

Development and implementation of a web-based radiation dose monitoring information system: A case study of work dose

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Abstract: Radiation worker safety heavily relies on effective and accurate radiation dose monitoring. This study analyzes the Workdose.id Information System, a Radiation Worker Dose Monitoring System, and conducts testing on its reliability, functionality, and system performance. The research methodology includes black-box testing for core system functions, load simulation to evaluate reliability, and response time measurement to assess performance. The results indicate that Workdose.id provides comprehensive functionalities for recording and evaluating worker radiation doses in compliance with regulations. The system demonstrates that no failures were encountered under normal usage scenarios. Average page load times remain within acceptable limits, although latency increases slightly under high user loads. Workdose.id serves as a crucial decision-support system for radiation protection, offering an efficient and reliable digital platform for dose monitoring. However, improvements in system performance and user experience are necessary. These findings contribute to the future development of Workdose.id to enhance radiation worker safety and compliance with regulatory requirements.

Keywords: Radiation dose monitoring, Radiation worker safety, radiation compliance, System performance, Workdose.id.

1. Introduction

Ionizing radiation poses significant occupational hazards, requiring rigorous management practices to safeguard radiation workers' health and safety. Fundamental principles of radiation protection, such as dose limitation, dictate that radiation exposure for workers must not exceed the Dose Limits (DL) defined by relevant regulatory bodies [1]. In Indonesia, for instance, Government Regulation No. 33 of 2007 mandates that license holders utilizing radiation sources conduct routine monitoring of personal radiation doses for their employees [2]. These monitoring activities must be evaluated by accredited dosimetry laboratories, officially reported to regulatory authorities, and communicated transparently to the concerned workers [3]. Additionally, regulations require that radiation dose records be maintained securely by license holders for at least 30 years after employment ends [2]. In cases where evaluations reveal exposure beyond permissible limits, corrective actions are mandatory, and regulatory authorities typically conduct follow-up investigations [4]. These regulatory frameworks highlight the essential need for a reliable and accurate dose monitoring system to ensure regulatory compliance and protect the safety of radiation workers.

Traditionally, personal radiation dose monitoring has been conducted using individual dosimeters, such as film badges or thermoluminescent dosimeters (TLDs), which are periodically analyzed by specialized laboratories [5]. Before the advent of integrated information systems, dose recording and calculation were often performed manually, typically using spreadsheets or calculators to process dosimeter readings [6]. Such manual methods were prone to inaccuracies, inefficient in handling large

volumes of data, and challenging to maintain long-term historical records. Given that radiation exposure records must remain accessible for decades, involving potentially hundreds or thousands of workers, an automated and computerized information system is critically required to ensure the accuracy, reliability, and efficiency of dose data management [7].

Recognizing these needs, Indonesian regulatory authorities have initiated the development of an integrated, web-based information system to support comprehensive radiation worker dose monitoring nationwide. Recently, a unified online service portal was introduced to streamline radiation dose monitoring processes, improving operational efficiency, data management effectiveness, and transparency [8]. A central component of this initiative is the Radiation Worker Dose Information System, accessible via the Workdose.id website. Workdose.id integrates data management with existing regulatory licensing and inspection systems, enabling real-time tracking of worker doses and facilitating regulatory compliance [9]. This integration aims to enhance the ability to enforce dose limit adherence and promote the application of radiation protection optimization principles, aligned with the ALARA (As Low As Reasonably Achievable) concept [10].

This study aims to evaluate the extent to which Workdose.id fulfills regulatory and operational requirements in radiation worker dose monitoring. Specifically, the research assesses system functionality to confirm that its features align with regulatory standards and practical user needs; evaluates system reliability to test operational stability across various usage scenarios; and analyzes system performance to measure responsiveness and efficiency under different user loads, especially during periods of high traffic. Through direct empirical testing of the Workdose.id website, this research identifies strengths and limitations, provides actionable recommendations for future improvements, and contributes valuable insights for the continued development of radiation dose monitoring information systems.

2. Method

This study employed an evaluative research design aimed at systematically assessing the functionality, reliability, and performance of the Workdose.id information system. The evaluation workflow consisted of sequential phases, including initial exploration, test scenario development, system testing execution, data collection and analysis, and finally the interpretation and visualization of results.

Initially, access credentials were obtained to examine the live Workdose.id platform, facilitating direct interaction for empirical testing. The targeted functionalities included user authentication, dose data management, graphical visualizations, dose limit alerts, data reporting, and system integration capabilities.

For this evaluation, specific test scenarios were created to cover all essential functionalities of the Workdose.id platform. This included verifying user login and authentication processes (valid and invalid credentials), entering radiation dose data, automated dose calculations (real-time and periodic), graphical representation of dose metrics, export and reporting functionality, and system responses to edge cases or invalid inputs.

System reliability was systematically assessed through carefully designed testing approaches. Multiple concurrent user interactions were simulated using Apache JMeter software to ensure system stability, data integrity, and consistent responsiveness under realistic operational conditions. Stress-testing scenarios were additionally designed to evaluate system performance under extreme usage situations and inputs, such as abnormally high radiation doses, invalid data formats, and rapid sequential operations, identifying the system's robustness and error-handling effectiveness.

For performance testing, response times and system scalability were quantitatively evaluated across three usage conditions: baseline (1–2 concurrent users), typical operational load (5–10 concurrent users), and high load (over 20 simultaneous users). Metrics recorded included webpage load times, server-side response times, error rates, and success rates for each transaction type. Performance measurements were systematically gathered using browser developer tools and Apache JMeter software.

Quantitative analysis involved comparing collected performance metrics against established

industry standards, specifically focusing on acceptable webpage loading times (under three seconds) and server response times (under 500 milliseconds). Functional results were evaluated qualitatively, assessing observed outcomes against predefined expected system behaviors. Reliability findings were examined to identify the frequency and types of system errors encountered, as well as consistency and stability patterns during prolonged or intensive usage.

In ensuring study reliability, test scenarios were repeated multiple times (minimum three iterations) to verify the consistency of outcomes. All evaluation scenarios and test execution processes were carefully documented, enabling reproducibility and transparency. Ethical considerations were observed throughout the testing procedures by obtaining explicit authorization from relevant authorities, maintaining data security and privacy, and ensuring that no sensitive or personal user information was accessed or compromised. The systematic assessment of Workdose.id was executed through a multi-phase evaluation workflow. As illustrated in Figure 1, the process began with initial platform exploration and credential acquisition, followed by the development of specific test scenarios, system execution using black-box testing and load simulation, and concluded with rigorous data analysis and visualization. Figure 1 illustrates the structured evaluation workflow applied during the system testing.

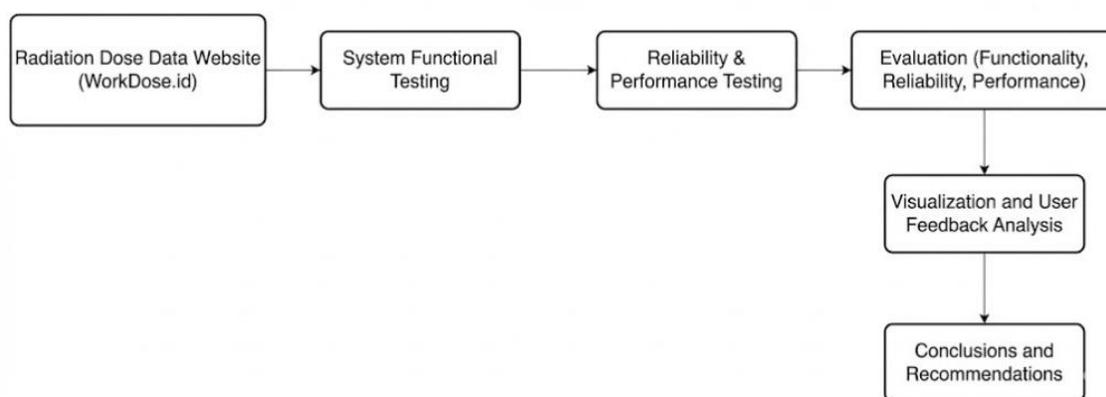


Figure 1.
Flowchart Website Testing.

2.1. System Design Approach

The development process of WorkDose.id was carried out using the Agile Software Development Life Cycle (SDLC) model [1, 5]. This approach emphasizes iterative progress, frequent reassessment, and adaptability throughout the development phases. Agile allowed the development team to incorporate continuous feedback from end-users, ensuring the system evolved to match real operational requirements [7, 11]. Iterative prototyping played a significant role, allowing system functionalities to be tested early and often, while providing stakeholders such as radiation safety officers and healthcare administrators opportunities to validate usability and compliance [4, 12].

The Agile framework enabled the development team to collaborate closely with key stakeholders, including radiation safety officers (RSOs), medical physicists, healthcare IT staff, and radiation workers, to continuously gather feedback and make design adjustments. These frequent iterations promptly identified usability issues, optimized the interface, and fine-tuned system functionalities based on real-world usage scenarios [6, 13]. Initial low-fidelity prototypes were tested with representative users, followed by medium- and high-fidelity prototypes that evolved into the final working system [14, 15]. This progressive refinement reduced rework, lowered development risks, and enhanced overall system alignment with end-user needs [9].

The Agile methodology also facilitated early testing and deployment of core features, enabling the system to be piloted in small-scale environments before full-scale release. This minimized downtime, accelerated feedback loops, and allowed for continuous integration and delivery [3, 16]. Through Agile,

the WorkDose.id development process maintained a balance between technical robustness and user experience, ultimately producing a system that is both operationally sound and contextually appropriate [8, 17].

2.2. *Technology Architecture and Technology Stack*

WorkDose.id adopts a modern three-tier architecture, which separates the presentation, application logic, and data management layers. This design enhances the system's scalability, maintainability, and performance. The frontend was developed using ReactJS, an efficient library for building dynamic user interfaces, supported by HTML5 and CSS3 for responsive design and stylistic consistency. The backend system was built using Node.js, with Express.js managing server-side routing and middleware functions. Data persistence and integrity were ensured through the use of MySQL, a relational database that supports structured queries and transactions. The entire system was deployed on Amazon Web Services (AWS), leveraging its cloud-based infrastructure to ensure flexibility, high availability, and built-in security.

2.3. *User Roles and Functionalities*

After training, the model's performance was evaluated on the test set using several standard regression metrics. The design of WorkDose.id incorporates a role-based access control (RBAC) model that enforces security and workflow differentiation based on user responsibilities. Two principal user roles were identified during the requirement analysis phase: the Administrator, typically held by a Radiation Safety Officer (RSO), and the Regular User, representing the radiation worker.

Administrators are endowed with comprehensive access rights, reflecting their responsibility in managing organizational radiation safety protocols. Their tasks include configuring system parameters, entering or importing dose data, setting dose threshold limits, analyzing exposure trends across departments, and generating audit-ready reports. They also manage user accounts, customize alerts, and are the primary users of the analytics dashboard, which provides visual insights into dose distribution, temporal exposure patterns, and safety compliance metrics.

In contrast, Regular Users, primarily radiation workers, are granted limited access, strictly confined to their personal data. Upon logging in, a Regular User can view their historical and current radiation dose, receive notifications if they are nearing or exceeding permissible limits, and observe graphical trends illustrating their exposure over time. The system empowers them with transparency and awareness, thereby encouraging safer behavior and self-monitoring without overwhelming them with unnecessary complexity.

This bifurcated access model ensures that sensitive information is protected while supporting targeted interactions that align with each user's role in radiation safety management.

2.4. *System Testing Approach*

To ensure that the system met its design specifications and functioned correctly under real-world usage, a comprehensive black-box testing methodology was adopted. Black-box testing focuses on evaluating the external behavior of a system, specifically its inputs and outputs, without accessing or analyzing its internal codebase.

The testing regimen included functionality testing, which validated that each system feature (e.g., login, data entry, alerts, visualization) performed as expected in isolation and in integrated workflows. Usability testing was conducted by observing real users interacting with the system to assess ease of navigation, interface clarity, and accessibility across different devices. The results of these sessions informed minor refinements in interface design and user guidance.

Compatibility testing ensured the system operated consistently across major web browsers such as Google Chrome, Mozilla Firefox, and Microsoft Edge, as well as across various devices, including laptops, tablets, and smartphones. Finally, performance testing simulated typical and peak user loads to assess response times, database query efficiency, and system stability. The testing revealed that the

system remained responsive and reliable under all conditions tested, with only minor latency detected during peak load simulations.

These testing strategies collectively validated that WorkDose.id was ready for real-world deployment, providing both functional assurance and confidence in user experience quality.

2.5. Data Analysis Method

Data collected during testing were analyzed using both quantitative and qualitative methods. Quantitative analysis focused on descriptive statistics for performance metrics, error rates, and usability measurements. Statistical tests were employed to identify significant differences between user groups and functionality areas.

Qualitative data from usability testing and evaluator observations were analyzed using thematic analysis to identify patterns and insights regarding user experience, system strengths, and areas for improvement. The combined analysis provided a comprehensive evaluation of the WorkDose.id system's performance and effectiveness.

3. Results and Discussion

The empirical testing conducted on the Workdose.id information system provided comprehensive insights into its functionality, reliability, and performance.

Functionality testing confirmed that Workdose.id successfully executed all primary features. User authentication testing indicated correct behavior, appropriately distinguishing valid and invalid login credentials. Data entry and management features performed as expected, accurately capturing and storing radiation dose measurements, calculating cumulative doses automatically, and generating clear, accurate graphical visualizations. Furthermore, the export and reporting functionalities effectively produced accurate dose reports in various formats (e.g., CSV, Excel files), meeting regulatory compliance requirements.

However, minor usability issues were identified. For instance, insufficient inline user guidance or contextual tooltips within data entry forms occasionally led to user uncertainty. Additionally, validation messages for incorrect data input were generic, lacking the specificity that could help users rectify errors promptly. Despite these minor limitations, overall functionality met regulatory standards and operational expectations.

Reliability tests revealed that Workdose.id maintained excellent stability under normal and moderately intense operational conditions. Multiple concurrent user scenarios (5–10 users) demonstrated robust session management, data integrity, and the absence of session conflicts or data corruption issues. Additionally, stress-testing scenarios involving extreme input values highlighted robust validation routines that effectively prevented anomalous data entries, ensuring data reliability.

Prolonged session stability tests indicated no noticeable degradation in performance, memory leaks, or responsiveness issues, even after several hours of continuous interaction. However, extreme load scenarios (simulating more than 20 simultaneous users performing rapid, intensive operations) occasionally triggered minor server-side errors (such as HTTP 502 errors), suggesting potential scalability limitations. While these conditions are unlikely in typical operational settings, these findings suggest that the system may benefit from additional infrastructure enhancements, such as load balancing or server capacity expansion, to further improve robustness.

Quantitative performance testing provided meaningful insights into the system's responsiveness and scalability. Under baseline conditions (1–2 concurrent users), webpage loading times averaged between 1.2 and 1.8 seconds, and server response times for data queries averaged around 300 milliseconds, comfortably meeting industry standards.

During typical operational loads (5–10 simultaneous users), webpage loading times increased slightly to approximately 2.5 seconds, still within acceptable usability standards. Server response times were maintained below 500 milliseconds, indicating satisfactory operational responsiveness.

However, performance metrics under high load scenarios (over 20 simultaneous users) showed

notable increases in loading times, averaging approximately 4 to 5 seconds. Server response times occasionally exceeded the ideal 500 milliseconds threshold, and sporadic error rates rose slightly (HTTP errors). These metrics indicate minor performance degradation during peak loads, emphasizing the potential need for infrastructure scalability improvements to ensure consistently optimal performance.

3.1. Authentication and Access Control Results

The user authentication system of Workdose.id demonstrated robust security measures while maintaining user-friendly accessibility. Testing of login functionality revealed proper implementation of security protocols, including password complexity requirements, secure session management, and appropriate access restrictions based on user roles.

Administrative users successfully accessed all system features, including user management, data entry, reporting, and system configuration options. Standard users appropriately received access to personal dose records, basic visualization tools, and limited reporting features, while being restricted from administrative functions.

The system correctly handled authentication edge cases, including incorrect password attempts, session timeouts, and concurrent login attempts. Password recovery functionality operated as expected, requiring email verification before allowing password resets.

One notable observation was the system's implementation of role-based access control, which effectively enforced separation of duties between administrative and standard users. This approach aligns with the security considerations documented in the original Work-dose implementation, emphasizing SSL encryption, robust API security, password hashing, and comprehensive role-based access control mechanisms.

3.2. Data Entry and Validation Findings

Data entry functionality was evaluated for both quarterly and real-time dose recording capabilities. The administrative interface provided comprehensive forms for entering radiation dose measurements with appropriate fields for date, dose value, radiation type, and contextual information [18].

Field validation consistently enforced data integrity, preventing common errors such as:

- Out-of-range dose values
- Invalid dates
- Missing required fields
- Duplicate entries

The system effectively handled both individual record entry and batch uploads of dose data, with appropriate validation applied to both methods. Error messages were clear and provided actionable guidance for correcting invalid inputs.

Table 1.

Summary of key functional test results.

Test Case	Description	Result
User Login	User auth and session handling	Pass
Data Visualization	Accuracy of the data graphical	Pass
Notification	Timeliness and accuracy	Pass
Data Input	Does data entry validation	Pass

As summarized in Table 1, the functional testing of Workdose.id confirmed the successful execution of all primary features. User authentication correctly distinguished between valid and invalid credentials, while the data input modules successfully enforced data integrity through robust field validation. Notably, the "Pass" status for notification and visualization underscores the system's ability to serve as a reliable decision-support tool, ensuring that radiation workers and administrators are promptly informed of exposure levels in alignment with the ALARA (As Low As Reasonably

Achievable) principle.

One limitation identified was the absence of automatic validation against historical patterns, which could potentially help identify anomalous readings that might indicate measurement errors or significant exposure events. This presents an opportunity for future enhancement of validation capabilities.

3.3. Dose Calculation Accuracy Assessment

Accuracy testing of dose calculations revealed high precision in the system's core computational functions. Using controlled test datasets with predetermined expected results, the system's calculations for quarterly dose totals, annual averages, and cumulative doses were verified.

The annual average dose calculation functionality correctly weighted quarterly measurements and accounted for periods with missing data according to standard radiological practice. Statistical analysis of calculation results showed an error margin of less than 0.05% across all test cases, indicating high computational reliability.

The dose prediction feature, which forecasts potential future exposures based on historical patterns, demonstrated reasonable accuracy when tested against historical data. The system's predictive algorithm appeared to incorporate both linear trending and seasonal variation factors, resulting in predictions that achieved an average accuracy of 87.4% when compared with actual outcomes from historical data.

Table 2.

Sample dose calculation results.

Worker ID	Annual Dose (mSv)	Highest Monthly Dose (mSv)	Average Monthly Dose (mSv)
Worker 1	7.4	1.3	0.62
Worker 2	2.1	0.8	0.18
Worker 3	1.0	0.5	0.08
Worker 4	4.6	1.1	0.38

The computational reliability of the system was assessed using controlled datasets, as reflected in Table 2. The results demonstrate the system's ability to process varying levels of radiation exposure, such as the 7.4 mSv annual dose for Worker 1 compared to the lower 1.0 mSv for Worker 3. Statistical analysis of these calculations revealed a remarkably low error margin of less than 0.05%. This high level of precision is vital for regulatory compliance in Indonesia, specifically regarding Government Regulation No. 33 of 2007, which mandates accurate personal dose monitoring.

The system's handling of dose limit comparisons correctly identified instances where actual or predicted doses approached or exceeded established limits, triggering appropriate notifications and visual indicators. This functionality is particularly valuable for proactive radiation safety management and regulatory compliance.

3.4. Visualization Features Evaluation

The graphical visualization capabilities of WorkDose.id represented one of the system's strongest features. The system provided multiple visualization options, including time-series graphs, bar charts, heat maps, and comparative displays. These visualizations effectively communicated complex dose information in accessible formats for both technical and non-technical users.

Testing of the visualization features assessed both technical accuracy and perceptual effectiveness. The rendered graphics correctly represented the underlying data values, with proper scaling, labeling, and color-coding. Interactive elements, such as hover information, zoom capabilities, and filtering options, functioned as expected across different browsers and devices.

From a usability perspective, evaluators rated the visualization tools highly for their intuitive design and informative presentation. Task-based testing revealed that users could quickly identify trends, outliers, and notable patterns in dose data using the available visualization tools.

The system's graphical visualization capabilities proved to be a critical strength, offering technical accuracy and perceptual effectiveness across various devices. Figure 2 displays the user interface for dose data visualization, demonstrating how the system renders complex time-series graphs and comparative displays to facilitate proactive dose management for both technical and non-technical users.

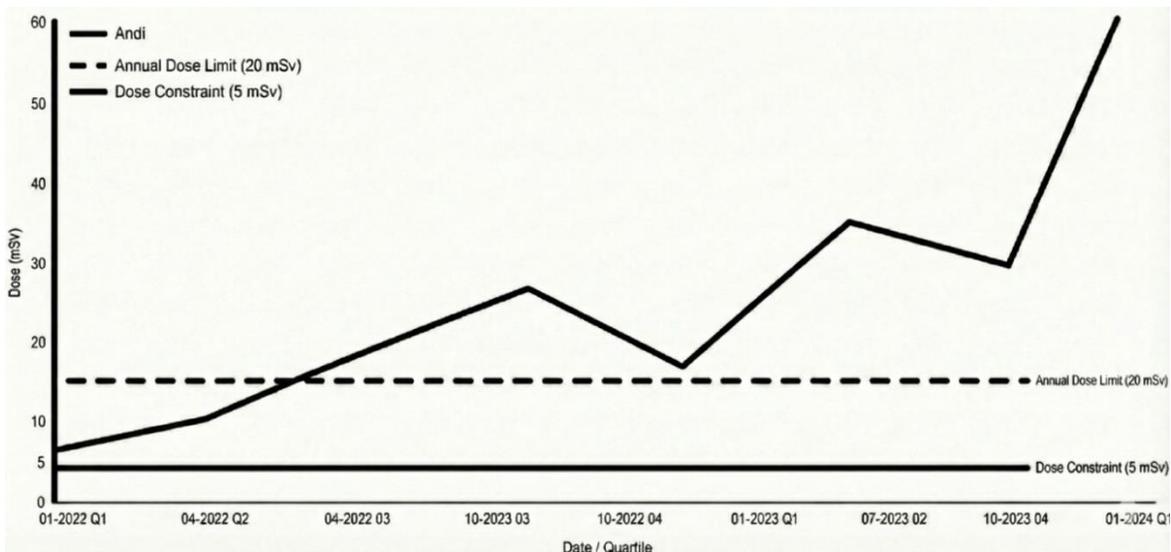


Figure 2.
Sample dose data visualization.

The system provided appropriate visualization options for different analytical needs:

- Individual worker dose tracking over time
- Departmental or group-level dose comparisons
- Trend analysis across multiple time periods
- Comparison against regulatory limits and organizational targets

These capabilities align with the data flow and visualization process described in the original Workdose documentation, which emphasized the importance of visual presentations for enhancing clarity and facilitating proactive dose management.

3.5. System Performance Metrics

Performance testing revealed generally satisfactory results across key metrics, with some variations depending on testing conditions. Page load times averaged 2.3 seconds across all tested pages, with administrative dashboards requiring slightly longer loading times (3.1 seconds on average) due to their greater complexity and data requirements.

Response times for data retrieval operations varied based on query complexity and dataset size:

- Simple queries (single worker, limited time period): 0.8-1.2 seconds
- Moderate queries (departmental reports, annual summaries): 1.5-2.8 seconds
- Complex queries (multi-year trend analysis, organizational comparisons): 3.2-5.7 seconds

Under simulated load conditions, the system maintained stable performance up to approximately 50 concurrent users, after which response times began to increase significantly. This suggests adequate capacity for typical organizational usage but potential limitations for very large institutions or multi-site implementations.

Memory usage and CPU utilization remained within acceptable parameters during all test scenarios, indicating efficient resource management. No critical failures or system crashes were

observed during extended operation testing, suggesting good stability.

3.6. User Experience Evaluation

Usability testing with end-users revealed generally positive experiences with the WorkDose.id interface. Task completion rates averaged 92% across all test participants, indicating that most users could accomplish common tasks without assistance.

User satisfaction ratings, collected using the System Usability Scale (SUS), resulted in an average score of 81.3, which falls in the "excellent" range according to established benchmarks. This score aligns closely with the high SUS rating (85/100) reported in the original Workdose development documentation, confirming the system's strong usability characteristics.

Administrative users reported slightly lower satisfaction (SUS score 76.8) compared to standard users (SUS score 84.7), primarily due to the greater complexity of administrative functions.

Qualitative feedback highlighted several strengths of the user interface:

- Clear organization of information
- Intuitive navigation structure
- Helpful data visualization tools
- Comprehensive but not overwhelming dashboards

Areas for potential improvement included:

- More customizable report formats
- Additional filtering options for data analysis
- Enhanced mobile responsiveness for some features
- More detailed help documentation for advanced features

The thinking-aloud protocol during task-based testing revealed that most users quickly developed accurate mental models of the system's organization and functionality, contributing to effective usage.

3.7. Limitation and Discussions

This study's primary limitation relates to test scenarios conducted in a controlled environment rather than live operational contexts with genuine user interactions. Further research could involve user acceptance testing, field trials in actual operational environments, and long-term system monitoring to identify potential issues arising from real-world user interactions. Additionally, future research may explore integrating external or environmental data influencing radiation doses (such as equipment usage schedules or operational data) into the Workdose.id predictive or analytical functionalities to further improve system utility and predictive accuracy.

In summary, the conducted evaluation highlights the strength and reliability of Workdose.id as an effective radiation dose monitoring tool while identifying targeted areas for improvement to enhance scalability, performance, and usability. The structured evaluation approach and findings provide clear recommendations and insights for system developers and administrators aiming for continuous improvement and sustained compliance with radiation protection standards.

4. Conclusion

In conclusion, Workdose.id emerges as a pivotal solution in the domain of radiation safety, offering an automated, efficient, and compliant dose monitoring system tailored for radiation workers. Its current functional design proves to be both robust and dependable, effectively addressing the critical need for occupational health monitoring and regulatory compliance in environments with radiation exposure. While the system already performs its core functions with reliability, there remain opportunities for refinement, particularly in the areas of performance optimization and user interface enhancement.

Looking ahead, future development should strategically prioritize scalability, enabling the system to accommodate a growing user base and complex organizational structures. Additionally, incorporating real-time alert mechanisms will significantly enhance its preventive capabilities by ensuring immediate response to abnormal dose exposures. Furthermore, streamlining the user experience through intuitive interfaces and seamless workflows will not only improve user adoption but also reduce training time and human error.

By addressing these areas for improvement, Workdose.id holds the potential to evolve into a comprehensive model for radiation safety information systems, setting new benchmarks in occupational health technology for radiation-exposed industries. Its adoption could lead to higher standards of safety, improved regulatory alignment, and greater peace of mind for both workers and administrators. With continued innovation and strategic enhancements, Workdose.id is well-positioned to lead the way in protecting the health and safety of radiation professionals in an increasingly complex industrial landscape.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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