

DEVELOPMENT OF A SMART OCEAN RADIATION MONITORING SYSTEM

Nguyen Tien-Anh¹, Dinh Tien Hung², Nguyen Van Toan¹, Vu Anh Hung¹,
Nguyen Duc Anh³, Dinh Duc Manh⁴, Ngo Van Cong⁵, Le Tien Dung⁶, Tran Duc Tan^{7,*}

Abstract: Ocean radiation monitoring systems (ORMSs) are an essential component in the radiation early warning network that monitors radiation exposure and estimates radioactive propagation induced by nuclear activities or nuclear accidents in the sea. Numerous systems have been developed and installed in the radiation warning network in different countries. However, there is not any similar product that has been studied and developed in Vietnam. This paper presents a complete process in designing and manufacturing a marine buoy integrated with a radiation sensor. The radiation detector can measure both dose rate and radiological spectrum. The ORMS also combines multimodal data transmission and various programmed software for data processing, signal transmission, and system control. Therefore, the proposed configuration system has potential application in terms of performance and maintenance.

Keywords: Ocean radiation monitoring system (ORMS); Marine buoy; Nuclear accident; Radiation warning network.

1. INTRODUCTION

The Fukushima Daiichi nuclear disaster was the most severe nuclear accident caused by the earthquake and tsunami in 2011. Large amounts of water contaminated with radioactive isotopes were released into the Pacific Ocean after the accident causing economic consequences and long-term effects on the marine environment [1]. Nowadays, the risk of nuclear accidents with the ocean environment is increasing due to new installed nuclear power plants along the coast and the high use of nuclear submarines in the sea [2, 3]. Some countries, such as China have been developing new float nuclear power plants to operate in the islands. When a nuclear accident happens, it is necessary to have an early warning signal and complete information about the transmission of the radioactive flow to reduce the impact on the environment and to make promptly plans to evacuate residents. Therefore, it is essential to develop and install an ORMS network [4, 5, 8-10] to monitor the radioactive level in the sea.

Along with radiation monitoring systems which are used to monitor radioactive level on the land and in the air, the ORMSs is the remaining parts of the national radiation early warning network to monitor and estimate radioactive propagation in the sea. One ORMS normally composed of four main parts: (1) the radiation detector; (2) a buoy or a carrier device to hold the detector; (3) the electronic and telecommunication system, and (4) the power system [5]. Those systems can be fixed mounting in an area by anchors or installed on mobile monitoring devices such as ships and boats. Those ORMSs have been developed and installed in different countries. However, there is not any similar product has been studied in our country.

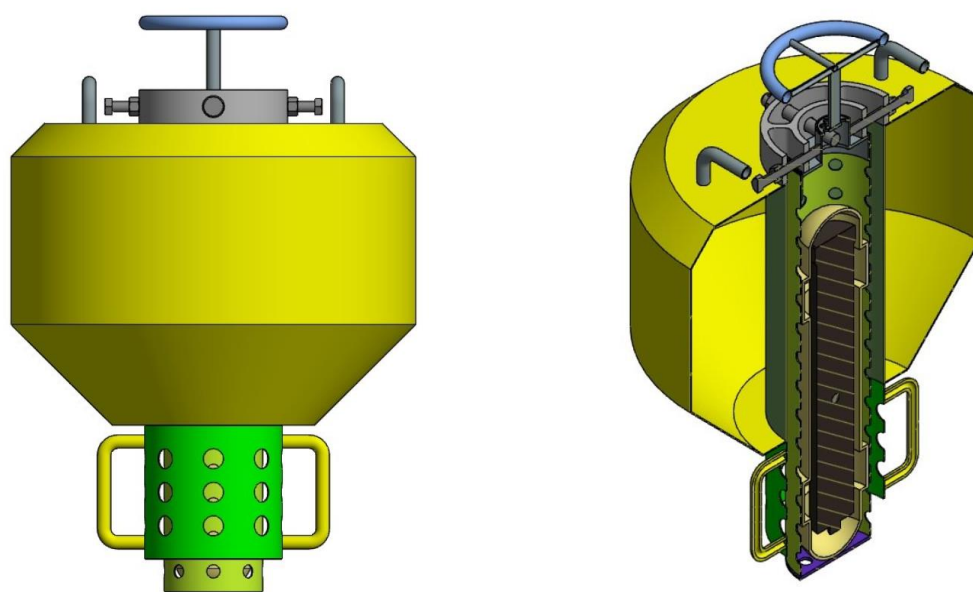
In this study, we present a complete process in designing, manufacturing, and testing an ORMS system which composes of a marine buoy integrated with a radiation sensor. The components to create the buoy such as structure, shape, and materials are selected to ensure it has appropriately operated in the marine environment for a long lifetime. The commercial radiation detector can measure both gamma dose rate and gamma-ray

spectrum. The ORMS also combines multimodal data transmission and various programmed software for data processing, signal transmission, and system control. Therefore, the proposed ORMS configuration system has potential application in terms of performance and maintenance. It will play an important role in our national radiation early warning network.

2. EXPERIMENTAL

2.1. Marine buoy design

Figure 1 illustrates the designed image and components of the marine buoy, in which fig.1 (a) and (b) are the front-view and the cross-section image, respectively.



(a) The front-view image of the design marine buoy

(b) The cross-section image of the design marine buoy

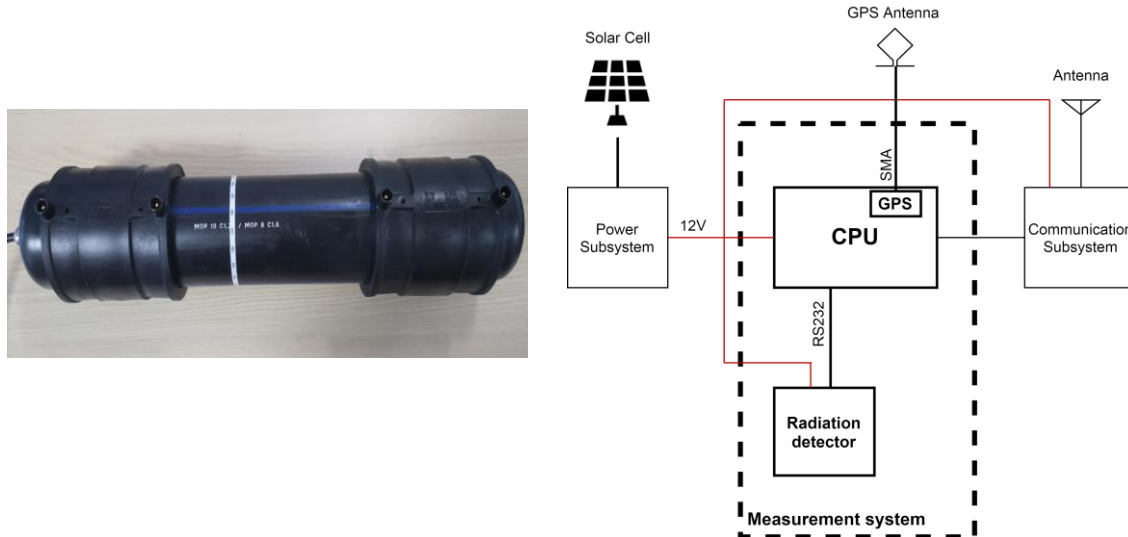
Figure 1. The design image of the marine buoy: (a) The front-view and (b) the cross-section of the design marine buoy.

The buoy consists of three main parts: the buoy body, the sensor canister, and the structures for changing the deep of the radiation detector. The buoy body has a cylindrical structure to ensure floating and is made of inox-316 to prevent the influence of the ocean environment. The radiation sensor is contained in a hollow cylinder with holes around it to help circulate water in and out while measuring in the sea. In addition, other details such as handles make the process of transportation and use conveniently.

2.2. The radiation detector

The commercial radiation detector was purchased from GIHMM company, Austria. This is an all-in-one integrated detector including a NaI spectrophotometer and a GM dosimeter for measuring both radiation spectra and dose rate. All sensors integrated with electronic elements and the power supply are packaged in IP63 standard aluminium block and covered by cylindrical hard plastic to ensure it can operate in the sea. Fig. 2.a shows the image of the commercial radiation detector. The block diagram of the whole

system is presented in fig. 2.b. All radiation detector, and GPS are connected to the CPU (Central Processing Unit) through RS232 ports in this system. The updated rate is 20 samples per second. The acquired data from the sensors are forwarded to the communication module after a preprocessing step. A solar photovoltaic system powers the whole system.



(a) The commercial radiation detector

(b) The block diagram of the whole system

Figure 2. (a) The image of the commercial radiation detector which is purchased from GIHMM company, Austria and (b) the block diagram of the whole system.

2.3. Materials and radioactive sources

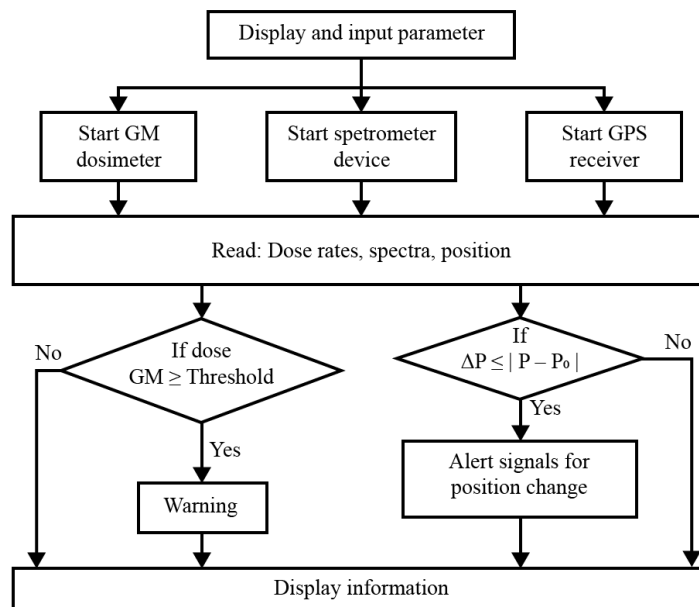


Figure 3. The flow chart describes the working principle of our ocean radiation monitoring system.

The marine buoy was fabricated using a specific alloy of stainless steel to prevent the affection from the marine weather. All electronic and telecommunication elements ensure IP63 standards.

The standard radioactive sources were provided by the military institute of chemical and environmental engineering for experiments. The flow chart in fig. 3 describes the working principle of our ocean radiation monitoring system. All the measured data from detectors and sensors are stored in a data logger module. It generated encrypted data and send it to the Central station through a transmitter. To reduce power consumption, only one-way transmission is activated.

3. RESULTS AND DISCUSSION

3.1. Positioning the buoy

The buoys will be fixed position by anchor and cable. To avoid the cable break, the cable's tension from anchor to buoy must be low, making an orbit around anchor on the sea appear. Fig. 4 shows the orbit model's side view, and top view, where R is the orbit radius and O is the orbit centre. The safe distance to decide the buoy not operate at a fixed position:

$$Distance_{safe} = R + 2.accuracy_{GPS} \quad (1)$$

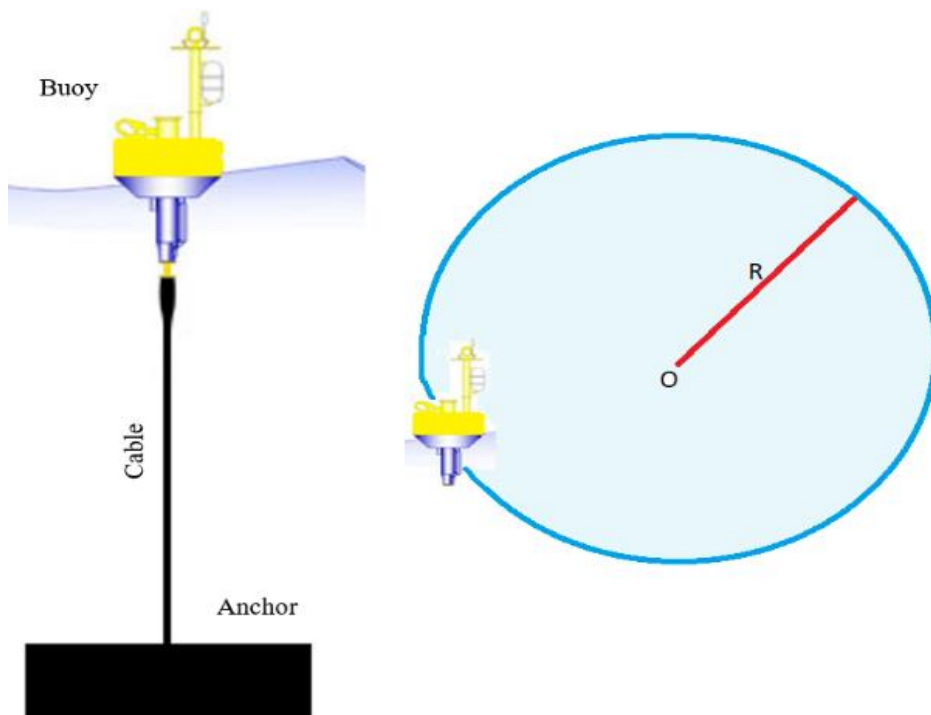


Figure 4. Side view and top view of buoy's orbit.

GPS is used to determine the position of the buoy [6, 7]. The experiment results show that vibrations from the ocean waves do not influence location data from GPS.

The data recorded in 10 minutes by module Quectel EC25 after converting to XY coordinate system is shown in fig. 5; with no altitude, we calculate maximum deviation on X-axis and Y-axis: maxX = 4.27 m; maxY = 3.91 m.

dev_a: Actual maximum deviation $\sqrt{\max X^2 + \max Y^2}$ 5,78m

This value fits with accuracy of GPS module.

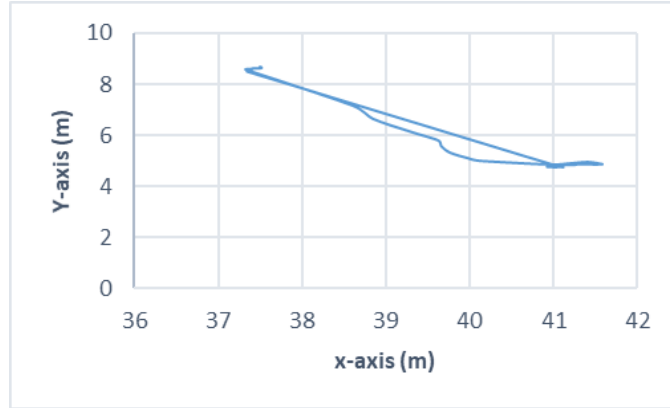


Figure 5. Position on XY coordinate.

3.2. The developed softwares

The software interface in figure 6 includes maps, GPS time, GPS location, and acceleration data. The map will show the location of the last contact of the buoy, the location of the previous contact, the distance travelled compared to the previous contact. If the travel distance exceeds a pre-set threshold, a travel alert will be generated and sent automatically to the parties involved. To ensure safety for electrical equipment inside the buoys, the accelerometer is used to evaluate the intensity of the waves; it's divided into multi levers from low to high. If it detects a high level, the buoys monitoring this value stop working and wait for low vibration to work again.

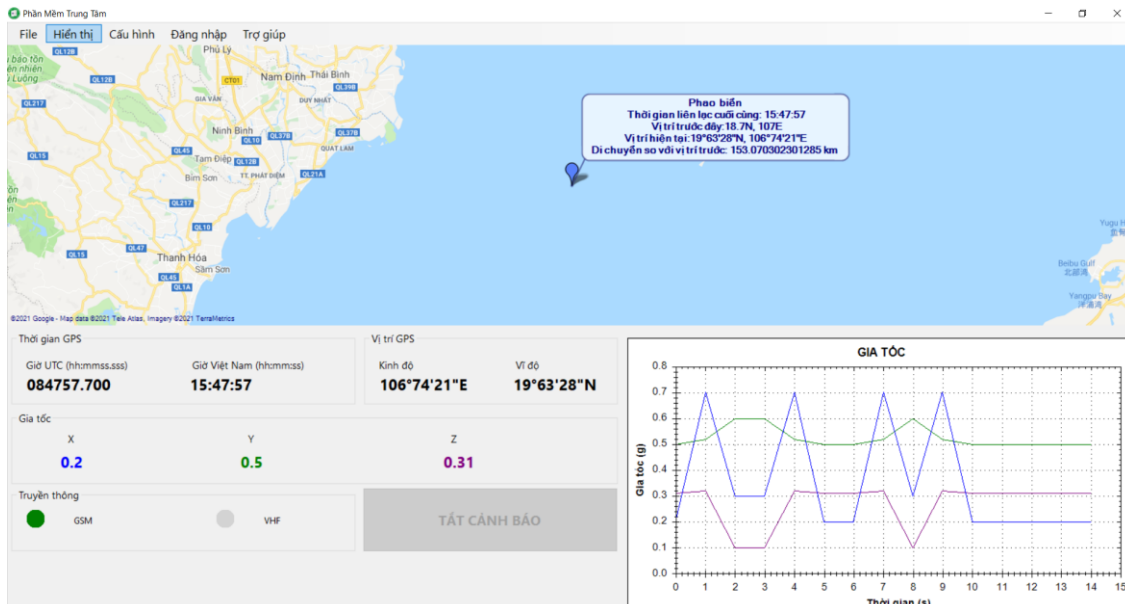


Figure 6. The GUI interface.

3.3. The measurement with radioactive sources

3.3.1. Radiation sensor calibration

Several benchmark tests were carried out using the sensor, and radioactive calibration sources (i.e., ^{137}Cs and ^{60}Co) were used, have been carried out. At the low count rate (i.e., below 35 kcps). Our sensor's functionality was compared to those of a commercial DSPEC jr 2.0 at the low count rate (i.e., below 35 kcps). The preamplifier's output has been simultaneously connected to our DMCA and DSPEC jr 2.0 both devices in these tests. The number of gamma-rays attained to the detector crystal is adjusted by using radioactive sources with different activities and altering the detector-to-source distance. For the high count rate benchmarks, the gamma spectra obtained from our DMCA at the count rates of 72 and 110 kcps have been analyzed. The calibrated difference is below 6.5%.

3.3.2. Measured results

Figure 7 is the measured data of the ^{60}Co source sample at a distance of 10 cm from the probe; the measured dose rate is 432.4 nSv/h. At a distance of 15 cm, the measured dose rate is 241.5 nSv/h, and at a distance of 20 cm, it is 209.1 nSv/h.

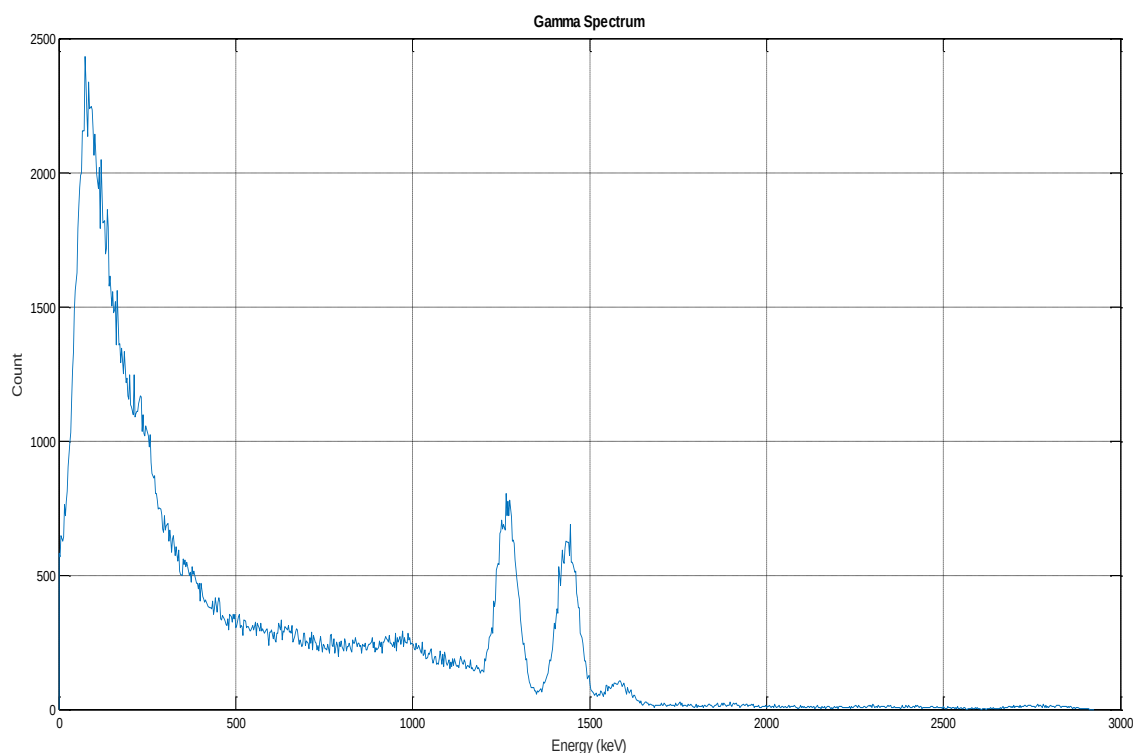


Figure 7. The measurement with Co-60 sample.

Figure 8 illustrates the gamma spectral of the ^{60}Co sample measurement at a distance of 10 cm. The averaging algorithm smoothed the gamma spectral data before being used to identify the energy peaks. Smoothing the data will help the energy determination process to be error-free due to local maxima. The image shows the 5th and 6th peaks for the 1173 keV and 1332 keV energy levels of the ^{60}Co isotope. The 7th peak corresponds to the 1460.8 keV level of the isotope ^{40}K , which is integrated as a calibration source of the sensor.

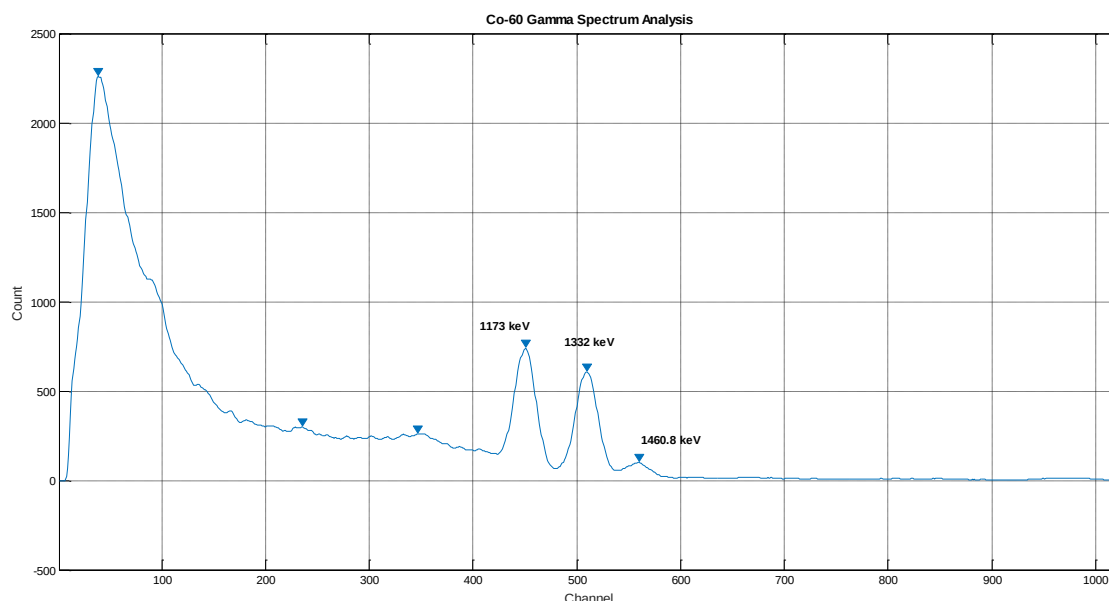


Figure 8. The gamme spectral.

4. CONCLUSIONS

In summary, this paper presents a complete process in designing, manufacturing and integrating an ORMS. The system consists of a radiation detector integrated with a marine buoy, electronics circuits, power supply and telecommunication devices. The system has been tested with standard radioactive sources to measure both gamma dose rate and radiological spectrum. Multimodal data transmission and various programmed software for data processing, signal transmission, and system control were also developed to build up a complete system. Therefore, the proposed configuration system has potential application in the early warning radiation network.

Acknowledgement: This research was supported by the Ministry of Defense Science Project in the KC.AT Program under the Contract No. 3238/2017/HĐKHCHN.

REFERENCES

- [1]. Zheng, J., Tagami, K., Watanabe, Y., Uchida, S., Aono, T., Ishii, N.,... & Ihara, S. (2012). "Isotopic evidence of plutonium release into the environment from the Fukushima DNPP accident". Scientific reports, 2(1), 1-8.
- [2]. Srinivasan, T. N., & Rethinaraj, T. G. (2013). "Fukushima and thereafter: Reassessment of risks of nuclear power". Energy policy, 52, 726-736.
- [3]. Mian, Z., Ramana, M. V., & Nayyar, A. H. (2019). "Nuclear submarines in South Asia: New risks and dangers". Journal for Peace and Nuclear Disarmament, 2(1), 184-202.
- [4]. McArthur, W. C., & Kniazewycz, B. G. (1978). "Radiation monitoring systems: current status and future prospects". IEEE Transactions on Nuclear Science, 25(1), 17-22.
- [5]. Kim, J. H., Lee, J. H., & Lee, S. H. (2019). "Development of New Ocean Radiation Automatic Monitoring System". Journal of IKEEE, 23(2), 743-746.
- [6]. Hiroaki Kato, et al., "Depth distribution of ^{137}Cs , ^{134}Cs , and ^{131}I in soil profile after Fukushima Dai-ichi Nuclear Power Plant Accident", Journal of Environmental Radioactivity, Vol. 111 (2012), pp. 59-64.

- [7]. Daisuke Tsumune, et al., "Distribution of oceanic ^{137}Cs from the Fukushima Dai-ichi Nuclear Power Plant simulated numerically by a regional ocean model", Journal of Environmental Radioactivity, Vol. 111 (2012), pp. 100-108.
- [8]. Kim, Jae-Heong, Joo-Hyun Lee, and Seung-Ho Lee, "Development of New Ocean Radiation Automatic Monitoring System", Journal of IKEEE 23, no. 2 (2019): 743-746.
- [9]. Lee, S., J. S. Lee, H. S. Kim, J. Park, Seungjae Baek, Yujae Song, J-M. Seo, and Soo Mee Kim. "In-situ remotely controllable ocean radiation monitoring system." Journal of Instrumentation 15, no. 06 (2020): P06027.
- [10]. Tsabaris, C., E. G. Androulakaki, S. Alexakis, and D. L. Patiris. "An in-situ gamma-ray spectrometer for the deep ocean." Applied Radiation and Isotopes 142 (2018): 120-127.

TÓM TẮT

PHÁT TRIỂN HỆ THỐNG GIÁM SÁT PHÓNG XẠ THÔNG MINH TRÊN BIỂN

Các hệ thống quan trắc phóng xạ trên biển là một trong những thành phần thiết yếu của mạng lưới cảnh báo sớm phóng xạ hạt nhân để theo dõi mức độ ô nhiễm và dự báo sự lan truyền phóng xạ gây ra bởi các hoạt động liên quan hoặc các sự cố hạt nhân trên biển. Rất nhiều hệ thống này đã được phát triển và lắp đặt trong mạng lưới cảnh báo phóng xạ hạt nhân ở nhiều nước trên thế giới. Tuy nhiên, không có bất kỳ sản phẩm tương tự được nghiên cứu phát triển ở nước ta. Nội dung bài báo này trình bày một quy trình hoàn chỉnh trong việc thiết kế, chế tạo một hệ phao biển tích hợp cảm biến phóng xạ. Đầu đo phóng xạ có khả năng đo cả tỷ lệ suất liều và phổ phóng xạ. Hệ thống còn được tích hợp nhiều phương thức truyền dữ liệu khác nhau cùng với các phần mềm được phát triển để xử lý dữ liệu, truyền tín hiệu và điều khiển hệ thống. Do đó, sản phẩm nghiên cứu có tiềm năng ứng dụng trên phương diện về hiệu suất sử dụng và quy trình bảo trì.

Từ khóa: Hệ thống quan trắc phóng xạ trên biển; Phao biển; Sự cố hạt nhân; Mạng cảnh báo hạt nhân.

Received 10th October 2021

Revised 08th November 2021

Accepted 11th November 2021

Author affiliations:

¹Department of Physics, Le Quy Don Technical University;

²Military Institute of Chemical and Environmental Engineering (MICEE);

³Faculty of Aerospace Engineering, Le Quy Don Technical University;

⁴Technology Center, Le Quy Don Technical University;

⁵Vietnam Metrology Institute (VMI);

⁶Vietnam National Space Center/VAST (VNSC);

⁷Faculty of Electrical and Electronic Engineering, Phenikaa University.

*Corresponding author: tan.tranduc@phenikaa-uni.edu.vn.