Medical work in Bac Ninh province while the hypothetical situation of a cross-border radiation accident

Nguyen Tien Quan[1,2,*], Nguyen Thi Minh[1], Bui Van Loat[2], Le Ngoc Thiem[3]

(1) Bac Ninh General Hospital, Bac Ninh province, Viet Nam

(2) Faculty of Physics, VNU University of Science, Ha Noi, Viet Nam

(3) Institute for Nuclear Science and Technology, Vietnam Atomic Energy Institute, Vietnam

Abstract

Introduction: The hypothetical situation of a cross-border radiation accident comes from a hypothetical accident at the Fanchenggang nuclear power plant, which could affect Bac Ninh province. Therefore, the Bac Ninh Provincial Department of Health must develop a medical response plan. In response to these challenges, this study assesses the absorbed dose during the hypothetical situation of a cross-border radiation accident and an appropriate medical response plan in Bac Ninh. **Materials and methods:** This study mentions the characteristics of reactor accident scenario. It used interpolation methods to evaluate the radiation dose in the event of a nuclear accident. In addition, the study presents the human resources infrastructure of the health sector to implement the response. **Results:** In the worst-case scenario, adults may be exposed to a maximum absorbed dose of about 1.4 mSv per day. If the projected dose exceeds the generic criteria of 100 mSv/year, the Bac Ninh Health Sector will take protective actions and provide medical response. **Conclusion:** In areas affected by nuclear power plants, it is mandatory to respond to radiation accidents.

Key word: *Radiation accident, radiation emergency, nuclear disaster, medical physics.*

1. INTRODUCTION

In recent times, many countries have continued to build and use new nuclear power plants as science and technology have advanced. China has mainly developed nuclear power plants in provinces adjacent to the sea or with large rivers. Two provinces near the Vietnam border that have constructed nuclear power plants are Hainan Island and Guangxi Province. The operating nuclear reactors include Fangchenggang 1, 2, 3, and Changjiang 1, 2, are listed in Table 1. Additionally, the power units under construction are described in Table 2.

Table 1. Operable nuclear power reactors [1]

Units	Province	Net capacity (each)	Model	Grid connection
Fangchenggang 1&2	Guangxi	1000 MWe	CPR-1000	Oct 2015, July 2016
Fangchenggang 3	Guangxi	1105 MWe	Hualong One	January 2023
Changjiang 1&2	Hainan	601 MWe	CNP-600	Nov 2015, June 2016

Table 2. Nuclear reactors under construction [1]

Units	Province	MWe gross	Reactor model	Construction start	Expected grid connection
Fangchenggang 4	Guangxi	1x1180	Hualong One	12/16	2024
Changjiang 3&4	Hainan	2x1200	Hualong One	03/21, 12/21	2026, 2027
Changjiang SMR 1	Hainan	1x125	ACP100	07/21	2026

The geographical distance from Bac Ninh to Fangchenggang nuclear power plants is approximately 220 km to 260 km [2]. Bac Ninh province is about 285 km to 345 km away from the Changjiang nuclear power plant[2]. Fangchenggang 1, 2, 3, 4, and Changjiang 3, 4 are the generator units with a capacity greater than or equal to 1000 MW. These units have a radius of 500 km and cover Bac Ninh province. Therefore, Bac Ninh province is under the influence of nuclear power plants in Guangxi province and Hainan Island [3].

Corresponding Author: Nguyen Tien Quan. Email: nguyentienquan189@gmail.com
DOI: 10.34071/jmp.2024.6.9

Received: 28/7/2024; Accepted: 10/10/2024; Published: 25/12/2024

Bac Ninh has the smallest area of 822.7 km2 in the country [4]. The terrain is quite flat, sloping mainly from north to south and from west to east, as shown by the surface water flowing to the Cau River, Duong River, and Thai Binh River [4]. The altitude variation across the province is not significant [4]. The climate is subtropical, humid, and monsoonal, divided into four distinct seasons (spring, summer, autumn, and winter). The average temperature has a difference of 15 - 16 °C between hot, humid summers and cold, dry winters [4]. In winter and spring, the average relative humidity is 79%[4]. According to the 2022 statistical yearbook, the province's population is 1,488,250 people, of which men account for 49.2% and women for 50.8% [4]. The average population density is 1,808 people per km^2 [4].

A Bac Ninh background radiation map was created as part of the 2021 science and technology mission: "Research, measurement, analysis, and assessment of environmental radioactivity in Bac Ninh province". The results of the background dose distribution are given in Table 3.

Table 3. The Bac Ninh background radiation [5]

No.	Sample locations	Ggamma absorbed dose rates in the air (μSv/h)		Gross alpha and beta activities in the air (Bq/m^3)		Gross alpha and beta activities in sedimentation samples (Bq/cm^2)		Gross beta activities in water samples (Bq/liter)		Gross alpha activities in water samples (Bq/ liter)	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	Bac Ninh city	0.03	0.12	0.01	0.03	0.02	0.04	<0.05	0.21	<0.01	0.03
2	Tu Son city	0.05	0.09	0.01	0.03	0.02	0.04	<0.05	0.23	<0.01	0.03
3	Gia Binh district	0.07	0.23	0.01	0.02	0.02	0.04	0.1	0.21	0.01	0.03
4	Que Vo district	0.07	0.22	0.01	0.02	0.02	0.04	0.1	0.25	0.01	0.03
5	Yen Phong district	0.05	0.09	0.01	0.03	0.02	0.04	<0.05	0.21	<0.01	0.03
6	Tien Du district	0.03	0.13	0.01	0.03	0.02	0.04	<0.05	0.23	<0.01	0.03
7	Thuan Thanh district	0.07	0.26	0.01	0.02	0.02	0.04	0.1	0.23	0.01	0.03
8	Luong Tai district	0.08	0.23	0.01	0.02	0.02	0.04	0.1	0.23	0.01	0.03

From the results in Table 3, it can be seen that the background radiation characteristics of air, water, and sedimentation samples are within the reference range of Vietnam. Table 3 is the basis for comparison with measured data in the case of a cross-border nuclear power plant disaster. In reality, no radiation incident has occurred. This study takes into account a hypothetical incident scenario in order to develop a response plan.

The hypothetical scenario involves a potential radiation accident at the Fanchenggang nuclear power plant, which could affect Bac Ninh province. Therefore, the Bac Ninh Provincial Department of Health must consider establishing and training teams to prepare for and respond to potential cross-border radioactive accidents. In response to these challenges, a study titled " Medical work in Bac Ninh province while the hypothetical situation of a cross-border radiation accident " was conducted with two main objectives:

- To assess the potential absorbed dose in Bac Ninh province in the event of a cross-border radiation accident;
- To develop a corresponding medical response plan for Bac Ninh province.

2. MATERIALS AND METHODS

2.1. Reactor accident scenario and radioactivity dispersion model

For the radiological impact assessment, we rely on the least severe reactor accident scenario, with a chance of occurrence of 1 in 50,000 per year. The accident is assumed to be caused by a loss of external power (station blackout) due to a seismic event,

leading to loss of coolant water, core meltdown, and reactor vessel rupture. Consequently, the majority of radionuclides can enter the containment within 36 h [6]. The subsequent containment failure occurs 45.3 h after the reactor shut down, leading to the release of radioactivity into the atmosphere 26.7 h after the containment failure[6]. The fission products released in this reactor accident scenario are ^{131}I ($T_{1/2}$ = 8.04d), ^{133}I ($T_{1/2}$ = 20.8h), 133Xe ($T_{1/2}$ = 5.25d), and ^{135}Xe ($T_{1/2}$ = 9.9h) with the total activities of 1E+07, 3E+07, 4E+09, and 1E+09 GBq, respectively, which account for 53% of noble gases and 0.3% of halogens of the core inventory [6]. ^{131}I and ^{133}I are assumed to be released as particles, fission products such as ^{90}Sr and ^{137}Cs are not released in this accident scenario [6].

To investigate the characteristics of radiation transport from the site of a hypothetical accident to the affected areas, it is necessary to rely on a simulation model capable of predicting transport according to typical weather conditions such as distance, terrain, wind direction, precipitation, moist air, dry air, etc. One of the complete simulation software programs used by the research community is FLEXPART simulation[7]. In the FLEXPART modeling, the accident is assumed to occur at the Fangchenggang, the radionuclides are assumed to be released daily uniformly over 24 h, and the plume dispersion is simulated for 48 h after the release starts [6]. The simulation was repeated every day from July 2018 to June 2019 [6].

This study does not examine the use of the aforementioned software. Instead, the study aims to utilize the research team of Duy-Hien Pham and Kim-Long Pham in order to estimate the absorbed dose. We chose the linear interpolation method because Bac Ninh province is between Hanoi and the Fanchenggang nuclear power plant, and distance is the primary data variable. Other characteristics, such as terrain and climate, are all calibrated in the software.

2.2. Material and human resources

The health sector's organizational structure in 2023 will include:

Board of Directors of the Department of Health: Director of the Department and 03 Deputy Directors.

Departments under the Department of Health: 6 departments under the Department, including the Department of Medical Affairs, the Department of Pharmaceutical Affairs, the Department of Organization and Administration, the Department of Planning and Finance, the Department of Population, and the Department Inspectorate.

Units under the Department of Health, including 18 units:

- 07 provincial-level hospitals: General Hospital, Obstetrics and Pediatrics Hospital, Eye Hospital, Traditional Medicine and Rehabilitation Hospital, Dermatology Hospital, Mental Health Hospital, and Lung Hospital;

- 03 provincial-level professional and technical centers: Center for Disease Control, Testing Center, and Forensic Center;

- 08 district, town, and city medical centers.

In addition to medical emergency equipment, specialized equipment for responding to radiation incidents includes 02 portable dosimeters and a decontamination kit.

3. RESULTS AND DISCUSSIONS

3.1. Predicted radiation doses

In the worst-case scenario, when the radioactive cloud passes, the results of recording the absorbed dose for adults in the localities are mentioned in Table 3.

Table 4. Predicted maximum total radiation doses (μSv) to an adult[6]

Sites Variable type	Mong Cai	Ha Long	Hai Phong	Ha Noi	Bac Ninh interpolation
Distance, km	65	175	218	300	240
Plume passage date	10/5	13/01	07/5	18/7	
Inhalation	5935	1062	1356	704	
Cloud shine	987	162	217	109	
Ground shine	415	65	240	3	
Total dose after plume passage (μSv)	7337	1309	1813	816	1429

The graph depicting the interpolated absorbed dose results is shown in Figure 1.

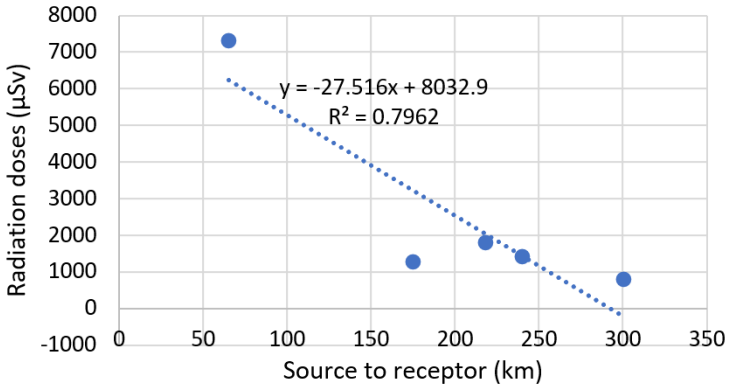

Figure 1. Linear interpolation of the result value in Bac Ninh

From the above value, it can be estimated that the maximum absorbed dose adults must endure is ~1.4 mSv per day. Projected dose not exceed 10 mSv/week. Response actions do not take urgent protective actions.

In the scenario, core meltdown, and reactor vessel rupture, leading to the release of radioactivity into the atmosphere in few months, there are two possible scenarios:

- In the event of a projected dose exceeding the generic criteria of 100 mSv/year, protective actions should be taken, such as temporary relocation, decontamination, replacement of food, milk, and water, and providing public reassurance [8];

- In the case of a projected dose ranging from 20 to 100 mSv/year, response actions include screening based on equivalent doses to specific radiosensitive organs (as a basis for medical follow-up) counselling [8].

3.2. Radiation emergency medical response work

According to the Atomic Energy Law, facilities using radiation equipment, provinces, and country must develop radiation emergency response plans. For each medical facility, there will be a facility-level radiation response plan, mainly addressing potential accidents from radiation equipment and radioisotopes. It is very difficult for a medical facility to build a nuclear disaster situation. So the Bac Ninh Provincial Department of Health needs to consider building forces in each hospital or concentrating in a few team so that they can mobilize forces when an accident occurs.

The form of force organization can be a radiation emergency team. This teams need to be trained to respond to radiation accidents and incidents.

Medical respond to cross-border nuclear radiation accidents is divided into three phases: prevention of radiation accidents, response to radiation accidents, and recovery work after radiation accidents.

In the simulation scenario, the radioactive source is controlled, the impact on Bac Ninh province is not immediately dangerous to human life. The maximum interpolated radiation dose is about 1.4 mSv/day. This value exceeds the public dose limit for one year (1 mSv). Although the value of 1.4 mSv is not high enough to require covert intervention, it is still recommended to limit outdoor activities on days when radioactive clouds pass by.

In bad case scenario, projected dose in range 20 ÷ 100 mSv/year, it is necessary to monitor and specifically measure the level of radioactive contamination in food and the environment after an accident because it contributes to the average dose of people in the province. This is important in medical examinations because the average dose per person is larger. The Provincial Department of Health carries out communication on food safety during the accident. With food from farms and fields in the province, people should wash it under running water to minimize the risk of exposure to humans. The Food Safety Board closely monitors food originating from areas affected by nuclear and radiation accidents.

In the worst-case scenario, projected dose exceeds 100 mSv/year, in addition to temporary relocation; decontamination; replacement of food, milk, and water; and public reassurance, the medical response work is as follows:

- Ensure facilities and human resources for medical assistance in radiation protection;

- Deploy field medical stations when requested;

- Develop appropriate treatment regimens for early diagnosis and treatment of radiation diseases;

- Take the lead and coordinate with relevant agencies to carry out decontamination for people exposed to radiation when an incident occurs.

- Receive and provide first aid and treatment or transfer victims to specialized hospitals for treatment;

Coordinate with specialized forces to classify objects contaminated with radiation and irradiated.

4. CONCLUSIONS AND RECOMMENDATIONS

The response to cross-border radiation accidents should be a practical consideration and needs to be included in the working plan of the Bac Ninh health sector

In the worst-case scenario, the organization of the response force needs to take protective actions and other response actions early in the response.

Conflict of interest

The authors declare that there is no conflict of interest in this study.

Funding This research did not receive any specific funding source.

Statement of Informed Consent

This article does not contain any studies involving human subjects.

Ethical Approval

Ethical approval was not required.

Authors' contributions

T-Q. Nguyen: Conceptualization, methodology, writing original draft, writing - review & editing. T-M. Nguyen: acquisition, writing-reviewing and editing. V-L. BUI: reviewing and editing. N-T. LE: reviewing and editing

Acknowledgments

The authors would like to thank Dr. Pham Kim Long, Vietnam Atomic Energy Institute; Dr. Nguyen Van Mui, MSc. Nguyen Dinh Khai, Military institute of medical radiology and oncology; Mr. Nguyen Van Dong and Mr. Nguyen Trong Nghia, the Department of Science and Technology of Bac Ninh province, allowed me to refer to the data and content for this article.

REFERENCES

1. World Nuclear Association. Nuclear Power in China [Internet]. 2023;Available from: https://world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx

2. Google. Map data [Internet]. 2023;Available from: https://www.google.com/maps/@20.7381085,107.0095268,8.75z?entry=ttu

3. The Minister of Science and Technology of Vietnam. Circular 12/2023/TT-BKHCN June 30, 2023 preparation and response to radiological and nuclear emergencies and approval of plans for responses to radiological and nuclear emergencies. 2023.

4. People's Committee of BacNinh province. Natural conditions [Internet]. 2023;Available from: https://www.bacninh.gov.vn/vi/web/bacninh/news/-/details/20182/-ieu-kien-tu-nhien-21395062

5. Ratoc Company Limited. Summary report on the results of research, measurement, analysis and assessment of environmental natural radiation safety in Bac Ninh province. Bac Ninh: People's Committee of BacNinh province; 2021.

6. Hien PD, Long PK. Assessing the potential radiological impacts on Vietnam from a hypothetical accident at a nearby Chinese nuclear power plant. Hum Ecol Risk Assess Int J 2023;29(5–6):916–26.

7. Stohl A, Hittenberger M, Wotawa G. Validation of the lagrangian particle dispersion model FLEXPART against large-scale tracer experiment data. Atmos Environ 1998;32(24):4245–64.

8. International Atomic Energy Agency (IAEA), Food And Agriculture Organization Of The United Nations (FAO), International Labour Organization (ILO), Pan American Health Organization (PAHO), World Health Organization (WHO). Criteria for use in preparedness and response for a nuclear or radiological emergency, IAEA Safety Standards Series No. GSG-2. Vienna: IAEA; 2011.