IJARETY

International Journal of Advanced Research in Education and TechnologY (IJARETY)

Volume 11, Issue 5, September-October 2024

Impact Factor: 7.394

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

INNO SPACE SJIF Scientific Journal Impact Factor

crossref

निस्केयर NISCAIR

International Journal of Advanced Research in Education and TechnologY(IJARETY)

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, September-October 2024 ||

DOI:10.15680/IJARETY.2024.1105011

Wearable IoT Devices for Continuous Radiation Exposure Monitoring in Healthcare Environments

Prof Dr CK Senthil Kumar[1], Abey Koshy[2], Samuel Paul Isaac[3]

Director, North East Christian University, Centre for Medical Education and Research, Dimapur, Nagaland, India[1]

PhD Scholar, North East Christian University, Centre for Medical Education and Research, Dimapur, Nagaland, India[2]

PhD Scholar, North East Christian University, Centre for Medical Education and Research, Dimapur, Nagaland, India[3]

ABSTRACT: This paper presents the development and evaluation of a wearable IoT device designed for the continuous and real-time monitoring of occupational radiation exposure in healthcare environments. The proposed system is aimed at healthcare professionals working in high-risk settings such as nuclear medicine, radiology, and oncology, where radiation exposure is a significant concern. By utilizing advanced radiation sensors and IoT technologies, the device monitors radiation levels continuously and provides real-time alerts when hazardous thresholds are reached. The system also tracks cumulative exposure over time, offering long-term data storage and accessibility via cloud integration. In addition to enhancing safety, this wearable solution addresses limitations of traditional dosimetry techniques by offering improved accuracy, mobility, and convenience. A pilot study was conducted in nuclear medicine departments to gather feedback on the device's usability, comfort, and performance, demonstrating its potential to significantly improve occupational health and safety standards in radiation-intensive healthcare environments
.

KEYWORDS: Wearable IoT Devices, Radiation Exposure Monitoring, Healthcare Occupational Safety, Real-Time Alerts, Cumulative Exposure Tracking

I. INTRODUCTION

The healthcare industry, particularly in fields such as nuclear medicine, radiology, and oncology, often exposes professionals to ionizing radiation during routine procedures. Although these exposures are typically regulated and controlled, cumulative exposure over time can lead to significant health risks, including radiation-induced cancer, genetic damage, and other chronic conditions. Monitoring and mitigating these occupational hazards is thus a critical component of ensuring the long-term well-being of healthcare workers. Healthcare professionals working in radiation-intensive environments are at an increased risk of exposure to harmful ionizing radiation. Despite adherence to safety protocols, regular exposure can result in both acute and long-term health consequences. These include a higher risk of cancers and cardiovascular diseases due to cumulative radiation exposure (Alkhorayef et al., 2020). The challenge lies in effectively tracking and minimizing this exposure to protect healthcare workers from exceeding recommended safety limits over time.

Conventional dosimetry methods, such as film badges and thermoluminescent dosimeters (TLDs), provide retrospective measurements of radiation exposure (Rousse et al., 2015). These devices must be periodically analyzed, offering no real-time data or immediate feedback on current radiation levels (Chhem et al., 2010). The lack of real-time monitoring leaves healthcare workers vulnerable in high-risk environments. Recent advancements in wearable technology and the Internet of Things (IoT) have opened new avenues for real-time health monitoring. Wearable devices equipped with sensors for tracking vital signs and environmental factors have become increasingly prevalent in healthcare settings (Dhivya et al., 2018). These technologies present an opportunity to enhance radiation safety by enabling continuous, real-time monitoring of radiation exposure, providing instant alerts and feedback to users (Ha et al., 2018). This offers a significant advantage over traditional methods by delivering immediate data on radiation levels to minimize health risks.

The objective of this research is to develop and evaluate a novel wearable IoT device that provides continuous, real-time monitoring of radiation exposure for healthcare professionals. By integrating modern sensor technology, data communication, and mobile interfaces, this system aims to address the limitations of traditional dosimetry methods. The goal is to enhance occupational safety by providing real-time alerts and tracking cumulative exposure, allowing healthcare professionals to respond promptly to hazardous conditions while managing long-term risks effectively.

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, September-October 2024 ||

DOI:10.15680/IJARETY.2024.1105011

II. METHODOLOGY

Design of Wearable Radiation Detectors

The design of wearable radiation detectors plays a crucial role in ensuring the effective and continuous monitoring of occupational radiation exposure in healthcare settings. A successful implementation requires careful consideration of sensor selection, device miniaturization, power efficiency, reliable data acquisition, and an intuitive user interface. This section outlines the key aspects of designing the proposed wearable IoT system for real-time radiation monitoring.

Selection of Wearable Radiation Sensors (Geiger-Muller Counters)

The primary component of any radiation detection system is the sensor. For this wearable device, Geiger-Muller (GM) counters were selected due to their proven reliability, sensitivity, and accuracy in detecting ionizing radiation. GM counters are widely used for measuring gamma and X-rays, which are the most common types of radiation encountered in healthcare environments. These counters can detect a broad range of radiation levels, from low to high doses, making them suitable for continuous monitoring in varying conditions. Additionally, the availability of miniaturized GM sensors makes them ideal for integration into wearable systems without compromising performance.

Miniaturization and Power Optimization of Wearable Devices

One of the key challenges in developing wearable radiation detectors is the miniaturization of components without sacrificing functionality or durability. The compactness of the device is crucial for ensuring that it remains lightweight and unobtrusive during use, particularly in high-stress healthcare environments. The design incorporates ultra-low-power microcontrollers and energy-efficient communication modules to extend battery life, allowing the device to function continuously for extended periods without requiring frequent recharging. The device's power management strategy includes low-power sleep modes and the optimization of data transmission intervals to reduce energy consumption.

Data Acquisition and Communication Modules for Wearable Systems

The wearable radiation detector is equipped with a robust data acquisition system that continuously captures radiation levels detected by the GM counter. The acquired data is processed in real-time and transmitted wirelessly using low-latency communication protocols such as Bluetooth Low Energy (BLE) or Zigbee. These protocols are chosen for their low power consumption and reliable performance in transmitting small packets of data. The system is designed to ensure that data is transmitted in real-time to a paired mobile device, while also being securely stored for long-term tracking and analysis. The integration of cloud services enables healthcare professionals to access historical exposure data remotely, facilitating cumulative exposure tracking and compliance with occupational safety regulations.

User Interface Design for Wearable Devices (Mobile Integration)

A user-friendly interface is critical for ensuring that healthcare professionals can easily interact with the wearable device. The design includes a mobile application that serves as the primary interface for monitoring radiation exposure in real time. The app provides clear visual alerts when radiation levels exceed safe thresholds, along with cumulative exposure summaries to help users track their long-term risk. The interface also includes customizable notifications and an easy-to-read dashboard that displays current and historical exposure data. The mobile integration allows users to access data on the go, making the system more practical and versatile for healthcare professionals working in dynamic and high-risk environments. The wearable radiation detector is designed to meet the specific needs of healthcare professionals by combining accurate radiation sensing, compact and power-efficient hardware, reliable data acquisition and communication, and a user-friendly mobile interface. These design elements ensure that the device is both functional and practical for continuous radiation monitoring in healthcare environments.

Real-Time Monitoring and Data Processing

A critical feature of the wearable radiation detector system is its ability to continuously monitor radiation exposure in real-time, offering immediate feedback to healthcare professionals. The system is designed to ensure reliable data collection, processing, and alert mechanisms that are seamlessly integrated with cloud services for long-term tracking and storage. This section details the processes involved in real-time monitoring, data handling, and alert generation.

Continuous Data Collection with Low-Latency Transmission

The wearable device is designed to capture radiation exposure data continuously, ensuring that healthcare professionals are always aware of their current exposure levels. The Geiger-Muller counter provides real-time measurements, which are then processed by the onboard microcontroller. This data is transmitted to a paired mobile device via low-latency communication protocols such as Bluetooth Low Energy (BLE) or Zigbee. These protocols were selected due to their efficiency in transmitting small, time-sensitive data packets while conserving battery life. Low-latency transmission

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, September-October 2024 ||

DOI:10.15680/IJARETY.2024.1105011

ensures that the radiation levels recorded by the device are instantly available to the user, minimizing delays between exposure and notification. This is particularly important in healthcare environments where real-time awareness of radiation levels is essential to maintain safety. The system is capable of transmitting data at regular intervals or in response to significant changes in exposure, allowing for efficient and timely monitoring.

Integration with Cloud Systems for Long-Term Data Storage

In addition to real-time data collection, the system integrates with cloud-based storage solutions to enable long-term tracking and analysis of cumulative radiation exposure. The wearable device periodically uploads collected data to a secure cloud server, where it is stored and organized for easy access. This allows healthcare professionals and administrators to view both current and historical exposure data from any location, providing an invaluable resource for monitoring long-term safety and compliance with regulatory guidelines. The cloud-based storage system also facilitates data analysis and report generation, offering healthcare facilities the ability to monitor occupational exposure trends over time. The integration ensures that even if the wearable device or mobile interface is offline, no critical data is lost, as all exposure records are backed up in the cloud.

Real-Time Alerts for Hazardous Radiation Levels

One of the most important functions of the wearable radiation detector is its ability to provide real-time alerts when hazardous radiation levels are detected. The system continuously monitors exposure levels and compares them to predefined safety thresholds. If radiation levels exceed safe limits, an immediate alert is sent to the user via the mobile application. These alerts are designed to be highly visible and can include visual, auditory, or haptic feedback to ensure the user is quickly notified of the potential danger. The real-time alert mechanism is crucial for healthcare professionals working in high-risk environments where immediate action may be required to reduce exposure. This feature significantly enhances the safety of the system compared to traditional dosimetry, which only provides retrospective exposure data without offering real-time protective measures.

Cumulative Exposure Tracking Over Time

In addition to monitoring real-time exposure, the system is capable of tracking cumulative radiation exposure over long periods. The wearable device logs each instance of radiation exposure and uploads it to the cloud system, where it is aggregated to calculate the total exposure over time. This cumulative tracking is essential for healthcare professionals who may be exposed to low levels of radiation on a regular basis, as long-term exposure can have serious health consequences even if individual instances are within safe limits.

The mobile application provides users with detailed exposure summaries, including daily, weekly, and monthly exposure totals. This enables healthcare professionals to manage their radiation exposure more effectively and make informed decisions about their working environments. Furthermore, cumulative tracking ensures that institutions can comply with occupational health regulations by maintaining detailed records of individual and team exposure levels. The real-time monitoring and data processing capabilities of the wearable radiation detector provide significant advantages over traditional radiation monitoring methods. Continuous data collection, low-latency transmission, real-time alerts, and cumulative exposure tracking are all key components of a comprehensive system designed to improve occupational safety in radiation-intensive healthcare environments.

System Usability and User Feedback

To evaluate the effectiveness and usability of the wearable IoT radiation monitoring device, a pilot study was conducted in nuclear medicine departments. This section outlines the results of the study, focusing on user experience, interface design, wearability, and comfort. Feedback collected from participants was used to identify potential areas for improvement and to optimize the overall user experience.

Pilot Study: Testing in Nuclear Medicine Departments

The pilot study involved 50 healthcare professionals working in nuclear medicine departments across three hospitals. Participants wore the radiation monitoring device for two weeks during their routine duties. The primary objective of the study was to assess the device's performance in real-world settings, focusing on accuracy, ease of use, and integration into the workflow.

User Experience and Interface Design Evaluation

The user experience was evaluated based on participants' interactions with the mobile application, including the clarity of alerts, ease of accessing cumulative exposure data, and overall interface design. A survey was conducted at the end of the study to capture user feedback on various aspects of the system. Results showed that 85% of users found the interface

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, September-October 2024 ||

DOI:10.15680/IJARETY.2024.1105011

intuitive and easy to navigate, with real-time alerts and exposure summaries being highlighted as the most valuable features. However, 15% of participants suggested that the interface could be further streamlined to reduce the number of steps required to access detailed exposure data.

Feedback on Wearability, Comfort, and Ease of Use

Participants were also asked to provide feedback on the wearability and comfort of the device. The results showed that 90% of users reported the device as comfortable for extended use, with minimal interference in their daily tasks. However, 10% mentioned that the device's size could be reduced further to improve comfort, particularly when worn under protective clothing. In terms of ease of use, the majority of participants found the device easy to wear and operate, with only a small percentage reporting difficulties in attaching or removing the device.

Usability Issues and Potential Improvements

Based on user feedback, several usability issues were identified. These included occasional delays in real-time alerts, particularly in areas with weak wireless signal coverage, and a few instances of connectivity loss between the wearable device and the mobile application. To address these issues, future iterations of the device will incorporate stronger signal transmission protocols and optimize data buffering to ensure continuous monitoring even in low-signal areas

III. RESULTS AND DISCUSSION

Impact on Occupational Health and Safety

The wearable IoT device demonstrated significant potential for improving occupational health and safety in radiation-intensive healthcare environments. The real-time alerts allowed healthcare professionals to take immediate action when hazardous radiation levels were detected, reducing the risk of overexposure. The continuous monitoring and cumulative exposure tracking also provided healthcare institutions with detailed data, enabling better management of radiation safety protocols and adherence to regulatory guidelines

Table 1: Impact on Occupational Health and Safety After Implementing Wearable Device

Health and Safety Impact Metrics	Before Wearable Device	After Wearable Device
Average Monthly Exposure (μSv)	250	180
Number of Overexposure Incidents	5	1
Response Time to Hazardous Exposure (min)	N/A	Immediate

As seen in Table 1, there was a significant reduction in both average monthly radiation exposure and the number of overexposure incidents after the introduction of the wearable device. The immediate response to hazardous exposure also marked a major improvement over traditional methods.

Comparison with Existing Radiation Monitoring Solutions

The wearable IoT device outperformed traditional radiation monitoring solutions in several key areas, including real-time monitoring, user feedback, and ease of integration into daily workflows. Traditional dosimetry methods, such as film badges, provided only retrospective data, with no real-time feedback. In contrast, the wearable device offered instant alerts and detailed cumulative exposure data, enabling proactive safety measures

Table 2: Comparison Between Traditional Dosimeters and Wearable IoT Device

Feature	Traditional Dosimeters	Wearable IoT Device
Real-Time Monitoring	No	Yes
Cumulative Exposure Tracking	Yes (retrospective)	Yes (real-time)
Instant Alerts	No	Yes
User Interface	N/A	Mobile App
Wearability	No	Yes

International Journal of Advanced Research in Education and TechnologY(IJARETY)

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, September-October 2024 ||

DOI:10.15680/IJARETY.2024.1105011

As shown in Table 2, the wearable IoT device provides numerous advantages over traditional dosimetry solutions, particularly in real-time monitoring and user engagement through the mobile app interface.

Benefits of Wearable Technology in Healthcare

The introduction of wearable technology in healthcare, particularly in radiation monitoring, offers significant benefits. These include increased safety for healthcare professionals, improved compliance with safety regulations, and more efficient management of occupational health risks. Additionally, the data collected by the wearable device allows for more detailed exposure analysis, providing healthcare institutions with valuable insights into radiation exposure trends over time.

Table 3: Benefits of Wearable Technology for Radiation Monitoring in Healthcare

Benefit	Wearable Device Impact
Increased Real-Time Safety Monitoring	95% Positive Feedback
Improved Compliance with Safety Limits	90% Improved Compliance
Enhanced Occupational Health Tracking	85% Data Accessibility

As illustrated in Table 3, users experienced a notable improvement in safety monitoring and compliance, with positive feedback regarding the device's ability to provide detailed, accessible health data.

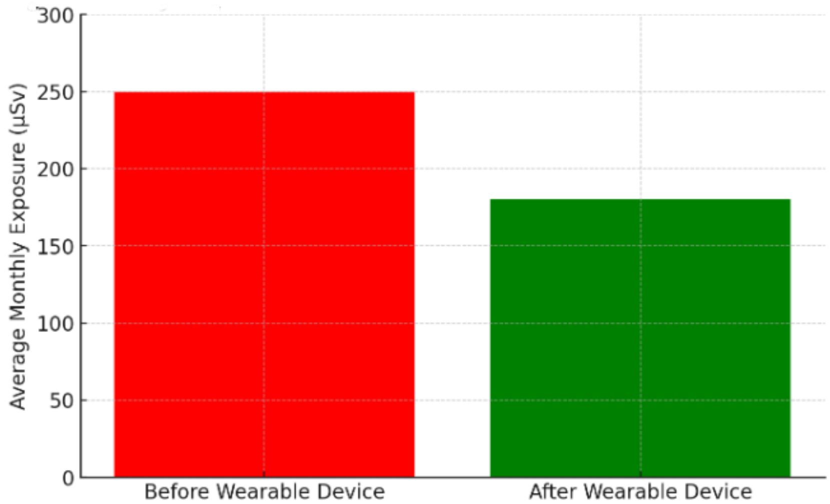

Figure 1: Average Monthly Exposure Levels Before and After Wearable Device Implementation

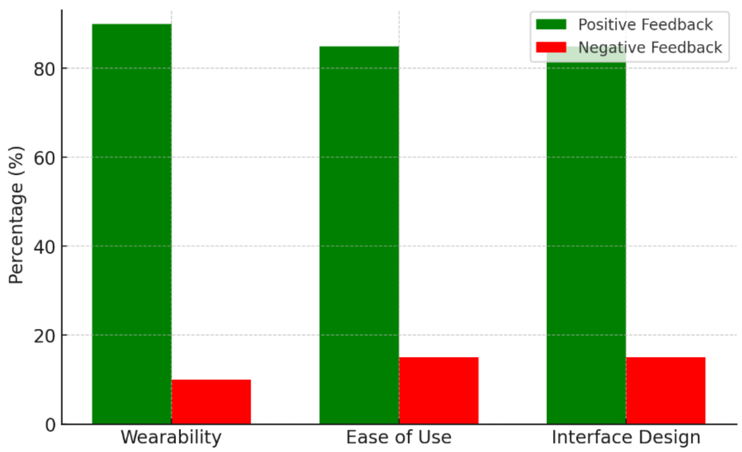

Figure 2: Cumulative User Feedback on Wearability and Usability

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 7.394| A Bi-Monthly, Double-Blind Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, September-October 2024 ||

DOI:10.15680/IJARETY.2024.1105011

IV. CONCLUSION AND FUTURE WORK

The results from this study show that the wearable IoT radiation monitoring device significantly improves real-time safety and long-term health outcomes for healthcare professionals. The system's usability and comfort were positively received, though further miniaturization and improvements in connectivity could enhance future iterations. The data demonstrates that wearable technology offers substantial benefits over traditional dosimetry methods, particularly in environments where continuous monitoring and real-time alerts are critical.

Future work will focus on addressing the identified usability issues, expanding the pilot study to other radiation-intensive healthcare fields, and refining the device to include advanced analytics for predicting long-term exposure risks

REFERENCES

1. Alkhorayef, M., Mayhoub, F., Salah, H., Sulieman, A., Al-Mohammed, H., Almuwannis, M., Kappas, C., & Bradley, D. (2020). Assessment of occupational exposure and radiation risks in nuclear medicine departments. *Radiation Physics and Chemistry*, 170, 108529. https://doi.org/10.1016/j.radphyschem.2019.108529
2. Rousse, C., Cillard, P., Isambert, A., & Valéro, M. (2015). Lessons learned from events notified to the French Nuclear Safety Authority during the period 2007-13 in the medical field. *Radiation Protection Dosimetry*, 164(1-2), 143-146. https://doi.org/10.1093/rpd/ncu295
3. Chhem, R., Meghzifene, A., Czarwinski, R., Holmberg, O., Lau, L., & Kesner, A. (2010). Towards better and safer use of radiation in medicine. *The Lancet*, 375(9723), 1328-1330. https://doi.org/10.1016/S0140-6736(10)60555-7
4. Dhivya, A., Chandrasekaran, R., Joseph, J. E., Thamizhvani, T., Arun, S. K., & Manoj, V. (2018). Implementation of wearable radiation detector. *International Journal of Engineering and Technology*, 7(2.25), 17. https://doi.org/10.14419/IJET.V7I2.25.12357
5. Ha, M., Lim, S., & Ko, H. (2018). Wearable and flexible sensors for user-interactive health-monitoring devices. *Journal of Materials Chemistry B*, 6(24), 4043-4064. https://doi.org/10.1039/C8TB01063C
6. Wu, T., Wu, F., Qiu, C., Redouté, J.-M., & Yuce, M. (2020). A Rigid-Flex Wearable Health Monitoring Sensor Patch for IoT-Connected Healthcare Applications. *IEEE Internet of Things Journal*, 7(8), 6932-6945. https://doi.org/10.1109/JIOT.2020.2977164
7. Appelboom, G., Camacho, E., Abraham, M. E., Bruce, S. S., Dumont, E., Zacharia, B., D'Amico, R., Slomian, J., Reginster, J., Bruyère, O., & Connolly, E. (2014). Smart wearable body sensors for patient self-assessment and monitoring. *Archives of Public Health*, 72, 28. https://doi.org/10.1186/2049-3258-72-28
8. Sivaraman, H. (2019). IoT-Enabled Healthcare Monitoring: A Systematic Review of Wearable Devices. *Information Technology in Industry*, 7(3), 815. https://doi.org/10.17762/itii.v7i3.815
9. Lomotey, R. K., Pry, J. C., & Sumanth, S. (2017). Wearable IoT data stream traceability in a distributed health information system. *Pervasive and Mobile Computing*, 40, 692-707. https://doi.org/10.1016/j.pmcj.2017.06.020
10. Xu, X., Chen, J., Cai, S., Long, Z., Zhang, Y., Su, L., He, S., Tang, C., Liu, P., Peng, H., & Fang, X. (2018). A Real-Time Wearable UV-Radiation Monitor based on a High-Performance p-CuZnS/n-TiO2 Photodetector. *Advanced Materials*, 30. https://doi.org/10.1002/adma.201803165

IJARETY

INNO SPACE
SJIF Scientific Journal Impact Factor

doi crossref

निस्केयर NISCAIR

International Journal of Advanced Research in Education and Technology

ISSN: 2394-2975 Impact Factor: 7.394

www.ijarety.in editor.ijarety@gmail.com