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Development of a Quality Assurance Safety Assessment Database for Near Surface Radioactive Waste Disposal

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Abstract

A quality assurance safety assessment database, called QUARK (QUality Assurance Program for Radioactive Waste Management in Korea), has been developed to manage both analysis information and parameter database for safety assessment of low- and intermediate-level radioactive waste (LILW) disposal facility in Korea. QUARK is such a tool that serves QA purposes for managing safety assessment information properly and securely. In QUARK, the information is organized and linked to maximize the integrity of information and traceability. QUARK provides guidance to conduct safety assessment analysis, from scenario generation to result analysis, and provides a window to inspect and trace previous safety assessment analysis and parameter values. QUARK also provides default database for safety assessment staff who construct input data files using SAGE(Safety Assessment Groundwater Evaluation), a safety assessment computer code.

Key Words : quality assurance, safety assessment, database, low- and intermediate-level radioactive waste disposal, confidence building

1. Introduction

Quality Assurance (QA) is an important factor in building confidence in the safety assessment for a near surface radioactive waste disposal facility. Safety assessment of disposal facility involves large amounts of information. The information includes scenario development, conceptualization, calculations, results analysis, and parameter values used in calculations. As the project proceeds from preliminary to comprehensive stages, the information becomes complicated. Application of QA standards is a means of ensuring that activities are properly planned, data and methods are properly documented, and an auditable trail is developed as the safety analysis proceeds. QA procedures provide a tool to ensure that sources of input data are traceable and that analysis are carried out in a reproducible manner.

The use of QA does not necessarily ensure that the analysis is right, but the use of quality procedures does ensure that the decision process is documented, the staff carrying out tasks and reviews are identified, the method of arriving at conclusions is reviewed by identified people and there are clear signoff responsibilities. Properly managing the information according to prescribed QA standards is important to ensure traceability and transparency in safety assessment, which has impacts on regulation and public perception. The seemingly dispersed information has to be integrated into the model assessing the total system of the disposal facility.

In fact, the information from different areas of expertise is more or less related, just in the same way as they are integrated. To uncover the relationship among the information and hardwire them is a step forward to achieve quality assurance for safety assessment. QUARK(QUality Assurance Program for Radioactive Waste Management in Korea), a database program to be described in this paper, is such a tool that serves QA purposes for managing safety assessment information properly and securely. QUARK stores and manages the information related to safety assessment of LILW disposal program undertaken by users.

In QUARK, the information is organized and linked to maximize the integrity of information and traceability. For a program staff, QUARK provides guidance to conduct safety assessment analysis, from scenario generation to result analysis. For a general public, QUARK provides a window to inspect and trace previous safety assessment analysis and parameter values. QUARK also provides default database for safety assessment staff who construct input data files using SAGE(Safety Assessment Groundwater Evaluation), a safety assessment computer code [1,2].

In this paper, QA requirements for safety assessments set up for the development of QUARK are reviewed. Then the structure and content of QUARK and its built-in procedures are described.

2. The Quality Assurance Requirements for Safety Assessments

2.1. The QA Standards for Safety Assessment

As a formal QA standard for radioactive waste disposal facilities (both near-surface disposal and deep geological disposal) in Korea, Ministry of Science and Technology(MOST) Notice No. 92-17, "Quality Assurance Criteria for Radioactive Waste Disposal Facilities" was promulgated in Nov. 1992. This standard specify the well-known 18 criteria for QA based on the internationally recommended requirements from IAEA and US Nuclear QA Standards, but did not provide specific requirements or criteria for safety assessment.

As another technical standard specifying QA requirements for safety assessments, MOST Notice 96-11, "Performance criteria for LILW Repository" can be used. This notice specifies the detailed necessities for assessing the performance of the repository for the LLW disposal. An article related QA is as follows;

- Article 12 (Confidence building) In order to enhance the reliability of the results of the safety analysis and calculations, QA principles and the related specific QA procedures should be applied to all phases of safety assessment process such as input data collection and implementation, modeling, detailed calculations, and comprehensive safety assessment, etc.

As part of the effort to provide specific examples of QA measures that can be applied within the safety assessment process, the QA standards that are being or have been applied in the safety assessment for near surface repositories were reviewed [3,4,5]. Many organizations have no specific quality assurance standards that originate from their own countries, and have been adapting QA standards from other jurisdictions. The standards includes the ISO 9000 and 14001 family, the IAEA Code on Quality Assurance for Safety in Nuclear Power Plants and Other Nuclear Installations and Safety Guides to describe acceptable methods of implementing the Code, such as Safety Guide Q8 and Q9. Several US nuclear standards on QA include 10CFR50 Appendix B, NUREG 1293, "Quality Assurance Guidance for a Low Level Radioactive Waste Disposal Facility", NUREG 1383, "Quality Assurance for Characterizing LLRW Disposal Sites", and ASME NQA-1-1989, "Quality Assurance Program Facilities for Nuclear Facilities".

2.2. The QA Requirements for Safety Assessments

The key principle of QA should be transparency and traceable processes from the start to the completion of the safety assessment. Presentation of safety analysis information and results are considered to be an important element in the process. For the confidence building in the safety assessment, all elements of the safety assessment process-i.e., Assessment context, System description, Development and Justification of the Scenarios, Formulation and Implementation of the Models, Performance of Analysis, Interpretation of Results, Comparison against Assessment Criteria, Adequacy of the Safety Case, Review and Modification, Collection of Data and/or Modification of Design - should be reviewed periodically to ensure that the requirements and procedures remain appropriate and adequate [6].

The systematic approach for including or excluding scenarios is to be very well described, together with the criteria defined for this purpose. The process of development and justification of scenarios has to be well-documented, transparent, and enable to trace. Justification of the screening process needs to be defensible. One of the tools for tracking the screening and decisions made could be performed in detailed manner by using the matrix approach, which process is described in ref [7]. At the stage of "Performance Analysis," the confidence building is ensured through the quality assurance which can be interpreted quite broadly to include documentation of assumptions and significant decisions. The case when the results meet the assessment criteria has to be carefully analyzed. In the case of running sensitivity analysis and defining the important model parameters, it may be considered important to review those parameters. This could be achieved by reviewing the variability of the parameters used, by obtaining additional data, etc. which has to be decided case by case.

With respect to QA for safety assessment, the aspects to be required include, but are not limited to;

(1) Decisions in selecting scenario for analysis,
(2) Processes of selecting pathway,
(3) Reasons for selecting particular model,
(4) Sources of all input data, and
(5) All results of the analysis matched to the input data.

KHNP/NETEC has focused considerable effort on the topic of FEPs and their screening and the development of scenarios based on relevant FEPs for LILW disposal. As a result, a computer program named IMFEP_NS(Interaction Matrix and FEPs for Near Surface disposal) was developed to select project FEPs, to make its Interaction Matrix at users°Ø disposal, and to visualize the interface between FEPs and Interaction Matrix [7]. IMFEP_NS aids scenarios development (Item (1) in the above list) and pathways selections (Item (2) in the above list) using systematic approach. This program utilizes modern relational database technology to organize information (FEPs), which, in fact, imposes QA procedures during the process of scenario development and pathway selection. In this regard, this program is required to be embedded into the QUARK as a module.

Similarly, traceability of input and output data (Items (4) and (5) in the above list) must also be assured in safety assessment. To ensure traceability, safety assessment staff must take the following four measures:

(1) Protect integrity of data by linking different parameters that are intrinsically related. Without enforcing relationships, parameters are scattered information, which cannot be traced, inspected, and updated accurately and comprehensively.

(2) Document all the data sources, which include published work, analysis and lab tests performed by the staff, field observations, natural analogue, etc. In cases that expert judgment is required to select the most appropriate values from all of the available sources, the rationale for data selection must also be documented.

(3) Document the use of data in the safety assessment calculations.

(4) Document the results of the safety assessment calculations.

The purpose of developing QUARK is to manage safety assessment information and parameters under QA guidelines that are consistent with international standards. Figure 1

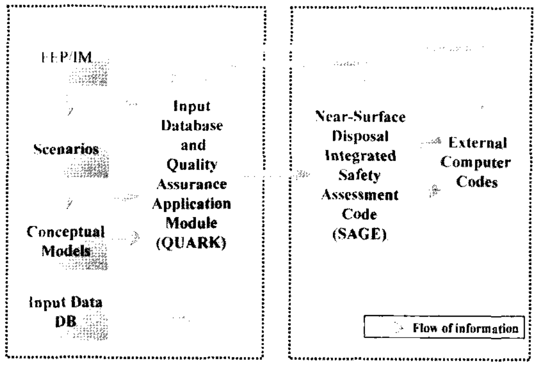

Fig. 1. Interaction and Relationship Between QUARK and SAGE.

shows relationships among safety assessment data, QUARK, and SAGE that will be implemented.

3. QUARK Information System

As illustrated in Figure 2, the information stored in QUARK includes the following two categories:

- Safety assessment analysis that includes scenarios information and analysis documentations, and
- Parameter database.

3.1. Analysis Information

Safety assessment of a radioactive waste disposal program predicts the performance of the disposal system under a series of expected and/or potential disruptive scenarios in order to address uncertainties arising from natural and societal evolution over a long period of time. This activity involves first defining the scenario to be studied, constructing Interaction Matrix or PID(Process Influence Diagram) from FEPs(Features, Events, and Processes), conceptualizing the scenario based on the Interaction Matrix or PID, performing calculation of the conceptual model, and finally analyzing the results obtained. QUARK is designed to manage the information from these activities

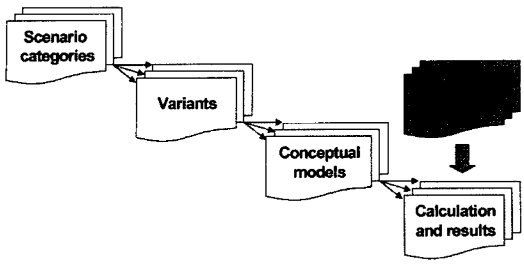

Fig. 2. QUARK Information System and Structure

and display them to public when needed.

Scenario analysis information is organized into a hierarchical structure. The top of this hierarchy is the scenario category. Categorizing scenarios is the first step to organize scenario information appropriately. Currently, there are two categories in QUARK:

(1) 'Design scenario category' is the collection of all radionuclide release scenarios under expected evolution of the disposal system, and

(2) 'Alternative scenario category' is the collection of all release scenarios other than design scenarios, e.g., human intrusion, poor design concepts, and other disruptive events.

It is possible that the alternative scenario category can evolve into several categories. Specific scenarios under each category are called "variants", which constitute the second tier of the information hierarchy in QUARK. Apparently, each category may have multiple variants, as shown in Figure 2. For example, different biosphere pathways (i.e., wells, lakes/ocean, or river) are different scenario variants under the design scenario category. A variant should have detailed information that is required for quantitative analysis.

To analyze a scenario variant, one will first conceptualize the variant. The approach and rationale to establishing conceptual model for a variant constitutes the third tier of the information hierarchy in QUARK as shown in Figure 2. Because the conceptualization for a given variant is non-unique, there may be multiple models for a given scenario variant. If a model is calculated, the parameter values used in calculation and calculation results are the fourth tier of the information hierarchy in QUARK. Important,

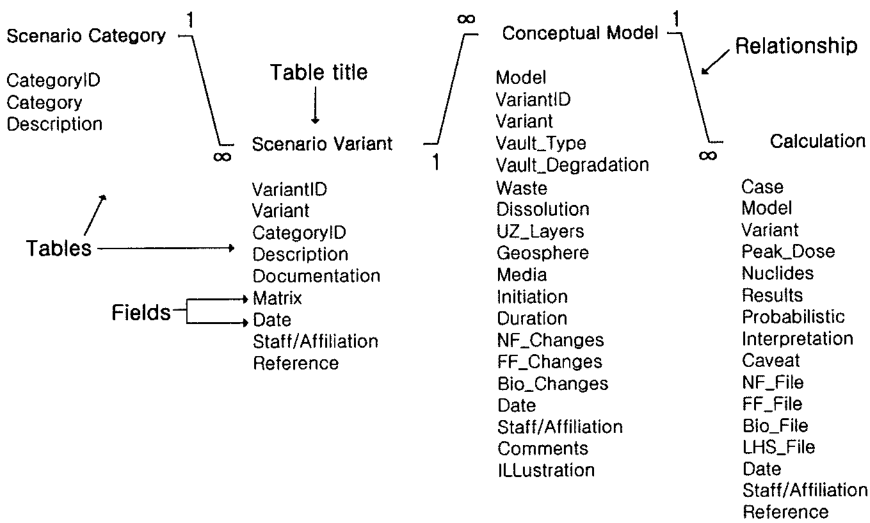

Fig. 3. Implementation of Safety Assessment Scenario Analysis Hierarchy

conclusive description of the results is also contained in this tier of the information hierarchy, along with the input files used. Of course, one model can be calculated several times, each with different parameter value(s) in case of, e.g., emergence of new parameter values. All the results are contained in the fourth tier of the information hierarchy.

Figure 3 illustrates how the information is stored and how the hierarchy shown in Figure 2 is implemented in QUARK. The four boxes shown in the figure represent four tables in QUARK database. The names of the columns are shown in each table. The contents of these columns define a record in the table. For QA purposes, the date when the information is entered, the person and affiliation who performed the entry, and references are required in most of the tables.

In the Scenario Variant table, the column Documentation documents rationales of the scenario variant created from IMFEP_NS [7] that contains IAEA FEP database. The column Matrix in Scenario Variant table is actually the graphic Interaction Matrix that is created from IMFEP_NS during the scenario variant construction.

The columns in the Conceptual Model table are the information necessary for modeling and calculating a specific Variant using SAGE assessment codes. These codes [1, 2] were constructed using the conceptual models that have been adopted by most international LLW disposal programs. Some columns, i.e., Initiation, Duration, NF (Near Field) Changes, FF (Far Field) Changes, and Bio (Biosphere) Changes, are designed for modeling external, disruptive events that happen at a certain time after the closure of the disposal facility. For normal evolution of a disposal system, these columns are not applicable. The Calculation table records Peak Dose, key Nuclides, the dose rates vs. time graph (Results) for a Variant that has been conceptualized (Model), and whether the variant is calculated probabilistically (Probabilistic) or deterministically. Input files used in the calculation are embedded in the table (NF File, FF File, Bio File and LHS File). Some discussions of the results are also recorded (Caveat and Interpretation).

In each of these tables, there is a column that has a unique number (or words) for each record stored:

- CategoryID in the Scenario Category table,
- VariantID in the Scenario Variant table,
- Model in the Conceptual Model table, and
- Case in the Calculation table.

These columns are called the °∞primary key°± that is used to differentiate one record from another in a table. Most importantly, they are used to establish relationships between two tables, to be explained below.

Figure 3 shows lines connecting tables, which are "relationships" between the tables. The database engine connects tables according to the relationship assigned to the tables, so that information can be managed and accessed correctly. The symbol "1 - ∞"± means "one-to-many" relationship between two tables. For example, there may be many variants (in the Scenario Variant table) for one scenario category (in the Scenario Category table). Correspondingly, there may be many models (in the Conceptual Model table) for one variant, and there may be many calculation cases (in the Calculation table) for one model.

3.2. Parameter Database

Another important component in QUARK is safety assessment parameter database. These parameters are required in safety assessment calculations using SAGE assessment codes. QUARK provides a mean for storage, retrieval, and update of these parameters. For QA

Table 1. Distribution and Parameter Definitions in QUARK

Distribution	Parameter 1	Parameter 2
Constant	Parameter value	N/A
Normal	Mean	Variance
Lognormal	Mean	Error factor
Uniform	Lower bound	Upper bound
Loguniform	Lower bound	Upper bound

purposes, these parameters are linked to maximize the integrity of their intrinsic relationships. The parameter tables are linked through the following "primary keys":

- Element,
- Nuclide,
- Waste Type,
- Material,
- Vault Type,
- Geosphere, and
- Biosphere Medium.

All of the parameters depend on one or more of the above "primary keys". For example, sorption coefficients depend on both elements and materials. Inventories depend on both nuclides and waste types.

For QA purposes, all of the parameter tables record date of data entry, person/affiliation who performed data entry, and references for data sources for each data record.

Uncertain parameters have the following information attached to each data record:

- Distribution type,
- Parameter 1, and
- Parameter 2.

The distribution types currently considered by SAGE and corresponding parameter definitions are shown in Table 1. All other parameters are assumed to be fixed. It is possible that some of them will be treated as uncertain in the future.

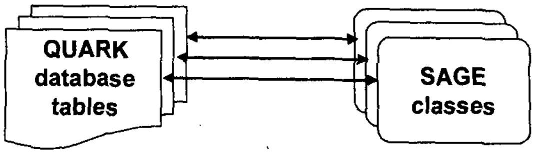

Fig. 4. Linkages Between QUARK and SAGE GUI

Even with identical parameter primary key(s), a parameter can have multiple records. They differ from each other by one or more of the following:

- Numerical values,
- Distribution types (for uncertain parameters),
- Parameter 1 values (for uncertain parameters),
- Parameter 2 values (for uncertain parameters),
- Entry dates, and
- References.

They represent different data sources, different physical and/or chemical conditions (temperature, pH, etc.), and updates based on new information and understanding.

These parameter tables are linked with the SAGE user interface and serve as default database for SAGE users who prepare input files. Every parameter table in QUARK database is represented in SAGE GUI code by a class object that is derived from a parent object in MFC(Microsoft Foundation Class) designed for database records. Figure 4 illustrates the design employed in SAGE GUI to link the QUARK parameters to the SAGE GUI code. The class member functions include retrieval of parameter values for given filters and sorting criteria. For example, to retrieve the newest inventory data for a given nuclide and waste type, the filter would be the nuclide name and the waste type. The sorting criterion would be sorting by date in descending order (i.e., from the latest to the oldest). If the database has the record stored in the table, the inventory value for the given nuclide and waste type will be retrieved along with the unit.

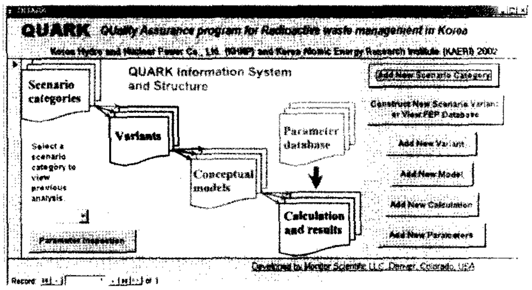

Fig. 5. The Main Form (interface) of QUARK

Otherwise, zero values are returned along with a warning message.

4. Application of QUARK

Usage of QUARK is made easy through menu-driven, self-explanatory interfaces and buttons. Use of QUARK requires Microsoft ACCESS installed on the host computer. QUARK is designed for both safety assessment staff and general public. For the later who wish to inspect safety assessment analysis and parameter database only, no user authorization is needed. For the former, user authorization is granted in order to update the information. ACCESS provides a wide range of security options to secure the database.

To use QUARK, the user clicks QUARK icon, which brings up the main interface as shown in Figure 5. The QUARK information system diagram is shown in the main interface for a quick reference. On the lower left corner of the diagram, inspection users can start inspection by selecting a scenario category or clicking 'Parameter Inspection'. On the right of the interface, there are a series of buttons for information updating. A link is provided to allow users to constructing a new scenario variant or viewing the FEP database via the button labeled 'Construct a New Scenario Variant' or 'View FEP Database'.

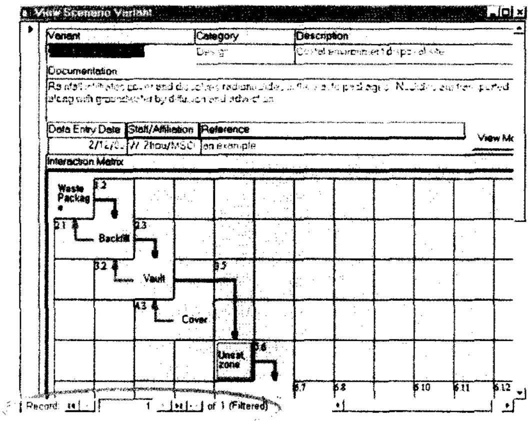

Fig. 6. Display of Scenario Variant Information

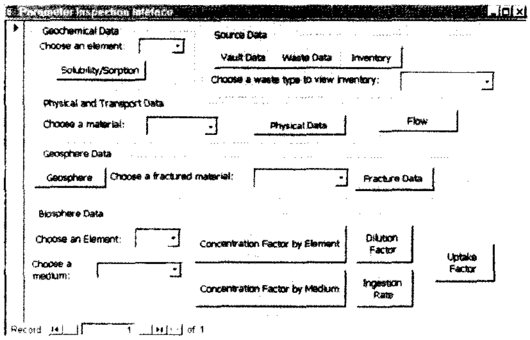

Fig. 7. Parameter Inspection Interface

4.1. Information Inspection

Any users can view existing information in QUARK database. Information is displayed upon user°Øs command from the inspection interface. For QA purposes, QUARK ensures that the viewed information cannot be deleted or modified.

To inspect the previous analysis, the user starts by selecting a scenario category from the list in the main interface. Then, information can be retrieved according to the hierarchy shown in Figure 2. For example, if the user wishes to see variants for

"Design" category, the user can click 'View Variant Information'. Then, all the information for the variant from the Scenario Variant table is shown, including the Interaction Matrix, as shown in Figure 6. If there are more than one variants for the Design category, the user can view the information of all the variants by using the record navigator at the bottom of the interface. By clicking the 'Parameter Inspection' on the main interface, the "Parameter Inspection Interface" is brought up as shown in Figure 7. The parameters are organized into the following groups:

- Geochemical,
- Source terms,
- Physical and transport,
- Flow,
- Geosphere, and
- Biosphere.

4.2. Information Update

In QUARK, all the authorized users are allowed to add new records into QUARK. Whenever the user issues an update command from the main interface, QUARK prompts a login interface as shown in Figure 8. The user should find his/her name and affiliation by navigating the records at the bottom of the interface, and then types in the password. Once the correct user/password information is provided, the user should close the login interface by clicking the "×" symbol at the top of the interface. If login is successful, the update interface is brought up. If not, a message is delivered. QUARK memorizes the user and automatically put date and user/affiliation into the record that the user will be working on. For QA purposes, QUARK ensures that the authorized users can only add new information and cannot delete or modify the existing information.

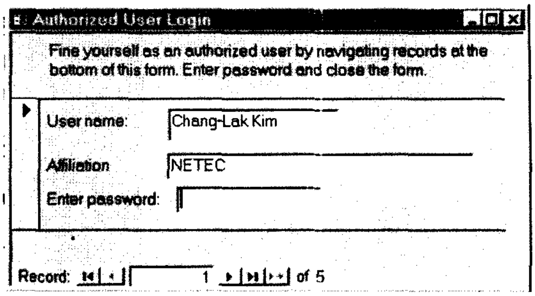

Fig. 8. Authorized User Login Interface

5. Conclusions

In this paper, the development of QUARK, a QA program for safety assessment of radioactive waste disposal project using SAGE, is described. The idea is to link seemingly unrelated information using modern relationship database technologies. To uncover the intrinsic relationship of information is the first step to maximize information integrity. QUARK contains two types of information: safety assessment analysis and parameters. QUARK employs a "top-down" hierarchical structure to manage analysis information from scenario development to calculation results. A link to IMFEP_NS developed by KHNP-NETEC is provided and the information generated by this program can be stored and retrieved by QUARK users. The parameter database in QUARK is represented by a number of parameter tables and relationships. Based on this structure, interfaces for information inspection and update are provided to make QUARK fully functioning with mandatory QA procedures. VBA (Microsoft Visual Basic for Applications) modules are developed to ensure correct information retrieval and QA standards be met when updating information. The parameter database is also linked with SAGE GUI that is a user interface for preparing input data for SAGE assessment codes.

It should be noted that, during the development phase, the QUARK structure is made to optimize data integrity and QA procedures with ease of use during applications.

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