Web-based Personal Dose Management System for Data Recording on Dosimeter Usage: A Case of Tanzania AtomicEnergy Commission

Angela Mseke[1+], John Ben Ngatunga[2++], Anael Sam[3+++], Devotha G. Nyambo[3+++],

[1†,3++] The School of Computational and Communication Sciences and Engineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania
[2††] Tanzania Atomic Energy Commission Arusha, Tanzania

Abstract
Modern technology drives the world, increasing performance while reducing labor and time expenses. Tanzania Atomic Energy Commission (TAEC) tracks employee's levels of exposure to radiation sources using dosimeters. According to legal compliance, workers wear dosimeters for three months andone month at the workplace. However, TAEC has problems in tracking, issuing and returning dosimeters because the existing tracking is done manually. The study intended to develop a Personal Dose Management System (PDMS) that processes and manages the data collected by dosimeters for easy and accurate records. During the requirements elicitation process, the study looked at the existing system. PDMS' requirement gathering included document reviews, user interviews, and focused group discussions. Development and testing of the system were implemented by applying the evolutionary prototyping technique. The system provides a login interface for system administrators, radiation officers, and Occupational Exposed Workers. The PDMS grants TAEC Staff access to monitor individual exposed workers, prints individual and institutional reports and manages workers' information. The system reminds the users when to return dosimeters to TAEC, generate reports, and facilitates dispatching and receiving dosimeters effectively. PDMS increases efficiency and effectiveness while minimizing workload, paperwork, and inaccurate records. Therefore, based on the results obtained from the system, it is recommended touse the system to improve dosimeter data management at the institution.

Keywords: *Personal dose management; dosimeter; radiation; worker; exposure.*

1. Introduction

Globally, there has been a noticeable shift in how information and communication technology (ICT) is used in various industries such as agriculture, banking, mining, transportation, and communication, to name a few. Furthermore, the ever-changing technologies brought by the internet have put a lot of pressure on many industries and individuals to access all online resources and stay current with modern technological developments.

The development of a Personal Dose Management System (PDMS) came to light since the Tanzania Atomic Energy Commission (TAEC) has been experiencing problems while collecting, processing, and managing the data obtained through dosimeters worn by workers in radioactive environments. The goal of monitoring each employee's radiation exposure level is to record the level of exposure of each worker who is exposed to radioactive sources. The objectives of reducing the likelihood of deterministic effects such as radiation-induced skin burns and acute radiation syndrome effects occurring and the probability of stochastic such as cancer induction and radiation-induced hereditary effects occurring by keeping the doses as low as reasonably achievable. For a variety of reasons, occupational radiation exposure levels are regularly monitored by the use of dosimeters. The primary reason is to regulate dose limits by routinely monitoring personal dosimetry, one of the most important approaches for attaining, demonstrating, and detecting new dangers due to unacceptable degrees of radiation exposure. It is also one of the key instruments for reaching and showing an adequate degree of radiation protection in the framework of the ALARA principle [1].

The term "dosimetry" refers to the process of determining and measuring the amount or dosage of radiation absorbed by a substance or biological creature using a dosimeter. Dosimetry is routinely used to keep track of people who work with radioactive materials or patients undergoing radiation therapy. A passive radiation detection instrument used for the personal dosemonitoring or measurement of a patient dosage is a Thermoluminescent Dosimeter (TLD) [2]. Different dosimeters used for individual monitoring include film badge dosimeters, thermoluminescent dosimeter, electronic personal dosimeter, and metal-oxide-semiconductor field-effect transistor (MOSFET) dosimeters.

Workers at radiation laboratories must wear dosimeters so that their exposure level to radiation can be accurately

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recorded. This record is required to protect workers from the long-term effects of radiation exposure.

Having only the dosimeter is insufficient unless it is used correctly and monitored on a regular basis.

According to a study conducted by the department of radiation at TAEC, the department's primary function is to ensure that workers in various locations throughout Tanzania who work at radiation sites receive dosimeters and return them after a specified period, typically three months and one month for some few centers. [3].

Thus, TLDs provided to the workers by TAEC are currently not monitored by any online system, but records are kept manually. Therefore, it makes accurate monitoring and management of TLDs impossible due to human errors.

The proposed dosimeter management system will helpusers (workers) and administrators monitor and remind users when to return a dosimeter to TAEC, print individual reports from different sites, and provideinformation about the amount of radiation received by an individual at each site.

As a result, the proposed system will assist administrators and workers in tracking when dosimeters are dispatched and when they must be returned to TAEC. The system will also print individual reports from different locations and retrieve data on how much radiation they received at each location.

2. Literature Review

According to [4], [5] have proven that a database developed with MS-Access to collect annual effective dosages of people, tracked by the Individual Monitoring Service, can highlight critical characteristics.

According to the researcher [4] developed a database that has information on the annual effective dose for workers, which includes roughly 32,700 people who have been under ITN-observation DPRSN since the 1950s. Facilities and personnel that utilize tracking data are included in the database. Health and medical facilities are spread throughout various areas, including traditional industry, research, and mining. The practice or behavior that was reported most frequently in each category has also been identified. Additionally, significant effort needs to be put into collecting and entering all of the data relating to facilities, staff, and the appropriate dosage that other organizations operating in Portugal have documented [4]. According to [5], the authors offer the databases used by the Portuguese Radiological Protection and NuclearSafety Department (DPRSN) in the Individual Monitoring for External Radiation Service (IMS). A dosimetry system using film and another using thermoluminescent detectors are operational at the IMS (TLD).

The database has administrative features for the services and is a good interface for ordinary users. It helps determine who gets the most radiation and helps them figure out the employees with higher doses quickly. However, the researcher recommends the development of databases designed to increase the facility and worker records' closeness, which would enable easy and quick transfers of data and database updates on the National Dose Registry.

The study published by [6] reveals that workers in the Philippines have become more likely to experience occupational exposure, which has made it difficult to follow, monitor, and evaluate this exposure. As a result, the International Atomic Energy Agency (IAEA) commissioned the development of a national dose registry (NDR) to address the problem. The NDR will also act as a centralized repository of occupational external doses whenever requested by the IAEA. This study used PHP with an open-source programming language to develop a web-based system. It gathers occupational external exposure data from IMS providers to make various reports. In addition, this investigation has not yet explained how people are accessing and sending their dosimeters to different locations.

More than 20 years ago, the Brazilian external occupational dose management system was studied [7], found that 120,000 workers who had been individually monitored for ionizing radiation had a centralized data store developed for individuals. A new system was built to minimize manual activities, to handle tedious administrative duties, increase communication between systems, facilitate the creation of reports, and control the data storage.

A study conducted on the effects of radiation exposure on the workers in China addressed many issues in a review study. The paper also provides a fundamental analysis of the current status and issues in personal monitoring. It guides future research into individual monitoring, for instance, the development of tools such as ring dosimetersand eye lens dosimeters [8].

Many researchers across the world, including researchers in Portugal [4], Brazil [7], and the Philippines [9], have done relevant studies on dosage registry systems and national dose registries.

Still, most of these experts failed to describe dosing management and how workers are notified in those countries towards the end of wearing dosimeters. Most of the existing systems continue to be modified and added new

features. Although the implemented systems are useful to their respective countries, they are customized according to the need of the specific institution. The developed system facilitates the procedures for requesting dosimeters, reminding users when to return the dosimeter,and printing quarterly and annual reports for individuals and institutions.

3. Methodology

3.1 Study Area

The study focuses on TAEC Staff, constructors, miners, radiologists, and other radioactive users. The two regions of Arusha and Kilimanjaro, located in the northern part of Tanzania, were surveyed to collect data since both have various facilities using dosimeters. These two regions were selected because they are close to the headquartersof TAEC, where research was done and there are more resources for processing dosimeters are available and it was easy to meet the experts at the center frequently for any urgently needed comments and inputs.

3.2 Data Collection

Data collection methods for this study were carefully considered for getting the needed information. In August 2021, the data collection activity started for four weeks. This was the period used for gathering requirements from the users who are currently using the existing manualsystem. Various data collection techniques such asinterviews, group discussions, and document reviews were employed in the process. Information from different system users was collected. This information became essential for developing the proposed Personal Dose Management system. The Technical Services and Radiation Department in TAEC is responsible for all information on dosimetry usages from all radiation workplaces for monitoring and regulating the levels of exposure to radioactive sources. Interviews were conducted with various users, and documents on the existing systems were studied. Visiting different places was conducted to interview the users of the dosimeter; the process greatly helped obtain data for the system requirements.

3.3 System Development Approach

The qualitative approach used was unstructured interviews with TAEC experts in Technical Support and Radiation, group discussion, and document review of the existing system. Literature reviews are also used to collectsecondary data. Several phases were considered and applied for this project to be completed and implemented, including project planning and selection, requirement analysis, system design and development, and system testing.

3.3.1 Planning and Selection

During the stage of planning and selection, the primary goal was to identify the problem. A literature review was conducted initially to understand the current system and how it works.

3.3.2 Requirement Analysis

It was decided to divide the system requirements into two categories, functional and non-functioning requirements, independently identifying and analyzing eachrequirement. Modules such as login, dashboard, dose management (include add, read, update, and delete), dispatch and receive of the dosimeters process, and other functional requirements are included in the system's requirements. Non-functional requirements included things like maintainability, usability, security, and performance. The requirements for the system were gathered using a variety of different ways for gathering requirements for the system.

3.3.3 System Design

During the system design phase, the conceptual design of the system, the context diagram, the use case diagram, and the database were all designed as discussed in the following sections:

Conceptual Design

Complete conceptual framework helped create the suggested system by structuring and focusing on the concepts [10]. The Personal Dose Management System architecture includes a category for all users who access the web-based system, including occupationally exposed workers, system administrators, and other authorized TAEC staff officers. Tanzania Atomic Energy Commission technical support and radiation service officers are responsible for dispatching and receiving dosimeters. Once a dosimeter is received at TAEC, it is entered into a Harshaw 6000 dosimeter reader. After processing, the results are transferred to the Personal Dose Management system for further action. Occupational Exposed Workers can both retrieve and send data to the system. Fig.1 shows the conceptual design of a personal dose management system.

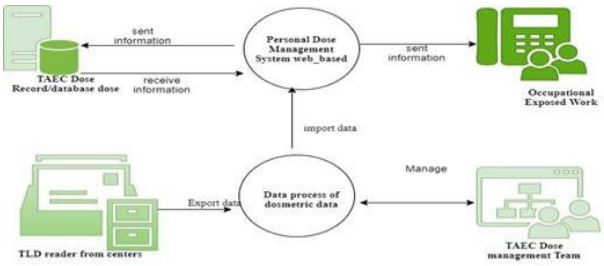

Fig. 1. Conceptual Design for the Proposed System

Context Diagram

The system's design is composed of modules that are integrated to give a personal dose management system. As shown in Fig. 2, the context diagram gives a better overview of the entire solution[11].

Fig. 2. Context Diagram of the Developed System

Use Case Diagram

Use cases show what the system does rather than why it does it. Use cases also have actors, symbols, and connecting lines. Actors are external entities that execute specialized functions outside the system's scope. The system's limits are defined by the actors' communication connections [12].

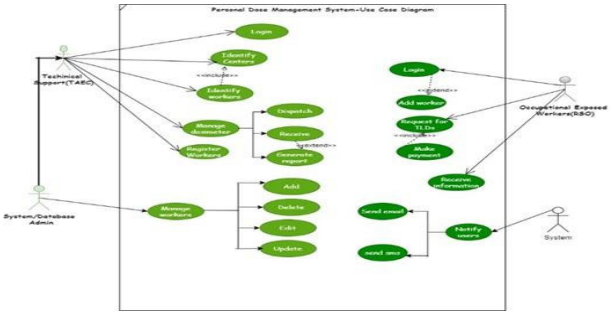

Fig. 3. Use Case Diagram of the proposed system

Before a database's schema or design can be developed, it must be planned. Multiple phases are required, including defining an entity, determining its relationships to other entities, and identifying its attributes. The databasedesigner is responsible for determining which data should be saved and how it should be related to other data. The design of a database is essentially the classification of data and the establishment of its relationships.

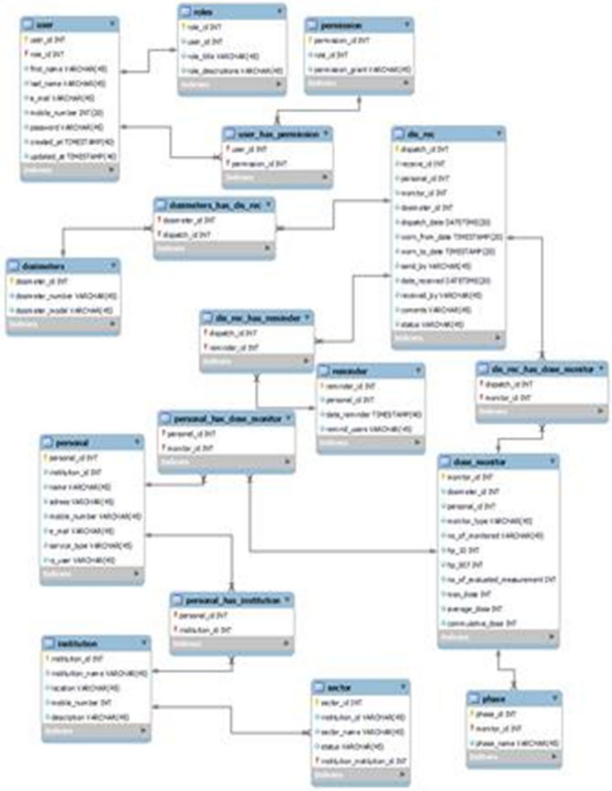

Fig. 4. Database Design of the Proposed System

3.4 System Development Framework

The personal dose management system was developed using client-side tools such as HTML, CSS, Bootstrap, and java scripts and server-side tools such as PHP and MySQL. It has been built around several modules, including login, dashboard, dispatch, and receiving processes for dosimeters, a reminder module, and areport generation module.

4 Results

4.1 Data Collection Resultsa

TAEC dispatches, receive, and prints report as part of the monitoring and controlling dosimeter usage to know the

level of radiation each user receives during the work at the radioactive sources. The current TAEC system for dosimeter management and control is a paper-based system that records and reports the amount of radiation each worker is exposed to.

During the data collection, it was discovered that the officers in the Personal Monitoring Laboratory spent much time on the system because of manual work, and sometimes inaccurate data were recorded because of human error.

During the data collection, the conducted officers said that they face difficulties in tracking dosimeters, recording information, delays in sending reports and results, and sometimes unknowingly, overusing dosimeters. Upgrading the PDMS would enable TAEC to efficiently perform its controlling and management functions with great ease in all radiation sources in Tanzania. The current system uses a logbook to record information on dispatching and receiving dosimeters. The excel calendar is used for dispatch and return dates for a particular institution. The answers gotten from the respondents provided a strong base for developing the proposed system. This means the developed system answers themuch-needed functions for better and effective performances.

4.2 Developed Personal Dose Management System

Based on the facts obtained from the clients, the system was successfully developed for providing the required functions for better services. The developed system has login interfaces for admin, Radiation Safety Officers, and TAEC radiation technical officers. Moreover, the system incorporates dispatching and receiving, reminding, and reporting functional requirements.

Login Interface

Everyone who wants to log in would be able to do so through a single login page. Before being granted access to the administrator-assigned rights, each user must first register with the system by providing their user name and password. Users are directed to a specific page based on the rights they have been granted. The first page of the personal dose management system is a dashboard page with menus for each system's roles available to users

Fig. 5. Shows Login Interface of the Proposed System

Admin

System administrator is visible to the administrator panel after successful login. Only the system administrator can access the newly developed configurations panel, simplifying the menu and submenu navigation.

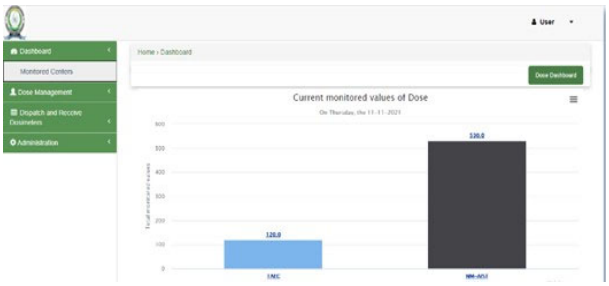

Fig 6. Admin Panel for the Proposed System

Dispatch and Receive Interface

After logging into the system, workers and Tanzania Atomic Energy Commission staff can view the dosimeters received and dispatched status. Additionally, it enables them to add, update and delete workers. The Tanzania Atomic Energy Commission staff are responsible for identifying institutions that require dosimeters and individuals exposed to radiation sources.

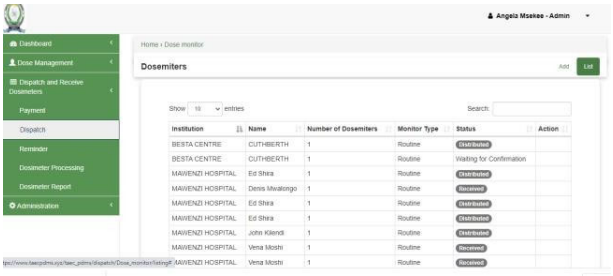

Fig. 7. Shows different institutions with different status of dosimeter.

Reminder Functionality

These are intended to assist those exposed to radioactive sources in determining when their dosimeter wear time will expire. Therefore, it will contact people who have been exposed to radiation sources through email and short messaging services. In this instance, the system is set up to notify individuals two weeks before the dosimeter's service life expires.

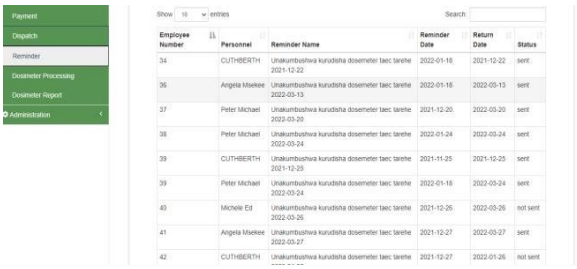

Fig. 8. Reminder Module visualize reminder information for theProposed System

Reports

The dose report module lets users view, download, and print PDF files relevant to certain institutions, sectors, and individual dosage reports.

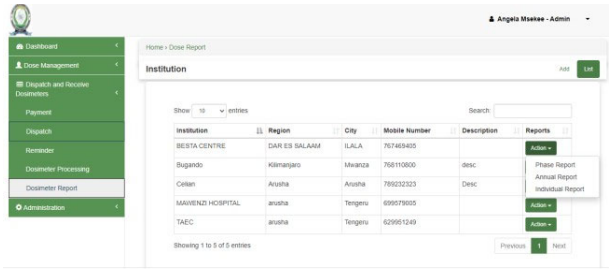

Fig. 9. Report of the different Institutions can be Printed

4.5 System Functional Testing

To ensure that all modules and associated processes were tested and functioned appropriately during the testing phase, functional requirement testing was carried out. User requirements were used to develop unit tests, integration tests, and system tests to guarantee that the PDMS functioned successfully. All tests were run per the requirements provided by users to ensure that the function worked well.

Table 1. Functional Requirement Testing

Test Type		Descriptions	ExpectedResu
Login		Tests whether registered users can access the developed system by logging in using their credentials	To successfull system.
Admin		This module tests whether the admin can register users and navigate to configuration panels.	The administra registerusers a administration
Dispatch and receive		Tests in the process of dispatching and receiving dosimeter can be done through a developed system.	The process of and receivingd done throug
Dashboard		Provides shortcut Features for accessing different functions of thesystem.	While logged i can view the can onlyacces right userleve
Reminder		This functionality was tested by notifying users of dosimeters via mobile phones and email when it is time to return dosimeters to the Tanzania Atomic Energy Commission.	Different syste Would be not the date the wearing thedo
Report		This function verifies that users are capable of generating dosage reports for individuals and institutions.	Generation of

Table 2. Non-functional requirements of the proposed PDMS

Requirements	Explanations	System Verification
Maintainability	The systemshould providesupport, modification, and reconfiguration over time.	The developed system provides supports and modification.
Usability	The system has to be simple to operate (interface).	The developed system proved tobe GUI
Performances	The systemshould respond to user queries and handle multiple users.	The system wasverified handle queries and multipleusers.
Security	The system Should allow users to beauthenticated using an encrypted password.	The developedsystem provided with credentials access

5 Discussion

The developed PDMS tried to satisfy all of TAEC's standards. The system's graphical user interface (GUI), designed expressly for managing data from dosimeters, is user-friendly and interactive. Its applicability accomplishes the objective through dosimeter services, which process dosimeter data and make it readilyavailable in an online version. Users must have internet access and login using the username and password they created during the registration process. The developed system shows different stages of processing dosimeters from Radiation Safety Officers to the TAEC office. The developed system showed processes such as dosimeter request, payment, payment approval, dosimeter dispatch, receipt of dosimeter, distribution to the exposed workers and reminding of users on when to return dosimeters to TAEC. Most of the existing systems do not have all the features developed in PDMS for example Researcher Alves, 2015 suggests more features should be added tothe existing systems because the other systems do not show the processes of accessing and sending dosimeters to different centers.

According to the study, the system has successfully created reports on specific institutions exposed to radioactive sources. Thorough tests were conducted to validate the system, and it appeared that the objectives of the system were satisfactorily met. Additionally, any non-functional issues identified during the development process were resolved at the time. As a result, it is believed that the project has been satisfactorilyaccomplished with all web-based personal dose management system's functional and non-functional objectives.

6 Conclusion and Recommendations

The developed system, known as PDMS, was presented in the study, followed by system testing. Deployment and validation. According to the results, the developed system will increase efficiency while decreasing manual work at TAEC. The system will help individual employees who have been exposed to radiation sources and they will be routinely monitored. The developed system allows the management of data collected by dosimeters, but it also allows the administrator to add information about sectors, institutions, dosimeters and register occupational employees exposed to radiation. Following that, users of all types will be able to log into the system and navigate to the appropriate page based on their respective roles.

The system minimizes workload and enables TAEC officers to speed up the procedure of processing dosimeters from dispatch to generation of the reports on radiation level for each exposed individual. The web- based management system built was beneficial to various stakeholders, including the health sector, mining, industries, TAEC officers, and in tracking individual workers' reporting and tracking dosimeter usage periods. Other researchers are invited to add more modules not yet implemented for future purposes, such as online payment and tracking modules. The additional modules will be required to enable monitoring of an individual's dosimeterreadings and time spent in a particular area via GPRS and other technologies.

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