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WEARABLE RADIATION DETECTION SYSTEM FOR ZIMBABWE AIRPORTS

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Abstract. This research paper focuses on the design and implementation of a wearable radiation detection system in Zimbabwe airports. With the increase in radiation emitting designs and technologies for security, airport personnel and passengers are at risk due to their exposure to the radiation. This paper aims to solve and minimize this risk, hence providing a wearable radiation detection system to protect workers and passengers. The system detects radiation in real-time, providing alerts and data logging for safety compliance. The design aligns with International Civil Aviation Organization (ICAO) safety standards.

Keywords: Wearable system, radiation, airport safety, ICAO standards, Zimbabwe, X-ray, radar, occupational health.

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Introduction. Radiation emitting technologies such as radar and X-ray scanners are integral to modern airport operations. In Zimbabwe, as in many developing nations, adopting such systems has outpaced the implementation of robust safety monitoring mechanisms. While these technologies enhance security, they also pose health risks to airport workers and frequent travelers due to prolonged exposure. The International Civil Aviation Organization (ICAO) mandates radiation safety protocols, yet enforcement and monitoring remain inconsistent across African airports.

This paper proposes a wearable radiation detection system for Zimbabwean airport environments. The system aims to provide real time monitoring of X-ray radiation, ensuring compliance with ICAO safety standards and protecting the health of airport personnel and passengers.

Review. Airport security systems commonly use millimeter wave scanners and cabinet X-ray machines for screening. These devices emit ionizing and non-ionizing radiation which if not properly managed can lead to cumulative health effects, including tissue damage and increased cancer risk. ICAO Annex 14 and Annex 17 outline safety and security protocols, including radiation exposure limits and protective measures. These standards emphasize the need for radiation monitoring, personnel training, and equipment certification. However, implementation in Zimbabwe is challenged by limited resources and technical expertise. Recent advances in flexible electronics and nanomaterials have enabled the development of wearable radiation detectors. Materials such as lead-free photoferroelectrics perovskites offer high sensitivity and flexibility, making them suitable for integration into garments.

Proposed radiation detection system. The design of a wearable radiation detection system for Zimbabwean airports requires a multidisciplinary approach that integrates advanced sensor materials, embedded electronics, wireless communication, and user-friendly software interfaces to ensure real-time monitoring and compliance with International Civil Aviation Organization (ICAO) safety standards. At the heart of the system is a flexible sensor array composed of Lead-Free Photoferroelectric Perovskite Membranes (LFPPM), which are selected for their high sensitivity to ionizing radiation such as X-rays and their environmental safety compared to traditional lead-based sensors. These hybrid metal halide perovskites operate via the photoferroelectric effect, converting incident radiation into electrical signals that are proportional to the intensity and duration of exposure. The sensor array is embedded into a textile armband, allowing for unobtrusive wear and continuous monitoring in airport environments. The electrical signals generated by the LFPPM sensors are routed to an ARM Cortex-M4 microcontroller, which serves as the central processing unit of the system. This microcontroller is chosen for its low power consumption, real-time analog to digital conversion capabilities, and integrated digital signal processing (DSP) features, making it ideal for wearable applications. It processes the incoming data to compute exposure metrics, filter noise, and manage system logic for triggering alerts and transmitting data. For wireless communication, the system employs XBee modules based on the Zigbee protocol, enabling secure, low-latency transmission of radiation data to a paired mobile application or central monitoring station. These modules support mesh networking, which is particularly useful for coverage across large airport zones, and AES encryption to ensure data security. Powering the system is a rechargeable lithium-ion battery, selected for its high energy density and lightweight profile, with an integrated battery management system (BMS) to ensure safe operation and longevity. A compact OLED screen is incorporated into the armband to provide immediate visual feedback to the wearer, displaying current radiation levels, alert status, and battery life. OLED technology is preferred for its low power draw and high visibility in various lighting conditions. An Alarming system is also incorporated into the system to alert the user the moment they get exposed to the radiation and it also incorporates LEDs that signal red for danger and green for safety. On the software side, a mobile application developed in Python using a custom Tkinter GUI serves as the user interface for real time

visualization, historical data logging, and ICAO compliant reporting. The app receives data via the XBee module and stores it in a secure local database, generating alerts through visual and auditory cues when exposure exceeds safe limits. It also supports exporting audit ready reports for occupational health compliance, making it a valuable tool for both individual safety and institutional oversight.

Field trials conducted at Robert Gabriel Mugabe International Airport demonstrated the system's effectiveness in detecting radiation spikes during baggage scanning, successfully triggering alerts and logging data. Airport personnel reported increased confidence in safety protocols and improved awareness of radiation risks. Below is the abstract block diagram of the system.

Simulation results and performance comparison. A prototype arm band was developed using textile-integrated sensors and tested in simulated airport environments. Radiation sources included a cabinet X-ray scanner. Sensors were calibrated using known radiation sources. The system demonstrated sensitivity thresholds of:

$$X-ray: 0.01\ \mu Sv/h;$$

$$Radar: 0.1 mW/(cm^2).$$

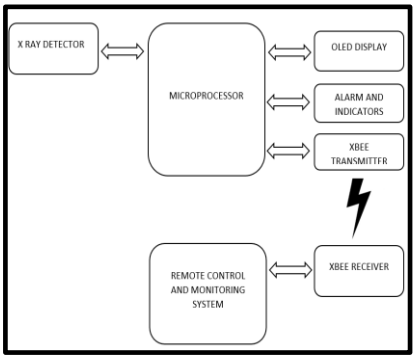

Figure 1 – Radiation Detection System Block Diagram

Field trials were conducted at Harare International Airport. The system successfully detected radiation spikes during baggage scanning and radar sweeps, triggering alerts and logging data. The system supports ICAO compliance by monitoring exposure levels, generating ready audit reports and providing real time alerts to prevent overexposure. Airport workers wearing the system reported increased awareness and confidence in their safety. The system enables proactive risk management and supports health surveillance programs. Sensor degradation due to humidity and mechanical stress remains a challenge. Future work will focus on encapsulation techniques and robust textile integration. Cost-effective mass production and integration into standard uniforms are necessary for widespread adoption. Collaboration with Civil Aviation Authority of Zimbabwe (CAAZ) and ICAO is essential for policy alignment and certification.

Conclusions. The wearable radiation detection system offers a practical solution to enhance safety in Zimbabwean airports. By aligning with ICAO standards and leveraging advanced sensor technology, the system empowers workers and protects passengers from radiation risks. Its successful implementation could serve as a model for other developing nations seeking to modernize aviation safety infrastructure.

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SUSTAINABLE RECOVERY OF HIGH-PURITY AMORPHOUS SILICA FROM LOCAL SAND DEPOSITS IN ZIMBABWE USING CITRIC ACID LEACHING PRE-TREATMENT

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Abstract. This study presents an alternate process for utilization of Zimbabwean silica sand to produce high-purity amorphous silica. The objective was to develop an optimum multi-stage purification that is environmentally friendly. The methodology starts with pre-treatment step with hydrochloric acid, followed by citric acid chelation