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Guidance for the monitoring of the karst carbon cycle and the evaluation of enhanced carbon sink in karst catchment

岩溶流域碳循环监测及增汇评价指南

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3 Terms and definitions

A karst catchment is defined as a complete catchment unit of a surface or underground water system in which the area of carbonate rock is not less than 10 %, the bicarbonate concentration of the groundwater or surface water body present is not less than 1 mmol per litre, and the hydrochemical type is the bicarbonate type.

The karst carbon cycle is defined as the process in which, within a karst catchment, the weathering and dissolution of carbonate rock consumes carbon dioxide from the atmosphere or the soil and forms inorganic carbon, the forms of carbon then converting into one another and migrating under physical, chemical and biological action. The karst carbon sink is the process, activity or mechanism by which carbon dioxide is absorbed from the atmosphere or the soil through the karst carbon cycle and stored in the water body.

The term for the artificial enhancement of the sink is printed in the document as artificail carbon sink increasing, and is defined as the process by which activities such as artificial afforestation and grass planting, soil improvement, the introduction of allogenic water and the cultivation of aquatic plants promote the absorption of more carbon dioxide from the

atmosphere or the soil by karst processes.

4 General provisions

4.1 The work surveys the geological and hydrological structural features of the karst catchment and monitors the source, migration, conversion, form of occurrence, distribution features and flux of carbon in the karst carbon cycle. It builds a database of the carbon cycle and of sink enhancement in karst areas, prepares maps of the karst carbon cycle and of carbon sink effects, assesses the source and sink effects of the cycle, computes the karst carbon sink intensity of typical catchments and carries out the evaluation of that intensity and of its enhancement. It analyses in particular the controlling factors of the karst carbon sink in the monitored area and selects the best techniques for enhancement, so as to serve national and local needs.

4.2.1 and 4.2.2 On the basis that the general pattern of the working area is grasped, the work is preferably carried out first in regions where regional geological, hydrogeological or environmental geological surveys have already been made. According to the exposure conditions and the features of karst development, the karst areas of China are divided into the southern karst area, the northern karst area and the Qinghai-Tibet plateau area, whose distribution and features are given in Annex A. In the southern karst area the recharge, runoff and discharge conditions of groundwater, the hydrodynamic features and the hydrochemical regularities are relatively complex, the regional hydrogeological conditions change markedly and ecological problems stand out, so that it belongs to the complex class, the other two areas belonging to the simple to moderate class. The main technical quotas of the survey follow GB/T 14158, GB/T 12719 and Annex B.

4.2.3 The survey and monitoring proceed by catchment. Catchments are divided into four classes by area: not greater than 20 square kilometres; greater than 20 and not greater than 500 square kilometres; greater than 500 and not greater than 10 000 square kilometres; and greater than 10 000 square kilometres. The monitoring indicators are settled according to the class of catchment, as set out in Annex C.

4.2.4 and 4.2.5 Full use is to be made of historical material; existing work that meets the quality requirements may be counted toward the technical quota, further work then being deployed as needed. In areas where the degree of hydrogeological study is low, the workload of survey points follows Annex B; where it is moderate, 70 % of that workload is deployed; where it is high, 50 %. Table 1 divides the survey area into three zones by degree of hydrogeological study: the zone of high study, where a dedicated hydrogeological survey at a scale of 1 to 50 000 or larger has been made, where in mountainous ground a regional geological survey at that scale or larger has been made, and where in plain and basin ground a Quaternary geological survey has been made; the zone of moderate study, where a regional hydrogeological survey at a scale of 1 to 100 000 or 1 to 200 000 has been made, or a hydrogeological investigation at a larger scale; and the zone of low study, a

blank area for regional hydrogeological work, or one where only a small-scale regional hydrogeological survey below 1 to 200 000 has been made.

4.2.6 and 4.2.7 Routine water quality analysis comprises the simplified analysis and the full analysis. The number of routine water quality samples preferably makes up 30 % to 50 % of the hydrogeological points, that is machine wells, dug wells, springs and surface water bodies, of which full analysis samples preferably reach 10 % to 20 % of the water quality samples; full analysis, pollution analysis and isotope analysis samples for monitored water points may be arranged as needed. Where the survey area contains special ground such as high mountain gorges, plateau permafrost, nature reserves or military control areas, the technical quota may be settled according to the real situation, the minimum monitoring density of Annex B being taken as the reference.

5 Work flow

The work flow of karst catchment carbon cycle monitoring and sink enhancement preferably comprises the preparation of the work programme, the survey of catchment structure, the monitoring of the carbon cycle process, the survey of artificial sink enhancement measures, the analysis of carbon sink intensity and flux and their evaluation by zone, the preparation of maps and the construction of the database. The flow is shown in Figure 1.

6 Content of monitoring and evaluation

6.1 The survey before monitoring covers relief, stratigraphy and structure, soil and vegetation, and hydrogeological features. For relief the survey covers elevation, slope, landform type and karst forms, so that their spatial distribution and association are established. For stratigraphy and structure it covers the rock association, the distribution of carbonate rock and of gypsum, sulphides and coal measures, so that the geochemical and structural type and position are established. For soil and vegetation it covers soil type, soil thickness, plant community type and composition, so that the ecological features are established. For hydrogeology it covers the hydrodynamic conditions and hydrochemical features of surface water and groundwater, so that the structure and boundary of the karst groundwater system are settled and the recharge, runoff and discharge conditions and the spatial layout analysed.

6.2 The monitoring of the conditions and processes of the carbon cycle covers six items. The conditions are air temperature, precipitation, potential evaporation, wind, solar radiation, net primary productivity of the vegetation and change of land use type, whose dynamic features are analysed. The soil carbon cycle process covers soil respiration, the carbon dioxide concentration of the air and the soil, and the dissolution amount of dissolution test tablets. The inorganic carbon cycle process of surface water and groundwater covers the migration of dissolved inorganic carbon in the underground karst aquifer medium and the change of carbon form, the flux and the source in caves, karst

springs and underground rivers. The exchange and release of carbon dioxide at the surface water covers the release or absorption flux of surface rivers and its dynamic features. The conversion process of aquatic plants covers the conversion flux between organic and inorganic carbon in surface rivers and its dynamic features. The deposition process covers the spatial and temporal distribution of organic and inorganic carbon in lakes and reservoirs, the carbon deposition flux of the bottom mud, the deposition rate and its source.

6.3 The evaluation of artificial enhancement measures covers four items: the survey and evaluation of the increase of surface biological carbon sink from afforestation, grass planting and ecological restoration and of the resulting intensity of the underground karst carbon cycle and the carbon sink increment; the survey and evaluation of the rise of soil quality and the strengthening of the soil carbon cycle brought by soil improvement measures such as organic fertilizer, farmyard manure and biochar-based fertilizer, and of the strengthening of the karst carbon cycle below the soil and the carbon sink increment; the survey and evaluation of the intensity of the karst carbon cycle and the carbon sink increment brought by introducing allogenic water into the karst area; and the survey and evaluation of the artificial selection and breeding of aquatic photosynthetic organisms that raise the conversion efficiency from inorganic to organic carbon, increase the stability of the karst carbon sink and lower the release of carbon dioxide at the water-air interface.

7 Technical methods

7.1 The survey of catchment structure collects material on physical geography, meteorology and hydrology, regional geology, structural geology, hydrogeology and the ecological environment, and may collect material on the socio-economic situation, on the present use of water, soil, rock and mineral resources, on development plans and on other matters related to the carbon cycle. In important or unascertained ground such as the conduit medium of an underground river or the divide between underground rivers, geophysical exploration, drilling and tracer methods are preferably used so that the structure and boundary of the groundwater system are settled. The collected material is then analysed as a whole, the geochemical, geological and ecological factors that affect the carbon cycle of the catchment being summarized so that the key processes to monitor and the layout of the monitoring points become clear.

7.2 For the monitoring of the conditions of the carbon cycle, meteorological conditions are laid out with one point in each main climate type area and rainfall belt, monitored every 15 min or every 30 min; existing ecological and environmental meteorological station data are preferably collected, and where the accuracy falls short a fully automatic small meteorological station may be installed to obtain air temperature and precipitation and may also obtain potential evaporation, wind, solar radiation and atmospheric carbon dioxide concentration. Vegetation net primary productivity, land use change and river evaporation are covered over the whole area once a year, preferably obtained by remote sensing