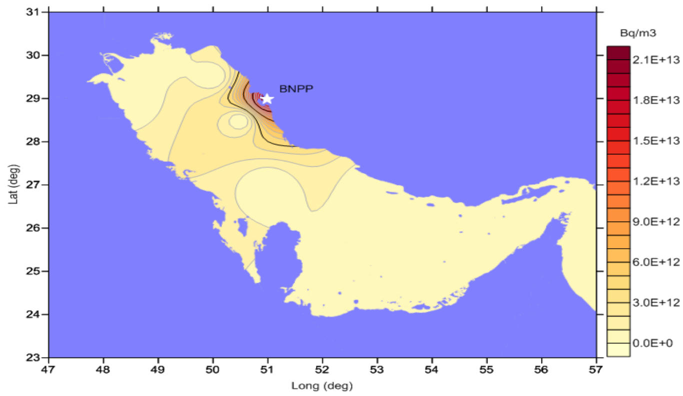

Fig 10. Dispersion Te-132 in the Persian Gulf (winter)

4. Conclusion

In this paper, a simulation of the dispersion and concentration of the Cesium 137 nuclear fugitive released from the incident of Bushehr Power Plant was studied using the CROM model on July 1, 2018.And surface water currents are assumed to be on average for the summer season Because the northwest winds (Shamal winds) that affect the bay and circulate the waters of this area are minimized and water flows can reach the Gulf, so that the flow of water in the Gulf is generally more regular than other seasons. The simulation results show when the Persian Gulf currents are similar to those in this paper, Cesium 137 released from the incident goes further towards the Gulf and the maximum polluting deposition is on the same northern coast and near the Bushehr province. It then advances towards the west and northwest, so that it reaches the head of the Persian Gulf after fifteen days, and is driven by the discharge of the Arvandrood river crater to the south coast and center of the Gulf, and from there, it is directed to the bottom. About two months later (late August), it will leave the Strait of Hormuz and will advance the Oman Sea and the Indian Ocean. If we choose the first of July, the first of January, winter season, for the incident, then the flows from the Strait of Hormuz are about half that in the summer. Also, due to the "Shamal" winds that flow northwest to the Persian Gulf, currents can not reach the Gulf and complete the entire cycle through the Gulf, which is very important in the release of nuclear pollutants.So that, after about

30 days, cesium 137 reaches the top of the Gulf, and four months later (late March) will leave the strait of Hormuz. Of course, given the 30-year-old half-life of 137 cesium, and that the Gulf is a closed water basin, and it takes about 3 to 5 years to change its water, we expect the cesium-137, a alkali metal, to be polluting for many years Deep in the Gulf, in particular, remain litter.

The strontium 90, which lies in the group of alkaline earth metals and has a half-life of about 28 years, has the same behavior as cesium.

Plutonium 239, from actinides (intermediate metals), due to its high density and half-life, moves more sophisticated than the rest of the pollutants in both seasons, and can not reach the summit of the Gulf in the summer and is strongly influenced by Arvandrood to the central and It is part of the Southwest coast; it has a large part of the southern coast. Before reaching the eastern half of the Gulf, it enters the bed due to heavy load, and is located in sediments. In winter, it can overcome the discharge of the Arvandrood river and have a short stay in the Gulf. And although he goes a little toward the west, he is still guided to the southwestern coast and goes from there to bed.

Iodine 131 and Tellurium 132 are both non-metallic and exactly interact with each other. In the summer, they move in a counterclockwise direction to the southwestern coast, but they are driven straight into the winter and enter the bed.

All of the nuclear pollutants are drifting more toward the southwestern coast in the winter. While in the summer they tend to reach the northwest. So, in the summer, they will have a more complete cycle of cycling. But in the winter they are direct from the coast of Bushehr to the southwest coast and then slowly enter the bed.

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