DEVELOPMENT OF GEO-INFORMATION DATA MANAGEMENT SYSTEM AND APPLICATION TO GEOLOGICAL DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE IN CHINA

by

Peng WANG [1*]***, Shu-Tao HUANG*** [1]***, Ju WANG*** [1]***, Yong-An ZHAO*** [1,2]***,***
Min GAO [1]***, Lun WU*** [2]***, and Heng CAI*** [2]

[1] CNNC Key Laboratory on Geological Disposal of High Level Radioactive Waste,
Research Institute of Uranium Geology, Beijing, China
[2] Institute of Remote Sensing and Geographic Information Systems, Peking University, Beijing, China

Technical paper
http://doi.org/10.2298/NTRP1703294W

In this paper, based on information technology, a geo-information database was established and a geo-information data management system (named as HLW-GIS) was developed to facilitate data management work of the multi-source and multidisciplinary data been which are generated during site selection process of geological repository in China. Many important functions, such as basic create, retrieve, update, and delete operations, full text search and download functions, can be achieved through this management system. Even the function of statistics and analysis for certain professional data can be provided. Finally, a few hundred gigabytes of data from numerous different disciplines were integrated, stored, and managed successfully. Meanwhile, the management system can also provide a significant reference for data management work of related research fields, such as decommissioning and management of nuclear facilities, resource prospection and environmental protection.

Key words: high-level radioactive waste, geological disposal, geo-information database, geo-information data management system

INTRODUCTION

With the rapid development of nuclear industry, high-level radioactive waste (HLW) disposal has become a strategic subject which can make influences on environment protection and sustainable development of nuclear industry. Deep geological disposal is regarded as the most reasonable and effective way to safely dispose high-level radioactive waste in the world [1]. Moreover, geological disposal of high-level radioactive waste is a large project with longevity, complexity and systematization. The site selection and evaluation results of disposal repository depend on effectiveness of a large amount of original data resources generated during the process. Actually, there is indeed a large amount of geo-information data generated during site selection process of disposal repository in China. However, there is not an effective sharing mechanism and data management system for management and application of these data resources in China.

Nowadays in the world, most developed countries have completed site selection work and entered into site evaluation or repository design process. Generally, they also have developed some data management systems to manage their data. Taking Swedish Nuclear Fuel and Waste Management Company (SKB) and Nuclear Industry Radioactive Waste Executive (Nirex) as examples, there are three stages for their data management work [2-4]: In the first stage, data tables were adopted to manage borehole data. In the second stage, relational database was used for comprehensive management of data. In later period, computer techniques, such as GIS, were used for integrated management and demonstration of data. Moreover, since 2000, OECD's Nuclear Energy Agency (NEA) established IGSC group for professional data integration and mining. A series of co-operation projects have been carried out by IGSC group, such as GEOTRAP, AMIGO, ModeRn and RepMet [5-8]. These projects emphatically resolved the problems of data acquisition method, data integrated management and long-term sharing application mode in different stages of R&D process. The geo-information database (NDGD) [9] of Sellafield disposal site in England and

* Corresponding author; e-mail: feiyu618@126.com

nuclear waste disposal information system [10] of Japan Atomic Energy Agency, have been in run and being in good operation.

As can be seen from research progress abroad, data obtained in the disposal process are of important significance in ultimate safe disposal. In China, since 1990s, site selection work has started [11]. Meanwhile, some research work about data management has been done successively [12-16]. However, all the work focused on professional data applications rather than data management. Therefore, the work of this paper is to resolve data management of multi-source geo-information data, obtained from site selection work, in previous thirty years of China. Through this, the ability of data management and data service for HLW research work also can also be highly promoted.

OVERALL ARCHITECTURE DESIGN OF GEO-INFORMATION DATA MANAGEMENT SYSTEM OF HLW DISPOSAL

To store and manage large amount of geo-information data successfully, there are three layers designed in the architecture. The first layer is data storage layer, the second layer is application layer and the third layer is expression layer. Overall architecture design is shown in fig. 1.

Data storage layer was designed to store multi-source geo-information data. According to the characteristics of different data, the geo-information datasets can be divided into professional databases (such as geology database, rock mechanic database and, hydrogeology database) and auxiliary databases (such as meta-data database, document database, and sample database). Meanwhile, according to actual requirements of data management, application layer can be developed by dividing it into: management module of meta-data, management module of data release and management module of professional data. Expression layer was designed by hybrid architecture of B/S and C/S. All the subsequent work is based on this architecture.

MODEL CONSTRUCTION OF GEO-INFORMATION DATABASE OF HLW DISPOSAL

Model construction of geo-information database is the basis of design and development of geo-information data management system for HLW disposal. That is to say, data concept model, logic model and physical model of geo-information database have to be constructed to guide structure design and development of management system.

Concept model of geo-information database of HLW disposal

According to Site selection criteria for geological disposal facility of high level radioactive waste in China [17], datasets generated during site selection process could include many different kinds of geo-information data resources. Therefore, concept model should be description of geo-information data resources of disposal repository object and surrounding environment. As shown in fig. 2, elements of disposal repository object in concept model should include pre-selected area, site and surrounding rock. These elements can be described with data type of point, polyline and polygon in three-dimensional space. Each element is described by data and their description data should belong to some subject which will be defined in fig. 3. Therefore, concept model is an abstract description of disposal repository object and its description data.

Logic model of geo-information database of HLW disposal

To establish a complete logical relationship among elements of disposal repository object and surrounding environment, the logic model should be designed on the basis of spatial data model and should be

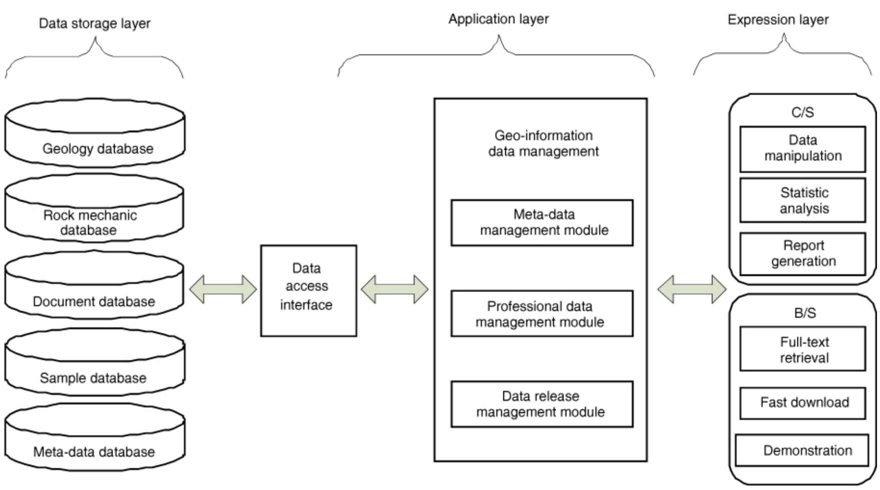

Figure 1. Overall architecture design of data management system for geo-information database

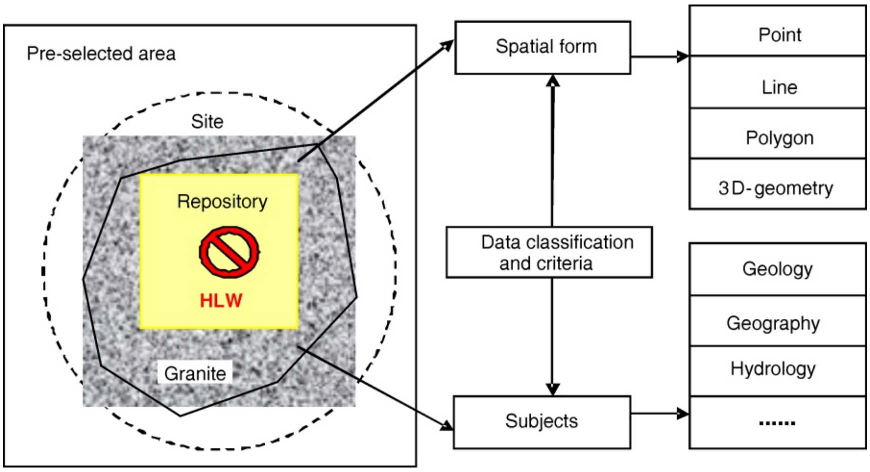

Figure 2. Concept model of geo-information data of HLW disposal in China

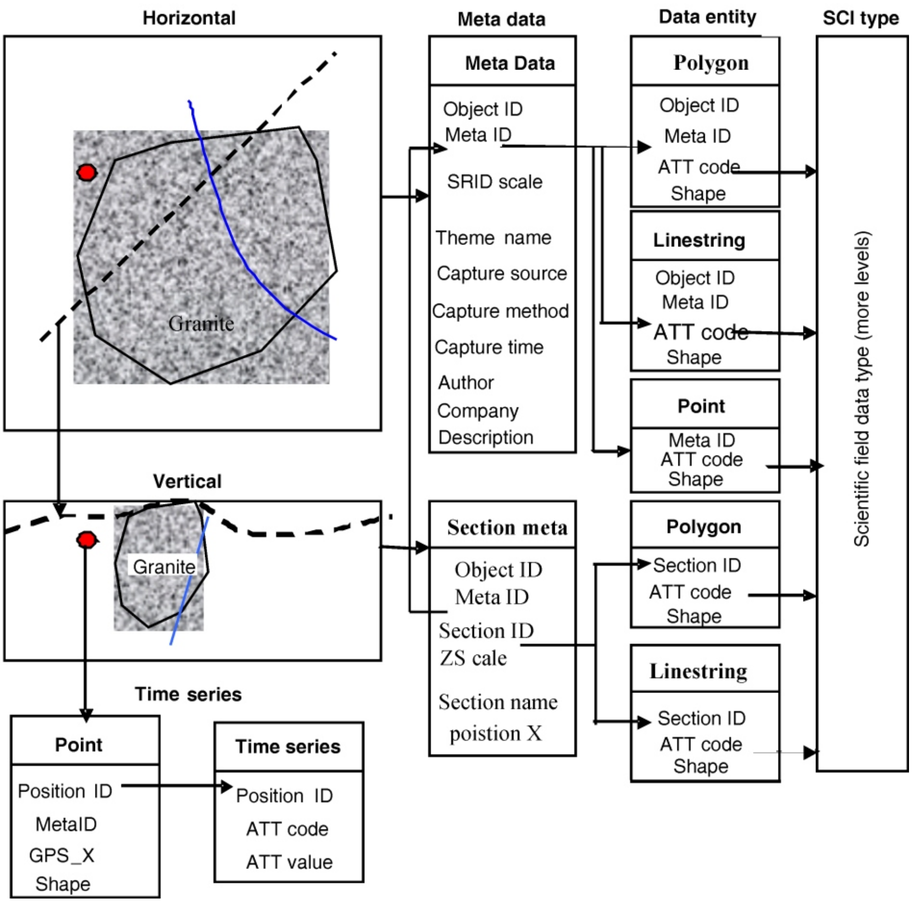

Figure 3. Logic model of geo-information data of HLW disposal in China

full representation of data characteristics and data relations.

As is shown in fig. 3, first of all, all the elements of disposal repository object should be defined as a point, a linestring or a polygon in planar space (horizontal direction) or section space (vertical direction), which is related to spatial location. The attribute data should include all the description information of the elements. In addition, there are three key connection fields in the logic model, *i. e*., „MetaID", „AttCode" and „Shape". Firstly, „MetaID" field is the key field for connecting different data layers which compose and describe the same element. Therefore, data table „MetaData" includes important and basic information of elements, such as „ThemeName", „SRID", „Author". Through „MetaID" field, other different non-spatial attribute tables of the same element can be freely defined, extended and connected. Organizing data in this way, makes it helpful for future extension of data model and facilitates application development. Secondly, „AttCode" field is a classification code which can connect to the categorical encoding table and be the only representation of the element. Moreover, „Shape" field is a geometry field which contains spatial geometry of elements. This field is helpful for connection between different elements through spatial location.

In a word, concept model is a comprehensive description of spatial data and attribute data. This logic model can be regarded as a template of other spatial data models and facilitate spatial data management.

Physical model of geo-information database of HLW disposal

There are some sub-databases and many data tables in the geo-information database. Physical model construction of geo-information database is mainly focused on establishment of correlations between different sub-databases and between different data tables. Essentially, it is designed to clearly define types of data elements and relations between different kinds of data during construction process of geo-information database. Meanwhile, the storage relationship between spatial data and attribute data of data elements should be well handled to ensure consistency of data storage and expression.

The content and relationship descriptions of the physical model are shown in tab. 1. Thematic sub-databases are the primary components of the physical model. Based on definition of mutual relations between different datasets and different storage methods, selected for different types of data, the consistency and integrity of database construction can be achieved.

DEVELOPMENT OF GEO-INFORMATION DATA MANAGEMENT SYSTEM OF HLW DISPOSAL

Development and technical implementation method

Firstly, a powerful underlying database management system (DBMS) was selected. Considering unstructured and multisource characteristics of geo-information data, the DBMS should support partition table and partition index technology, parallel data processing technology, distributed database construction technology and object-oriented functions. In this study, construction of geo-information database and development of data management system are both based on PostgreSQL, which is a powerful open-source object-oriented relational database [18]. To satisfy different demands of data management, hybrid architecture of B/S (browser/server) and C/S (client/server) were adopted in development of geo-information data management system. Then, object--oriented programming languages of JAVA and C# were selected as development languages [19, 20]. Finally, based on several function modules of commercial GIS software, a technical implementation framework of geo-information data management system was designed and achieved (fig. 4).

Function design of geo-information data management system

Based on model construction of geo-information database and technical implementation framework

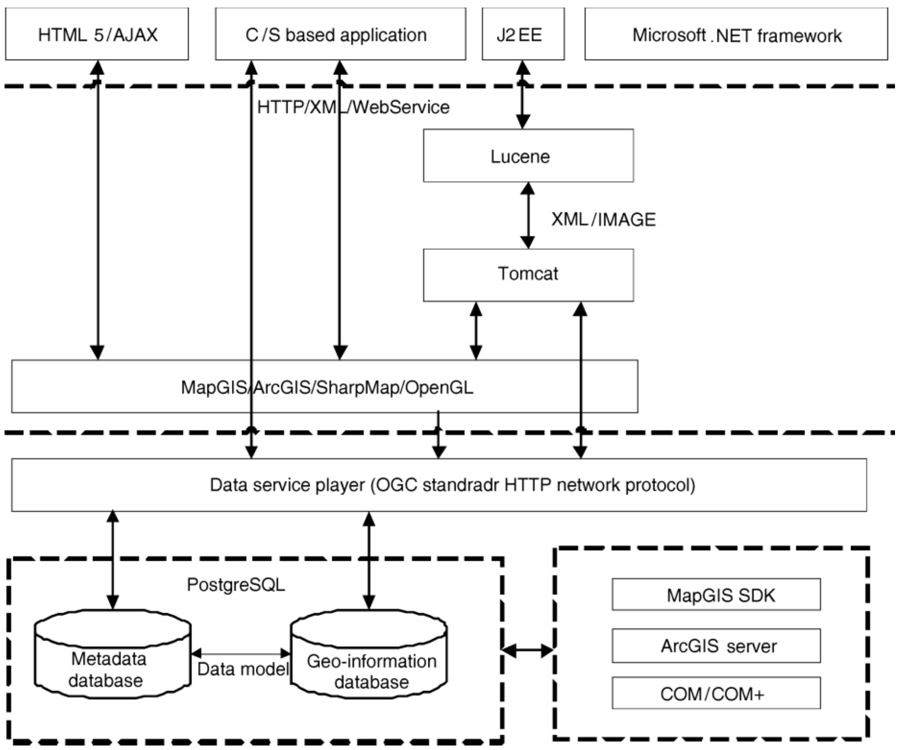

Figure 4. Technical implementation framework of geo-information data management system

Table 1. Physical model and correlation instruction of geo-information data

ID	Sub-database	Classification of data entity	Data type	Relationship illustration
1	Metadata database	Metadata information: identification, data quality, spatial reference, content and distribution and the responsible department's contact information	Spatial data, attribute data	Basic descriptive information for thematic data, construction of data dictionary, index reference for all other data
2	Basic geography database	Topography, transportation, pipelines, hydrographic net, geomorphology, vegetation, administrative area and protection zone	Vector data (point, polyline and polygon), attribute data	Basic data such as administrative district, relevant to other data through geometry field
3	Geology database	Rock mass data, characteristics of rock mass, tectonic, fault, stratum, geological boundary, fracture, minerals and alteration, geological section and label	Vector data (point, polyline and polygon), attribute data	Basic geology data, such as fault, lithology, geological boundary, relevant to other data through geometry field
4	Borehole database	Basic borehole information: Engineering geology, geology logging, hydro-geological logging, geophysical logging, hydrologic monitoring, daily drilling records, documentation	Vector data (point, polyline and polygon), attribute data	A series of data obtained around boreholes, relevant to other data through borehole ID and depth fields
5	Remote sensing database	Remote sensing data, target spectral data, image data descriptions, geographical environment, atmospheric environment, measuring method, instrument and equipment, typical spectrum	Raster data (image, photo), attribute data	Relevant to other databases through geometry field
6	Hydrology database	Surface water, underground water, geology body, geologic body, hydrological experiment and analytical test	Vector data (point, polyline and polygon), attribute data (test results)	Relevant data of hydrology scientific research field, relevant with other data through geometry field
7	Geophysical database	Airborne geophysical prospecting, geophysical logging, ground physical exploration, interpreted results for physical exploration	Vector data, attribute data and raster data	Borehole geophysical survey can be connected to the Borehole database through the borehole ID, Surface geophysical survey can be connected to the geology database through section ID
8	Geochemistry database	Field test data, indoor sample analysis results, geochemical exploration maps and results	Spatial data (vector and raster data), attribute data	Relevant to sample database through sample ID and geometry field
9	Rock mechanic database	Field test data, laboratory test data, regional survey, digital simulation for test results	Spatial data (vector and raster data), attribute data	Relevant to sample database through sample ID and spatial geometry field
10	Hazardous database	Thematic data such as earthquake, volcano and climate and historical data storage	Spatial data (vector and raster data), attribute data	Thematic data, such as natural hazards, relevant to other databases through spatial geometry field
11	Ecological environment database	Environmental impact assessment data	Spatial data (vector and raster data), attribute data	Relevant to other databases through spatial geometry field
12	Documents database	Achievements reports, scientific reports, domestic and foreign literature	Attribute data, documentation	Relevant to other databases through spatial geometry field
13	Photo database	Scientific results image, thematic images and photos	Vector data, attribute data and raster data	Relevant to other databases through spatial geometry field

mentioned above, logical architecture of functions was designed as shown in fig. 5. Firstly, basic functions should include all the operations of underlying database and provide support for more advanced functions. Secondly, support functions between basic functions and major functions should be provided for data extraction and format conversion, based on secondary development of commercial GIS software. In this way, the data link between underlying database and data management functions can be achieved. Last but not least, advanced functions, such as data presentation and data analysis, should be developed with final realization of HLW-GIS desktop system and web system. The name of HLW-GIS is abbreviation of geo-information data management system of HLW disposal. HLW-GIS desktop system can provide advanced functions of data management based on C/S architecture. HLW-GIS web system can implement data release function based on B/S architecture. Meanwhile, user interface design and implementation work were undertaken along with function development.

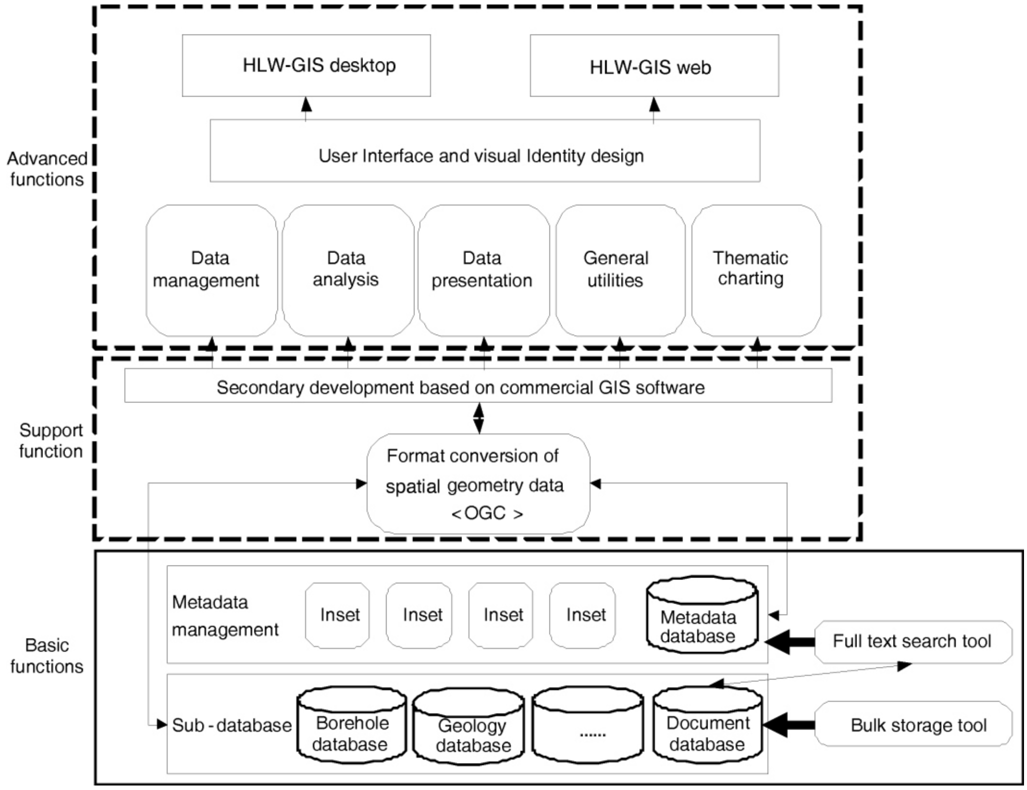

Figure 5. Logical architecture design of functions

Function implementation of geo-information data management system

Based on function development work, the first version of HLW-GIS was released and it included many functions such as „Data management", „Data search and statistic", „Chart expression", „Data release", „Data export" and other additional functions. Here, only introduce several important functions are introduced.

Data management

The function can provide comprehensive management of all the geo-information data, including both professional data and meta-data. Firstly, basic CRUD (create, retrieve, update and delete) operations of professional data and meta-data can be provided. In addition, GIS analysis functions for spatial data were also developed, such as buffer, overlay and cutting analysis.

Data search and statistic

Most powerful functions of this management system are data search and statistic. Through inputting one or more professional keywords, the target data can be retrieved and statistically gathered or filtered in a convenient and quick method.

Chart expression

After data statistic, the search results can be expressed in several different types of charts which include simple scatter plot chart, customizable chart and other expression ways. Taking customizable chart of geochemical test data as an example, the information of geochemical sample is stored in „Sample Database" and that of test data is stored in „Geochemical Database". To ensure integrity and accuracy of geochemical test data, datasets from different databases are invoked and a customizable chart is used for data expression.

Data release

To satisfy fast data retrieval and download demands, data release function of web server side was developed. Just like Google search, by inputting simple keywords and click search button, all the related documents, photos and professional data can be searched and downloaded. In addition, functions of detailed information display and spatial location display can also be used.

CONCLUSIONS

In this work, based on establishment of geo-information database of HLW disposal in China, a geo-information data management system (*i. e.* HLW-GIS) was developed to provide reliable data service functions. Many important functions have been provided by HLW-GIS.

HLW-GIS has been applied for research and development work of HLW disposal in China. It provided powerful data basis for site selection and evaluation work. In near future, the system can also provide sound technical background on the safety assessment and performance assessment. Meanwhile, it can also be a significant reference for data management work of in other similar fields, such as decommissioning nuclear facilities management, resource prospection and environmental protection.

ACKNOWLEDGEMENTS

The special fund of Nuclear facilities decommissioning and radioactive waste management supported this work.

AUTHORS' CONTRIBUTIONS

All the authors have contributed to design of geo-information database and data management system, while this work was done under the quidance of professor Shu-tao Huang. Database construction and management system integration were undertaken by P. Wang. The manuscript was prepared and written by P. Wang.

REFERENCES

[1] Wang, J., High Level Radioactive Waste Disposal in China: Update 2010, *Journal of Rock Mechanics and Geotechnical Engineering, 2* (2010), 1, pp. 1-11

[2] Eriksson, E., *et al*., GEOTAB, Overview, Swedish Nuclear Fuel and Waste Management Co.,TR92-01, 1992

[3] Anders, S., Geoscientific Programme for Investigation and Evaluation of Sites for the Deep Repository. Swedish Nuclear Fuel and Waste Management Co.,TR-00-20, 2000

[4] Hawkins, C., Geosphere Characterisation Project-Data Management Strategy, Nirex, England, Tessella Project Number 4998, 2007

[5] ***, GEOTRAP: Radionuclide Migration in Geologic, Heterogeneous Media, Summary of Accomplishments, Nuclear Energy Agency , OECD, Paris, 2002

[6] ***, AMIGO., Geoscience Information in the Radioactive Waste Management Safety Case: Main Messages from the AMIGO Project, Nuclear Energy Agency, No. 6395., OECD, Paris, 2010

[7] ***, MoDeRn Partners., MoDeRn Monitoring Reference Framework Report, European Commission, Contract Number: 232598., 2013

[8] ***, Nuclear Energy Agency, Radioactive Waste Management and Constructing Memory for Future Generations: *Proceedings*, International Conference and Debate, NEA No. 7259., OECD, Verdun, France, 2014

[9] Hawkins, C., Geosphere Characterisation Project Data Management Strategy, Nirex No. 4998, England, 2007

[10] ***, IAEA, International Conference on the Safety of Radioactive Waste Disposal, No. CN-1353-7., Tokyo, 2005

[11] Wang, J., *et al*., Studies on Geological Disposal of High-level Waste in China (in Chinese), *Atomic Energy Science and Technology, 38* (2004), 4, pp. 339-342

[12] Li, H. B., *et al*., WebGIS Based Geo-Information System for Beishan Disposal Repository of High Level Radioactive Waste (in Chinese), *World Nuclear Geoscience, 24* (2007), 1, pp. 39-43

[13] Gao, M., *et al*., Research on Geo-Information Data Nodel for Preselected Areas of Geological Disposal of *High-level Radioactive Waste, 46* (2016), 1, 012054

[14] Wang, P., *et al*., Development of Data Applications and Presentations for Geological Information Database of HLW Disposal (in Chinese), *Uranium Geology, 31* (2014), s1, pp. 477-482

[15] Zhao, Y. A., *et al.*, Study on Database Regulation of High-Level Radioactive Waste Disposal (in Chinese), *World Nuclear Geoscience, 31* (2014), s1, pp. 290-298

[16] Gao, M., *et al*., Metadata Design and Editing Module Development for the Geological Disposal of High-Level Radioactive Waste (in Chinese), *World Nuclear Geoscience, 25* (2010), 4, pp. 37-41

[17] ***, HAD 401/06., Site Selection Criteria for Geological Disposal Facility of High Level Radioactive Waste in China, The National Nuclear Safety Administration, 2013

[18] ***, The PostgreSQL Global Development Group, PostgreSQL 9.6.2 Documentation, 2017

[19] Horstman, C. S., Cornell, G., Core JAVA, ISBN: 978-0-13-235476-9, 2008

[20] Nagel, C., *et al*., Professional C# 4 and .NET 4, ISBN: 978-0-470-50225-9, Wiley Publishing, Inc., 2010

Received on April 5, 2017
Accepted on August 21, 2017

Пенг ВАНГ, Шутао ХУАНГ, Ђу ВАНГ, Јунган ЦАО, Мин ГАО, Луен ВУ, Хенг Цај

РАЗВОЈ СИСТЕМА УПРАВЉАЊА ГЕОИНФОРМАЦИОНИМ ПОДАЦИМА И ПРИМЕНЕ НА ГЕОЛОШКО ОДЛАГАЊЕ РАДИОАКТИВНОГ ОТПАДА ВИСОКОГ НИВОА У КИНИ

На основу информационих технологија успостављена је геоинформациона база података и развијен је систем за управљање геоинформационим подацима (назван HLW-GIS), како би се олакшао рад управљања мултидисциплинарним подацима различитог порекла који настају при процесу одабирања локације за геолошко одлагање у Кини. Многе важне функције, као што су основне операције формирања, прибављања, освежавања, брисања уноса, претрага текста и функције преузимања, могу бити остварене овим системом управљања. Шта више, обезбеђене су и функције статистиче обраде и анализе за одређене професионалне податке. Коначно, неколико стотина гигабајта података из различитих дисциплина успешно је интегрисано и сачувано. Систем управљања такође може пружити значајне референце за управљање подацима повезаних истраживачких области, као што су декомисија и управљање нуклеарним постројењима, проспекција ресурса и заштита животне средине.

Кључне речи: радиоактивни отпад високог нивоа, геолошко одлагање, геоинформациона база података, систем управљања геоинформационим подацима