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Construction of Trace Element in Coal of China Database Management System: Based on WebGIS

(Pembinaan Unsur Surih dalam Arang Batu Sistem Pengurusan Pangkalan Data China: Berdasarkan WebGIS)

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ABSTRACT

The combination of geographic information system and mineral energy data management is helpful to promote the study of mineral energy and its ecological damage and environmental pollution caused by its development and utilization, which has important application value. The Trace Elements in Coal of China Database Management System (TECC) is established in this paper, applying the techniques of B/S three-layer structure, Oracle database, AJAX and WebGIS. TECC is the first database system which aims at managing the data of trace elements in coal in China. It includes data management and analysis module, document management module, trace elements in coal data maintenance module and authority management module. The data entry specification is put forward in the present study and the spatial data is included in TECC system. The system achieves the functions of data query, analysis, management, maintenance and map browsing, thematic map drawing as well as satellite video display, which lay the foundation for the analysis of large data of trace elements in coal. It is a practical platform for the acquisition, management, exchange and sharing of trace element research and geochemical research data of coal.

Keywords: Database; data entry specification; spatial data; trace element in coal; WebGIS

ABSTRAK

Gabungan sistem maklumat geografi dan pengurusan data tenaga mineral membantu untuk menggalakkan kajian tenaga mineral dan kerosakan ekologi serta pencemaran alam sekitar yang disebabkan oleh pembangunan dan penggunaannya yang mempunyai nilai aplikasi penting. Sistem pengurusan pangkalan data unsur surih arang batu di China (TECC) telah dibangunkan dalam kertas ini dengan menggunakan teknik struktur B/S tiga lapisan, pangkalan data Oracle, AJAX dan WebGIS. TECC adalah sistem pangkalan data pertama yang bertujuan untuk menguruskan data unsur surih dalam arang batu di China. Ia merangkumi pengurusan data dan analisis modul, modul pengurusan dokumen, modul penyelenggaraan data unsur surih dalam arang batu serta autoriti pengurusan modul. Spesifikasi kemasukan data dikemukakan dalam kajian ini dan data ruang dimasukkan ke dalam sistem TECC. Sistem ini telah mencapai fungsi pertanyaan data, analisis, pengurusan, penyelenggaraan dan peta pelayaran, lukisan peta tema serta paparan video satelit yang meletakkan asas untuk analisis data yang besar daripada unsur surih dalam arang batu. Ia merupakan satu platform yang praktik untuk pengambilalihan, pengurusan, pertukaran dan perkongsian data penyelidikan unsur surih dan penyelidikan geokimia dalam arang batu.

Kata kunci: Data ruang; spesifikasi kemasukan data; pangkalan data; WebGIS; unsur surih dalam arang batu

Introduction

Trace elements in coal is a general term for toxic, carcinogenic, corrosive, radioactive and other environmentally harmful elements with content in the coal less than 0.1% (Ashraf et al. 2017; Tang & Huang 2002). Conducting study of trace elements in coal deeply and exploring its migration, transformation and occurrence principles provides theoretical basis for environmental geochemical investigation and has great realistic significance for development and utilization of coal resources (Tang & Huang 2002; Zou et al. 2013). It has become one of the research hotspots in the field of geochemistry.

WebGIS technique makes it possible to inquire, analyze, integrate and release the spatial data of Geographic Information System (GIS) on the Internet (Zhou et al. 2007) and it has been widely used in various fields of research. Combining WebGIS with data management of trace elements in coal to achieve database management system of trace elements in coal can provide powerful data and technical support for study of trace elements in coal and is of important theoretical and realistic significance for in-depth exploration of the ecological damage and environmental pollution resulted from trace elements in coal.

Much attention has been paid to the research of informatization in the field of minerals and energy abroad, and the establishment of minerals and energy database started in 1960s (Han et al. 2009). A famous one is the coal quality database system established by the United States Geological Survey (USGS) (Johnson 2012; https://minerals.usgs.gov/; U.S. Department of the Interior 2014). This system, containing complete data about coal quality information, microelement analysis and coal ash analysis, provides search and download service for users. The EarthChem database established by Columbia University is the most representative geochemical database in recent years (Walker et al. 2005). It contains complete data about geochemical property and provides search, analysis and diagram functions for users. GEOROC (Geochemistry of Rocks of the Ocean-sand Continents) contains nearly 600,000 items of data about total rock and minerals and supports inquiry with various indexes including author's literature, geological environment, coordinates and chemical elements (Sarbas & Nohl 2009). The GANSEKI (Geochemistry and Archives of ocean floor rocks on Networks for Solid Earth Knowledge Integration) established by Japan Marine Science and Technology Center contains large number of images data including basic attribute indexes of rock sample and pictures of rock samples. It is a deep-sea rock sample database with the most complete database (Ichiyama et al. 2011). MetPetDBA (a Database for Metamorphic geochemistry) is a metamorphic rock lithology database developed jointly by metamorphic rock experts and computer science experts organized by Rensselaer Polytechnic Institute and contains nearly 25,000 items of measured data and interpretation data (Radaideh et al. 2016; Spear et al. 2013).

The research on minerals and energy database in China started from 1980s. The early databases including the China Coal Resources Database (Cchen et al. 1984), CSRDS (Chen 1996) and China Energy Database (Zhuang 2000) mainly focus on data acquisition and compilation, and the analysis and application of data and interactive operation are still weak. Since 2005, the China Coal Characteristics Database established by Cao et al. (2005) provides a basic platform for the scientific research of coal resources and helps to comprehensively master the basic situation of coal characteristics in China. The Coal Geological Database System established by Han et al. (2009) provides the geologic and resources information of each coal exploration area. The system adopts C/S three-layer structure and has the functions of map browsing and remote image browsing. Geochemical data management system shows the content and distribution of chemical elements and compounds in the earth's crust by digital earth (Nie et al. 2012). In recent years, the Coal Resources Survey Database System established by Zhang and Huang adopts C/S and B/S integrated development mode to achieve the integration of GIS cartographic data and database creating and improves the ability in management and analysis of mineral resources data (Sardar et al. 2017; Zhang & Huang 2014).

Based on the achievements of research on minerals and energy database, the following problems in research on minerals and energy database of China urgently need to be solved:

The basic data entry of database is not standardized. Currently, there is no unified specification for the basic data entry of minerals and energy databases in China, which limits the expansion and lateral comparative research of the data in database. Therefore, the data needs to be entered in accordance with relevant national and international data specifications.

No research on database of trace elements in coal has been carried out. Even though lots of researches on minerals and energy database systems in China have been done and mass data is contained in the databases, data about trace elements in coal is very few. Currently, research on database system of trace elements in coal has not been started yet.

There are few database systems in deep combination with 3S (GIS; remote sensing, RS; global positioning system, GPS) technology, which limits the functions of database system, including management, data mining and in-depth analysis and display of data diversification.

Therefore, in order to solve the problems existing in minerals and energy databases in China, including no unified data specification, few basic data about trace elements in coal and single system function, the present study establishes the Trace Elements in Coal of China Database Management System (TECC), taking ArcGIS10.2 and Oracle as the platform, providing effective data support for the research on trace elements in coal and geochemical research through comprehensive application of AJAX, WebGIS, Geodatabase spatial data model and C# programming language and XMAL front-end assembly language. TECC aims at realizing system functions including inquiry, analysis, management, maintenance and thematic map display of data about trace elements in coal.

Data Sources

The data in TECC includes attribute and spatial. Attribute data mainly refers to related index data about trace elements in coal, geological and administrative information of the samples, which comes from the literature data and some field sampling data. The literature data refers to those in the related Chinese and English literature in CNKI, SCI and Elsevier literature search engine databases. The literature data and field sampling data needs to be screened and entered according to the data specification established based on this research. Even though there is plenty of document information, that satisfying the data specification and can be entered to database is little. Currently, over 5,000 items of data about coal samples have been entered to the database.

Spatial data refers to vector and raster graphic data and its spatial attribute value. Vector data refers to the 1:4,000,000 vector map of China provided by the website of National Fundamental Geographic Information System

and the vector data of coal samples obtained through the information about sampling point; raster data refers to the DEM data (resolution: 30 m) and Landsat8 satellite remote sensing image data of each mining area provided by geographical spatial data cloud platform as well as the pictures of the mining areas.

Database system design

B/S structure in TECC

TECC adopts B/S three-layer structure (Figure 1), i.e. data layer, server layer and presentation layer, to ensure the hierarchy, expandability and stability of the system. This system stores the attribute data and spatial data in database, processes the data with WebGIS server and send the information required by users back to the browser through IIS server.

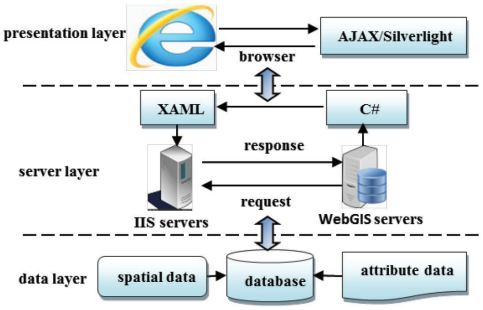


FIGURE 1. Structure diagram of B/S in TECC

Specification for data entry

Data entry is the first step in establishing a database and the basis and key to restrict the data accuracy and validity of the database. The attribute data of the system consists 6 parts: the basic information about sampling point, element content of the sampling point, element detection method, proximate analysis of the sampling point and mineral composition of the sampling point. This paper makes specifications for TECC data entry, including the specification for trace elements in coal measurements (Table 1) and attribute data entry specification (Table 2), based on relevant national and international standards, monographs including *Trace Elements in Coal of China* (Tang & Huang 2004) and *Trace Elements of Coal and its Significances on Research* and lots of scholar researches (Qu et al. 2016; Wang et al. 2014, 2012; Yang et al. 2014). 337 attribute fields are set in this database, covering the information about international coal type, Chinese coal type, sampling method, sample type, coal accumulating basin, industrial index, maceral and mineral composition. The spatial data attribute shall contain the fields correlative with attribute data, i.e. the number of sampling point. The geographic location and other attribute information of the sampling point will be determined by collecting information about the sampling point and then plane information layer of the sampling point will be generated by ArcMap, named as information about the sampling point.shp, such as location of the sampling point.shp. WGS1984 projection coordinate system is adopted for the coordinates of sampling point of the system.

TABLE 1. Specification for trace elements in coal measurements in TECC

Trace elements	Measuring method	Basis
As	Arsenic molybdenum blue spectrophotometric method Hydride-atomic absorption spectroscopy	GB/T3058-1996
Se	Hydride-atomic absorption spectroscopy	GB/T16415-1996
Hg	Cold atomic absorption spectrometry	GB/T16659-1996
Cr, Cd, Pb	Atomic absorption spectroscopy	GB/T16658-1996
U	Spectrophotometry	GB/T384-1996
Cl	High temperature hydrolysis - electrochemical determination method	GB/T3558-1996
F	High temperature hydrolysis - fluoride ion selective electrode method	GB/T4633-1996
Ga	Colorimetric method (spectrophotometry)	GB/T8207-1996
Ge	Colorimetric method (spectrophotometry)	GB/T8207-1996
V	Spectrophotometry	GB/T19226-1996
Zn, Cu, Co, Ni	Atomic absorption spectroscopy	GB/T19225-1996
Ba, Be, Cd, Co, Cr, Cu, Ga, Mn, Mo, Ni, Pb, Sr, V, Zn, Zr, B, As, Se, Ge, Hg	Inductively coupled plasma atomic emission spectrometry	SN/T1600-2005
Ag, As, Ar, B, Ba, Be, Bi, Br, Cd, Ce, Co, Cr, Cs, Cu, Dy, Eu, Er, Ga, Ge, Gd, Hf, Ho, I, In, La, Li, Lu, Mn, Mo, Nb, Nd, Ni, P, Pb, Pr, Rb, Re, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr	Inductively coupled plasma mass spectrometry	*Trace Elements in Coal of China* & *Trace Elements of Coal and its Significances on Research*

TABLE 2. Attribute data entry specification in TECC

Data sheet	Attribute field	Basis
Basic information of samples	Number of sample, original number of sample, name of sampling site, province, city, county, stratum, coal-forming age, coal accumulating basin, mining area, coal seam, sampling method, sample type, Chinese coal type, international coal type, longitude, latitude, author, reference, year	GB/T5751-1986, ASTM(D388-92), GB/T 17607-1998, GB 482-1995, GB/T 19222-2003
Element content of samples	Number of sample, original number of sample, name of sampling site, ID of sample, 84 concrete elements including As, Be, F, Hg and U	GB/T 20475-2006, Trace Elements in Coal of China and Trace Elements of Coal and its Significances on Research; (unit: ug/g). Keep three places of decimal and represent bdl (below detection limit) and nd (not detected) with 0
Industrial analysis of samples	Number of sample, original number of sample, name of sampling site, ID of sampling site, 18 specific indicators including Mad, Ad and Ashd	GB/T212-2008, GB/T214-1996
Maceral of sampling point	Number of sample, original number of sample, name of sampling site, ID of sampling site, 14 macerals including telinite, gel telinite and block gel	GB/T 15588-2001
Mineral composition of samples	Number of sample, original number of sample, name of sampling site, ID of sampling site, 63 mineral compositions including kaolinite, montmorillonite and illite	GB/T 7560-2001, MT/T 915-2002; bdl means below the detection limit; nd means not detected (unit: vol.%)

DATABASE STRUCTURE

TECC database consists of spatial database and non-spatial database (Figure 2). Non-spatial database, taking the database management software Oracle 11g, stores the attribute data collected in the form of two dimensional sheet, forming sampling site information sheet, basic information sheet of sampling point, geological information sheet of sampling point, element content data sheet of sampling point, element detection method information sheet of sampling point, industrial analysis data sheet of sampling point, maceral data sheet of sampling point, mineral composition data sheet of sampling point, administrative division sheet of sampling point, longitude and latitude sheet of sampling point and academic information sheet of sampling point. In addition, the user sheet, menu information sheet and role permission sheet are stored in the database as supplementary sheets.

The spatial database adopts Geodatabase spatial data model to store the basic geographic data of administrative division, river systems and national boundaries of China and the thematic layers including location of sampling point, remote-sensing image of mining area and DEM of mining area (Figure 2).

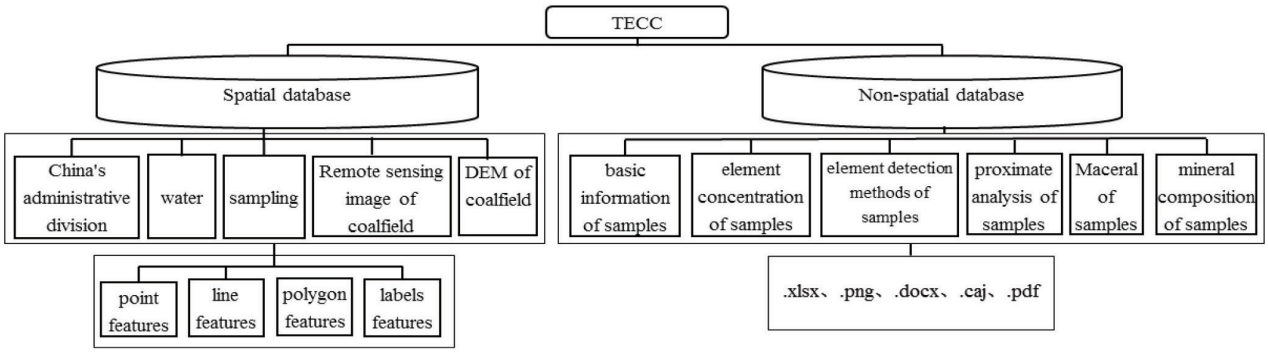


FIGURE 2. Structure of Data in TECC

Functions of TECC

As mentioned previously, the development environment of TECC includes Oracle 11g database, Windows10 user operating system, ARCSDE10.1 spatial data engine, IIS7.0 WEB server, Visual Studio.NET2012 development tool, HAML and C# development language, ArcGIS API for Silverlight programmatic interface and ArcGIS Server10.1 releasing platform.

TECC combines AJAX, WebGIS and database technology with relevant knowledge of coal chemistry to achieve the inquiry, management and analysis of data about elements in coal and harmful elements. TECC system consists of 4 modules: Data management and analysis module, document management module, trace elements in coal data maintenance module and authority management module (Figure 3).

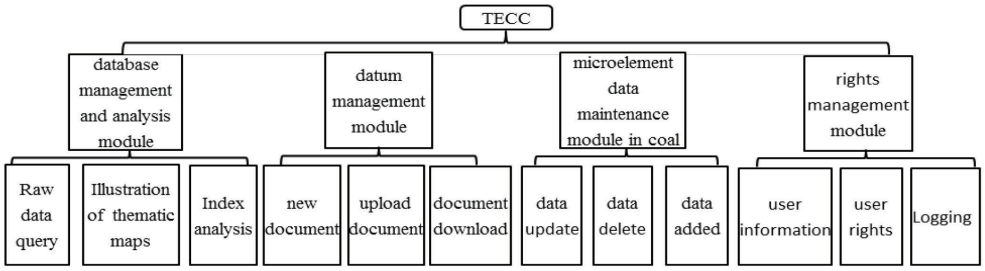


FIGURE 3. Functional structure of TECC

Data management and Analysis module

The main functions of this module are original data inquiry and index analysis. The function of original data inquiry inquires the basic information about trace elements in coal through administrative unit and geological unit, obtains related sheets and outputs for use and can also select, inquire and location the attribute information of sampling site on the map page (Figure 4) and browse the satellite image. The function of index analysis can highlight the inquiry target by positioning on the map and can show the original data about harmful elements in coal in the form of GIS thematic map (Figure 5), bar graph, broken line graph or sheet and to display the results of analysis of enrichment state, distribution characteristics and occurrence state of trace elements. This module can reflect the distribution of various index parameters in coal in time and space comprehensively and intuitively.

FIGURE 4. The schematic diagram of the sample sites distribution

DOCUMENT MANAGEMENT MODULE

The main functions of document management module are creating new document, document uploading and downloading. The new document can complete the entry of project name, type, responsible person and concrete data and papers, data and meeting minutes related to the project can be uploaded. Users can download the document literature in all projects, which not only achieves the sharing of project resources, but also ensures the general control of project information and schedule.

TRACE ELEMENTS IN COAL DATA MAINTENANCE MODULE

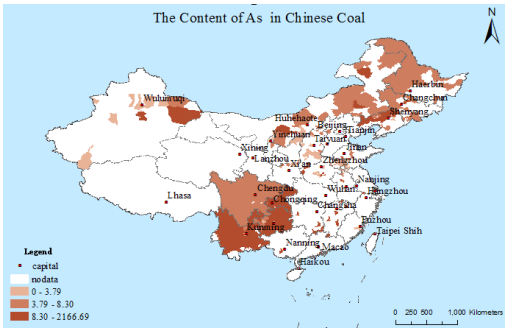
This module aims at maintaining and managing the data about trace elements in coal, including deleting, modify and import operation. Deleting operation can directly delete the selected information in the data sheet through the safety instructions; import operation requires that the table file imported has the same structure of the sheet in database. This module can be operated only when the user logs in as an administrator, which can prevent system breakdown caused by violation operation of common users.

AUTHORITY MANAGEMENT MODULE

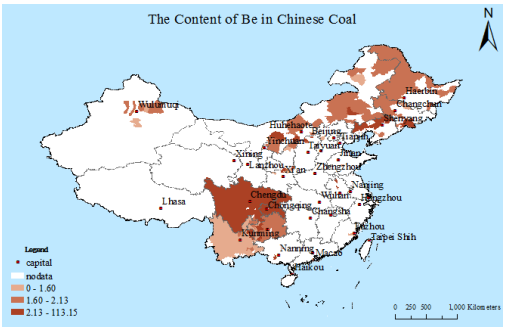
System security is of great importance. TECC achieves authority management through 4 parts: User, role, division and log. User management includes addition, inquiry, modification and deletion of user information. Super administrator, administrator and other common users are set for role management, and different users correspond to different operational modules. Division management and log management clear the records of user unit and operating system, respectively, that causes for system failure due to improper operation can be found, related persons can be tracked and the integrity and validity of the data can be guaranteed.

CASE ANALYSIS

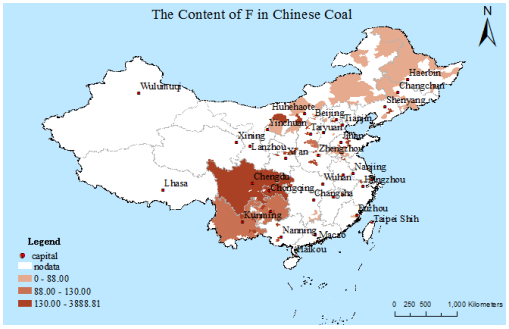
Take harmful elements in coal As, Be, F, Hg and U as the examples to study the spatial distribution of the five harmful elements by applying data management and analysis module in TECC.



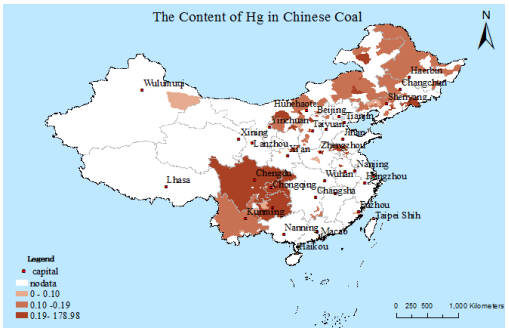
(a) As element content



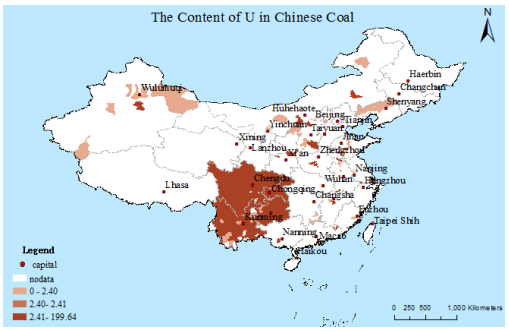
(b) Be element content



(c) F element content



(d) Hg element content



(e) U element content

FIGURE 5. The element of As, Be, F, Hg, U mean value distribution in coal of China in TECC

FIGURE 6. Sketch map of pie chart display (The element of Be mean value distribution) in TECC

Analysis method

The data analysis method in data management and analysis module includes conventional statistics, statistical test, element analysis, cluster analysis, principal component analysis and factor analysis. The spatial and temporal distribution, occurrence state and migration rules of elements can be found through the 6 analysis methods. Conventional statistics were used in the database to calculate the mean content of As, Be, F, Hg and U of each coal mine in China. The obtained mean values will be directly stored in the spatial database. Then draw a As, Be, F, Hg and U content level graph (Figure 5) with the thematic charting function and Be mean content distribution bar graph and pie graph (Figures 6-7). The content of harmful elements is divided into 4 levels according to the mean value of As, Be, F, Hg and U in China and in the world (Table 3). The default content of elements in regions without data is nodata.

TABLE 3. The average content of As, Be, F, Hg, U in China and the world (μg/g)

Element	As	Be	Hg	F	U
China level	3.79	2.13	0.19	130	2.41
World level	8.3	1.6	0.1	88	2.4

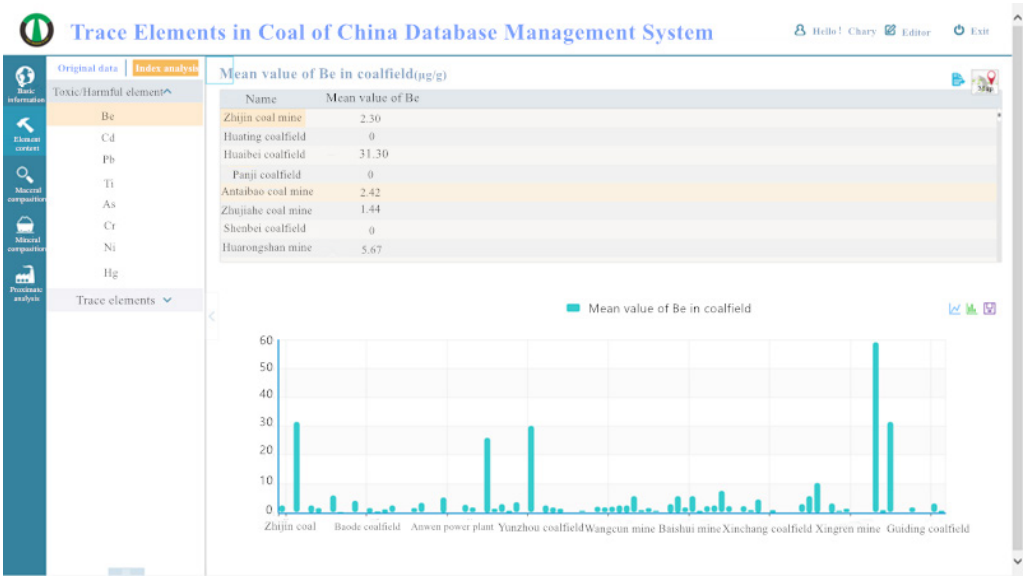


FIGURE 7. Sketch map histogram display (The element of Be mean value distribution) in TECC

Analysis results

The spatial distribution and mean content of As, Be, F, Hg and U can be obtained from the content level graphs of the five harmful elements:

The harmful elements As, Be, F, Hg and U in coal gather in southwest China, Shanxi, mid-eastern region of Inner Mongolia, northwest of Northeast China Plain, eastern part of Sinkiang Dzungaria and the counties in southwest Shandong. These elements are also widely distributed in mid-eastern region of Inner Mongolia and northwest of Northeast China Plain;

As highly gathers in Yunnan and Guizhou regions, eastern part of Sinkiang Dzungaria, some areas in Inner Mongolia and western Liaoning; Be highly gathers in Sichuan, Chongqing, some areas in Inner Mongolia and western Liaoning; Hg high gathers in Sichuan, Chongqing, Guizhou, Ordos Basin, some areas in Inner Mongolia, coal mines in eastern Jilin, southwest Shandong; F highly gathers in Sichuan, Chongqing, some areas in Guizhou and Ordos Basin; U highly gathers in southwest China, eastern part of Sinkiang Dzungaria and eastern Shanxi.

TABLE 4. Comparative study on mineral energy system in China

Researcher	Database	Development technology of database	Functions of database	WebGIS	Data entry specification	Innovation points
Chen (1996)	CSRDS	Unknown	Retrieval, mapping, statistical analysis, economic evaluation, data updating and checking	No	None	Large amount of information stored
Zhuang (2000)	China Energy Database	Unknown	Data inquiry, statistical analysis, report graph, comprehensive evaluation	No	None	Large data volume, various data categories and unified sheet
Cao et al. (2005)	China Coal Characteristics Database	Oracle9i	Data entry and editing, data checking and conversion, data network publishing, user query, data statistical analysis	No	None	Date can be updated and shared, with strong security control
Han et al. (2009)	Coal Geological Database Integrated Management System	OpenGIS, MySQLdata engine, C/S structure	Data and map browsing, metadata management, attribute data management, database reports and statistics printing, data output, system management, satellite image management, data input and standardized entry	No	Partial	More advanced development technology; add map browsing and remote-sensing image browsing functions
Nie et al. (2012)	Global Geochemical Data Management System	ArcGIS Server9.3, ASP.net2.0, Oracle, B/S structure, Web and Globe model	Data inquiry, visualization of information about sampling point, data analysis and output	Yes	Unknown	Achieve visualization of information about sampling point (two-dimension and three-dimension)
Zhang et al. (2014)	Coal Resources Survey Database System	MapGIS, VisualC# C/S, B/S strcuture	User management, graphic editing, inquiry statistics, printing and output	Yes	Partial	Achieve the integration and unification of multi-source and heterogeneous coal resources data
Yang et al. (this research)	TECC System	WebGIS, Oracle, AJAX, XAML, B/S structure	Inquiry of original data, thematic map making, index analysis, new file creating, file uploading, file downloading, data deletion, data change, data addition, user information management, user authority management, log management	Yes	In detail	Strict data entry specification; achieve thematic map making; add more advanced AJAX and XAML development technologies

Conclusion and Discussion

DATA VALIDITY

Currently, as for the establishment of domestic database related to minerals and energy (Cao et al. 2005; Cchen et al. 1984; Chen 1996; Han et al. 2009; Zhuang 2000), there is no strict data entry specification except the specifications required by the database software, which limits the data sharing between databases and greatly reduces the practical value of database system (Table 4). This research, according to relevant national and international standards, specifies the standards and principles for screening of data about trace elements in coal, making strict data entry specification and unifies the data format, which ensures the data validity, facilitates data sharing and data mining and provides experience for the establishment of data entry specifications of other systems.

SYSTEM FUNCTION AND DEVELOPMENT TECHNOLOGY

Most minerals and energy databases in China only contain attribute data (Cao et al. 2005; Chen 1996; Zhuang 2000) and only a few of them contains spatial data (Han et al. 2009; Nie et al. 2012; Zhang & Huang 2014), without strict data entry specification. The China Energy Database and China Coal Characteristics Database are mature in research on basic inquiry and analysis function (Cao et al. 2005; Zhuang 2000). The Coal Geological Database System and Global Geochemical Data Management System (Han et al. 2009; Nie et al. 2012) have breakthroughs in system function and are combined with GIS, but the deep data analysis function is inadequate. The Coal Resources Survey Database System (Zhang & Huang 2014) achieves wed issuing and is closely combined with GIS, but the combination of spatial data and attribute data is inadequate. It only achieves inquiry of existing thematic maps and cannot generate new ones. Besides, the development technology of most researches is single, which restricted the realization of new functions (Table 4). The TECC established by this research is based on distributed database management and can store spatial data and attribute separately, which achieves unified management, unified maintenance and distribution. TECC is researched and developed through the application of Oracle database, AJAX, WebGIS technology and B/S system structure, which breaks through the single-function nature of database and adds spatial data function, such as inquiry on maps, thematic map making, satellite image browsing and data analysis. This cannot only maintain and manage data efficiently and quickly, but also reflect the spatial and temporal distribution of trace elements in coal in the form of GIS maps and various charts. This system combines the current fast-developing 3S technology to achieve popularization, networking and intellectualization. It is of strong practicability and has more diverse functions and advanced development technology compared to the data bout existing minerals and energy database in China (Table 4).

However, the current data size and type of TECC need to be improved continuously by adding data in the database and hot spot information in the field of minerals and energy research to improve the vitality and value of the database. In addition, the analysis function of data about trace elements in coal is not strong enough, therefore, other element analysis functions need to be added to gradually perfect the database system and achieve multiple spatial analysis functions.

In conclusion, this research, based on valid literature data and field sampling data, establishes TECC with WebGIS, AJAX and Oracle database technology, which realizes the functions of data inquiry, statistical analysis, management, maintenance and thematic map making, achieves web issuing and puts forward the data entry specification to ensure data validity. The development and establishment of system can provide powerful data sharing and technical support for the research of trace elements in coal and has important theoretical and realistic significance for the research on ecological damage and environmental pollution caused by harmful elements in coal.

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