System Development Of Geosphere Environmental Informatics And Its Application

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Abstract. In this study, we examined cadmium (Cd) concentration in river-bed sediments using GIS system of geosphere environmental informatics, which has been being developed for the integration of geoshpere environmental information such as geology, soil texture, vegetation, topography, location of mineral deposit, alteration zone, anomaly of heavy metals, satellite image, the groundwater information, concentration of heavy metals in rocks, soils and river-bed sediments. In the GIS system, some original geoprocessing models were developed. Map integration model can integrate various type of information and take new insight from them. Search refinement model can extract the objective feature from various information by selecting attribute and location repeatedly. We carried out the hydrologic analysis in order to evaluate the concentration distribution of Cd. In the analysis, the stream network and the watersheds of sampling points were created from a digital elevation model in the Tohoku district, Japan. We integrated Cd concentration and the watersheds, and created the concentration distribution map at each watershed. In addition, the influence of topography and soil texture on the Cd concentration was considered. Finally, we concluded that the incorporation of geosphere environmental information into the concentration distribution is effective to the evaluation of the transfer behavior of Cd.

Keywords: GIS, Geosphere environmental information, Hydrologic analysis, Soil pollution, Heavy metal.
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INTRODUCTION

In Japan, the database about naturally-derived soil contamination has not been systematized because the survey results of soil contamination were held by each research institute. In such a situation, we have been developing the 'Geosphere Environmental Informatics' which is abbreviated to the '*Geoinformatics*' by using a geographical information system (GIS). The system has the database of various geoshpere environmental information which is indispensable for the evaluation of hazardous elements. The brief overview of the project has been reported by Kano *et al*. (2007) [1].

In this study, we will report the detailed system of the *Geoinformatics* and the result of examination about cadmium (Cd) concentration in river-bed sediments in the Tohoku district in Japan.

SYSTEM OF THE *GEOINFORMATICS*

Databases Included In The System

(i) Topographic map: Digital Map 50 m Grid (Elevation) published from the Geographical Survey Institute [2] was used as a topographic map. The map is a digital elevation model (DEM) derived from contour lines in 1:25,000 topographic map. A net of approximately 50 m grid is applied to the 1:25,000 topographic map (one grid is equivalent to the area of 1.5 seconds in latitude and 2.25 seconds in longitude) and provides the elevation data of the center of the grid. Topographic map was created by connecting 124 pieces of DEMs throughout Japan.

(ii) Geological map: We used the 1:200,000 seamless digital geological map of Japan, compiled by

CP987, *WaterDynamics: 5th International Workshop on Water Dynamics,*
edited by K. Tohji, N. Tsuchiya, and B. Jeyadevan,

the Geological Survey of Japan (GSJ), AIST [3]. The map was based on the 1:200,000 geological quadrangle maps that have been published by GSJ since the 1950s.

(iii) Soil map: Soil map was compiled from the result of 1:200,000 scale fundamental land classification survey conducted by the National Land Survey Division, Land and Water Bureau, Ministry of Land, Infrastructure and Transport. The map was published on the Web site addressed 'http://tochi.mlit.go.jp/tockok/index.htm'.

Configurations of soil distributions were traced from TIFF formal soil map by Adobe Photoshop, and then polygons of soil distributions were created by ArcScan which is an extension of ArcGIS (ESRI Co., Ltd.). The polygon has the attributes of a name of prefecture and a name of soil classification.

(iv) Vegetation map: We used a nationwide GIS data about the result of national survey on the natural environment conducted by the Biodiversity Center of Japan, Ministry of the Environment [4]. The map scale is 1:50,000.

(v) The map of alteration zone: The maps of alteration zone were made from the reports on the regional geological structure survey published by the Agency for Natural Resouces and Energy, Ministry of Economy, Trade and Industry [5]. The configuration of alteration zones where Pyrite, Sericite, Smectite, Chlorite, Epidote, Kaolinite, Alunite, Pyrophylite, Halloysite, Dickite were rich, were traced on a paper, and polygons were created using ArcScan. The polygon has attributes such as a name of prefecture, a name of city, types of alteration, altered mineral and area of alteration zone.

(vi) The map about anomaly of heavy metals: The map about anomaly of heavy metals was created from a result of multivariable analysis for Cu, Pb, Zn in some reports on the regional geological structure survey published by the Agency for Natural Resouces and Energy, Ministry of Economy, Trade and Industry [5]. The method of creating polygons is same as the case of alteration zone.

(vii) The location map of mineral deposit: Point data about the location of mineral deposit were compiled from previous reports [6]. The points have attributes of a name of prefecture, a name of city, a name of mine, longitude and latitude, and types of mineral.

(viii) Satellite image: Satellite images of Hokkaido and Tohoku district were provided by the Remote Sensing Technology Center of Japan (RESTEC) and the Earth Remote Sensing Data Analysis Center (ERSDAC).

(ix) Concentration of major and trace elements in rocks: Rock samples collected around the kuroko deposits in northern part of Akita prefecture are now analyzing for their content of major and trace elements by ICP-MS and ICP-AES. Point layers which have the attributes such as a name of prefecture, a name of sampling location, longitude and latitude, rock type and the concentration of major and trace elements will be created after analysis.

(x) Concentration of trace and ultra-trace elements in soils: Locations of sampling points and the content of trace and ultra-trace elements in soil samples [7] were compiled to one point layer. The number of soil samples was 514 from 78 sites in Japan, and 57 elements were analyzed by ICP-MS and ICP-AES.

(xi) Concentration of major and trace elements in river-bed sediments: 53 major and trace elements in river-bed sediments were analyzed by AIST. The data was published on the Web site addressed 'http://riodb02.ibase.aist.go.jp/geochemmap/index_e.htm'. A point layer was formed by using the results. Each point has attributes of sample No, a name of location, longitude and latitude and the concentration of elements.

(xii) Concentration of chemical composition and toxic elements in groundwater: The result of groundwater quality measurement investigated by the Ministry of the Environment [8] was used to create a point layer about the concentration of chemical composition (benzene, 1,2-DCA, 1,1-DCE, cis-1,2-DCE, DCM, 1,1,1-TCA, 1,1,2-TCA, TCE, 1,3-DBP, PCB, PCE, CCl4 and cyanogens) and toxic elements (Hg, As, B, Cd, Cr, F, Pb, Se) in groundwater.

Geoprocessing Models

Some original geoprocessing models were developed by the ModelBuilder interface in ArcGIS. These models were built up by stringing together a series of geoprocessing tools.

(i) Map integration model: The model was developed by using the computation of geometric intersection. This model extracts areas which overlap one another from number of input maps and calculates areas in units of m^2. For example, inputting watershed map and geological map, the model can extract polygons of geological layers within each watershed and can calculate their exposed areas. We can take the statistic about the geological settings for each watershed, and characterize watersheds by geology.

(ii) Search refinement model: The model was developed by using the selections of layer by attribute and location, change of coordinate system and area calculation tools. In the model, selections of input map by attribute and location was executed repeatedly to extract features which have specified parameter. For example, the model can be applied in the case that high level of contamination of heavy metals was found at a certain geological formation by the preliminary survey in a civil engineering work, and we want to know the exposed area of the formation. The model also calculates the selected area in units of m^2, so it is possible to evaluate spatial extent of the area quantitatively.

HYDROLOGIC ANALYSIS FOR CD DISTRIBUTION

It is important for an evaluation of heavy metal's spatial distribution in rocks or soils to consider an influence of regional topography and geosphere environment. In this study, we tried to evaluate the relationship between Cd concentration in the geochemical map by AIST and geosphere environmental information such as topography and soil. Analytical river systems consist of Kitakami river, Naruse river, Nanakita river, Natori river and Abukuma river in the Tohoku district.

As for topography, an elevation and the value of TPI were considered. TPI is a parameter about degree of water catchment of land, called "Topographic Index", and is calculated using the following equation [9].

$$\mathrm{TPI} = \ln(\alpha/\tan\beta), \quad (1)$$

where α is a catchment area and β is an inclination angle of land slope. The value of TPI is higher in the place where a catchment area is larger and land slope is smaller. Therefore, it could be said that TPI is an indicator about a degree of forming a water saturation zone.

Analytical Method

Step 1: Stream networks and watersheds were created from topographic map. After vectorization of the raster linear networks, 134 polygons of the area of upper stream from the sampling points of river-bed sediments.

Step 2: Integration of watersheds and soil map was executed by the map integration model. Soil map was divided at each watershed and the occupied ratio of each area of soil texture to a whole watershed area was calculated.

Step 3: Correlation coefficients of Cd concentration and the occupied ratio obtained at the step 2 was calculated.

Cd Concentration At Each Watershed

134 watersheds in 5 river systems were color-coded for 10 levels by Cd concentration (shown in Fig. 1). The white line shows the river systems. The highest concentration was 1.55 ppm in the downstream of the Kitakami river.

Relationship Between Cd Concentration And Topography

Figure 2 shows the relationship between Cd concentration, the elevation and the value of TPI. The elevation was at the sampling point, and the value of TPI was the average within a watershed. The contour maps were drawn by the Inverse Distance Weighting method. Dots in the contour map show the location of sampling points. The result shows that Cd concentration was obviously high in the place of low elevation and high TPI, which suggests that this is the result that Cd moved down the river and deposited at downstream sites.

Relationship Between Cd Concentration And Soil Texture

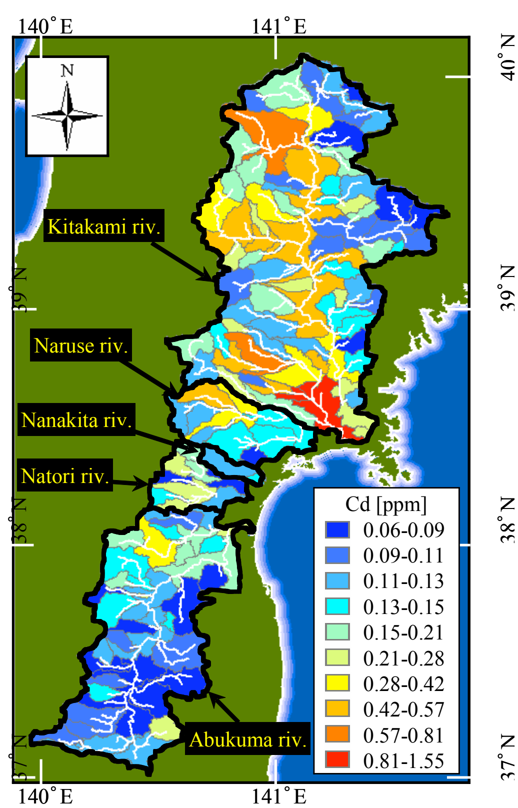

FIGURE 1. Cd concentration at each watershed

As the result of comparing the distribution of soil texture and Cd concentration, distribution of Cd concentration was slightly correlated with gray lowland soil (correlation coefficient was 0.29), muck soil (0.24) and peat soil (0.22; as shown in Fig. 3). The principal factor of the correlation could be the result of transfer by the river flow due to precipitous topography. The slight correlations with soil was thought to be reflected the topographic properties such as elevation and the TPI.

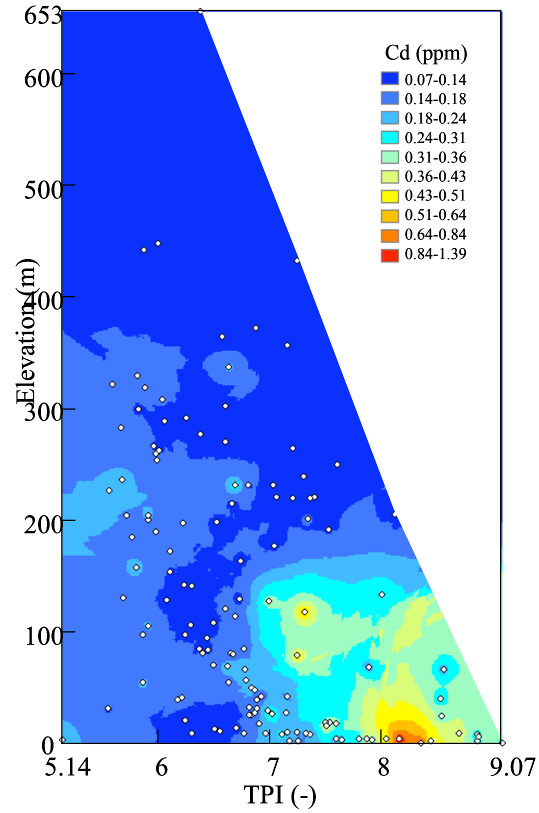

FIGURE 2. Relationship between Cd concentration, the elevation and the value of TPI

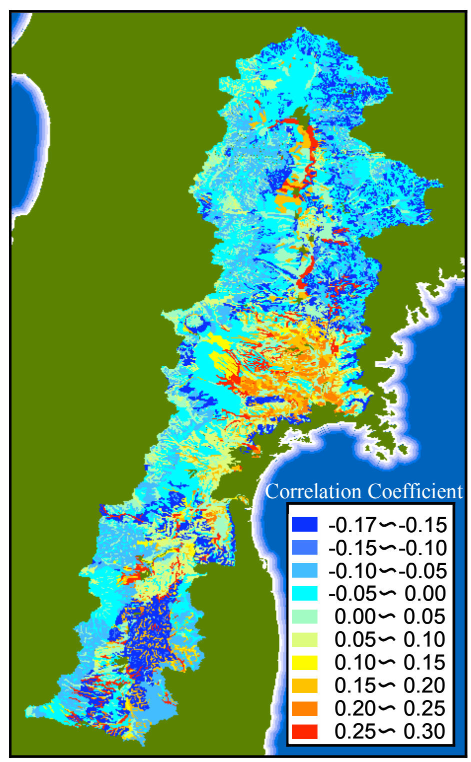

FIGURE 3. Correlativity between Cd concentration and soil texture

CONCLUSION

We have been conducted the industry-academic-government project called "System Development of Geosphere Environmental Informatics and its Nationwide Expansion" for three years from 2005 and are now developing the GIS system. In this paper, we introduced about the system and the hydrologic analysis in the Tohoku district was carried out to evaluate Cd concentration in river-bed sediments.

We will examine the relationship between heavy metal's concentration in river-bed sediments, soil, or rock samples, and geology, soil property, vegetation, etc. In addition, we will have several kinds of dissolution tests to know heavy metal's mechanical and chemical properties.

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