Journal of Asian Earth Sciences 54–55 (2012) 162–173

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Geochemistry and solute sources of surface waters of the Tarim River Basin in the extreme arid region, NW Tibetan Plateau

Jun Xiao [a], Zhang-Dong Jin [a,*], Hu Ding [b], Jin Wang [a], Fei Zhang [a]

[a] State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China
[b] State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, China

ARTICLE INFO

Article history:
Received 31 December 2011
Received in revised form 30 March 2012
Accepted 12 April 2012
Available online 22 April 2012

Keywords:
Tarim River
River water
Major ions
Solute sources
TDS flux

ABSTRACT

Major ion concentrations of river, lake and snow waters were measured to better understand the water quality, hydrochemical processes and solute sources of surface waters within the Tarim River Basin in the extreme arid region. Surface waters are slightly alkaline and are characterized by high total dissolved solids (TDS). TDS values varies over two orders of magnitude from fresh (76%) to brackish (24%) with a mean value of 1000 mg/L, higher than the global river average and river waters draining the Himalayas and the southeastern Tibetan Plateau. Most of the samples were Ca^{2+}—(Mg^{2+})—HCO_3^- type and suited for drinking and irrigation. Water quality of Aksu River (AK), Hotan River (HT) and Northern Rivers (NR) is better than the others. Rock weathering, ion exchange and precipitation are the major hydrogeochemical processes responsible for the solutes in rivers waters. Anthropogenic input to the water chemistry is minor and human activities accelerate increase of river TDS. The quantitative solute sources are first calculated using a forward model in this area. The results show that evaporite dissolution, carbonate weathering, atmospheric input, and silicate weathering contributed 58.3%, 25.7%, 8.7%, and 8.2% of the total dissolved cations for the whole basin. Evaporite dissolution dominated in Lake Waters (LW), HT, Yarkant River (YK), Tarim River (TR), and Southern Rivers (SR), contributing 73.5%, 53.4%, 56.7%, 77%, and 74.2% of the total dissolved cations, respectively. Carbonate weathering dominated in AK and NR, contributing 48% and 44.4% of the total dissolved cations, respectively. The TDS flux of HT, TR, AK, YK was 66.0, 118.6, 134.9, and 170.4 t/km^2/yr, respectively, higher than most of the rivers in the world. Knowledge of our research can promote effective management of water resources in this desert environment and add new data to global river database.

1. Introduction

Water resources and water quality play a key role in the development of the regional economy and stability of oasis ecosystems in the arid northwest and particularly in the desert area of China. Study of water geochemistry and its evolution under natural water circulation processes help to better understand the water quality and provide a basis for rational utilization and conservation of water resources (Simpson and Herczeg, 1991; Herczeg et al., 1993; Adams et al., 2001; Dessert et al., 2001; Wen et al., 2005; Tizro and Voudouris, 2008; Chang and Wang, 2010). Meanwhile, the dissolved components in river waters are important in the context of the major ion geochemical cycles at catchment and global scales (Berner and Berner, 1997; Spence and Telmer, 2005; Moosdorf et al., 2011). A detailed understanding of the processes controlling on water chemistry are crucial to better define geochemical cycles within a given catchment (Jin et al., 2011). Although natural controls of riverine chemistry at the global scale have been widely studied (Gibbs, 1970; Meybeck, 1987; Gaillardet et al., 1999), regional studies performed within remote areas are rare (Jin et al., 2009, 2010). Recently, studies of water chemistry in China are mainly concentrated in the Changjiang River (Yangtze River) (Chen et al., 2002; Han and Liu, 2004; Chetelat et al., 2008), Huanghe River (Yellow River) (Zhang et al., 1995a; Chen et al., 2005) and Zhujiang River (Pearl River) (Xu and Liu, 2007, 2010; Zhang et al., 2007) while very little is known about the water chemistry in the Tarim River.

Located in an extreme arid area in southern Xinjiang, the Tarim River is the largest inland river in China. It is also the lifeline to guarantee oasis economic and natural ecology of the Tarim River Basin with more than 8 million people living in oases clustered along its banks and in an alluvial plain down-stream, known as the "Life river" and "Mother River". The lower Tarim River nearly dried up in 1972 due to large-scale agriculture development and irrational water resources utilization in the upper and middle reaches of the river (Feng et al., 2005). In 2000 year, the Chinese Government initiated the largest environmental restoration project with 10.7 billion Yuan with water diversions from Bosten Lake

* Corresponding author. Fax: +86 29 88320456.
E-mail address: zhdjin@ieecas.cn (Z.-D. Jin).

1367-9120/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jseaes.2012.04.009

to Daxihaizi Reservoir with subsequent releases to the lower reaches of the river. Many previous works are well done on evaluating climate change (Sun et al., 2008) and its effect on water resources and its tendency in the Tarim River (Xu et al., 2004, 2005; Chen et al., 2007, 2009) and on studying change in value of the water transfer effects on local ecosystem in the lower Tarim River (Xu et al., 2007, 2008; Huang et al., 2010). Zhang et al. (1995b) studied on the evaporation, crustal weathering and the controls over water chemistry of the Tarim River waters. Zhu and Yang (2007), Zhu et al. (2011) studied well on the major elements and their qualitative sources in the river water and groundwater in the southern Taklimakan and northern of Xinjiang, respectively. Although water quality and solute sources in river water were very important for the local people's life and chemical process in this area, little is known about these. In addition, population increased rapidly and human activities strengthened in this area in recent years. How these influence the geochemistry of surface water in this area is needed to explore.

In the present study, major ions of rivers, lakes and snow water samples within the Tarim River Basin were analyzed to provide a full picture of solute geochemistry in the extreme arid environments. Then, hydrochemical processes controlling the water geochemistry were discussed and quantitative solute sources were first calculated in this area. Knowledge of these can provide information on the chemical weathering in desert environments, promote effective management of water resources, and add new data to the world river geochemistry.

2. Site description and catchment geology

The Tarim River is located in an extreme arid area of Tarim River Basin (34°–45°N, 73°–97°E) in NW China (Fig. 1), which is flanked by the Tianshan Mountains to the north and by the Kunlun Mountains to the south with a total catchment area of 1.02×10^6 km^2 (Fig. 1) (Chen et al., 2007, 2011). The Tarim River Basin is 1500 km long from east to west and about 600 km wide from north to the south. The altitude of the basin varies between 800 and 1300 m above sea level (a.s.l) and the west part of the basin is higher than the east part. Hydrologically, the Tarim River Basin represents a closed catchment and is a unique freshwater ecosystem located near the Taklimakan Desert, the second largest flow desert in the world. In history it included nine river systems and the mainstream of Tarim River. Nowadays, only three main headstreams, namely the Aksu River, the Yarkant River and the Hotan River, supply water to the mainstream. Bosten Lake has transferred water to the lower reaches of Tarim River, and therefore the pattern of "four headstreams and one mainstream" is formed. The mainstream of the Tarim River is 1321 km, starting from Alar to Taitema Lake. The upper stream of the Tarim River is from Alar to Yingbazha (495 km), the middle reaches from Yingbazha to the Qiala Reservoir (398 km), and the lower reaches from the Qiala Reservoir to Taitema Lake (428 km) (Fig. 1). The Yarkant, Hotan and Keriya Rivers are the three largest rivers originating from the northern Kunlun Mountains, after reaching ~200 km from the desert edge towards the interior, finally disappearing in the desert (Fig. 2). The Aksu River is the largest river originating from the southern Tianshan Mountains. The mean annual natural discharge of surface water in the Tarim catchment is 3.98×10^{10} m^3 (Chen et al., 2003). The mainstream of the Tarim River does not generate water flow, and the water in the Tarim River Basin is supplied by water converted from ice, snow and precipitation in the mountains. Glacial and snowmelt water accounts for about 40% of the total runoff (Chen et al., 2007). Thus, the Tarim River is a dissipation-only inland river, and the water source from the upstream/headstream area directly maintains the water flow in the mainstream of the Tarim River (Chen et al., 2011). The Aksu River, the Yarkant River and the Hotan River are three largest rivers in the west of the basin, which feed the Tarim River at Alar (Fig. 2). Among the three main headstreams, the proportions of water discharge from the Aksu River, the Hotan River and the Yarkand River account for 73.2%, 23.2% and 3.6%, respectively (Chen et al., 2003). The Aksu River can supply water to the Tarim River continually throughout the year, and the Yarkand River can do this only when it suffers extraordinary floods and the Hotan River supplies water only during annual flood periods (Zhou et al., 2011). The mean annual sediment contents varied from 2.0 to 5.6 kg/m^3 in the rivers from southern Tianshan Mountains, from 2.9 to 5.9 kg/m^3 in the rivers from northern Kunlun Mountains, from 2.0 to 11.5 kg/m^3 in the rivers from northern Alty Tagh Mountains, and from 4.1 to 5.0 kg/m^3 in the upper and middle reaches of the Tarim River (Arkin et al., 2007). The Tarim River Basin covers 42 counties and 55

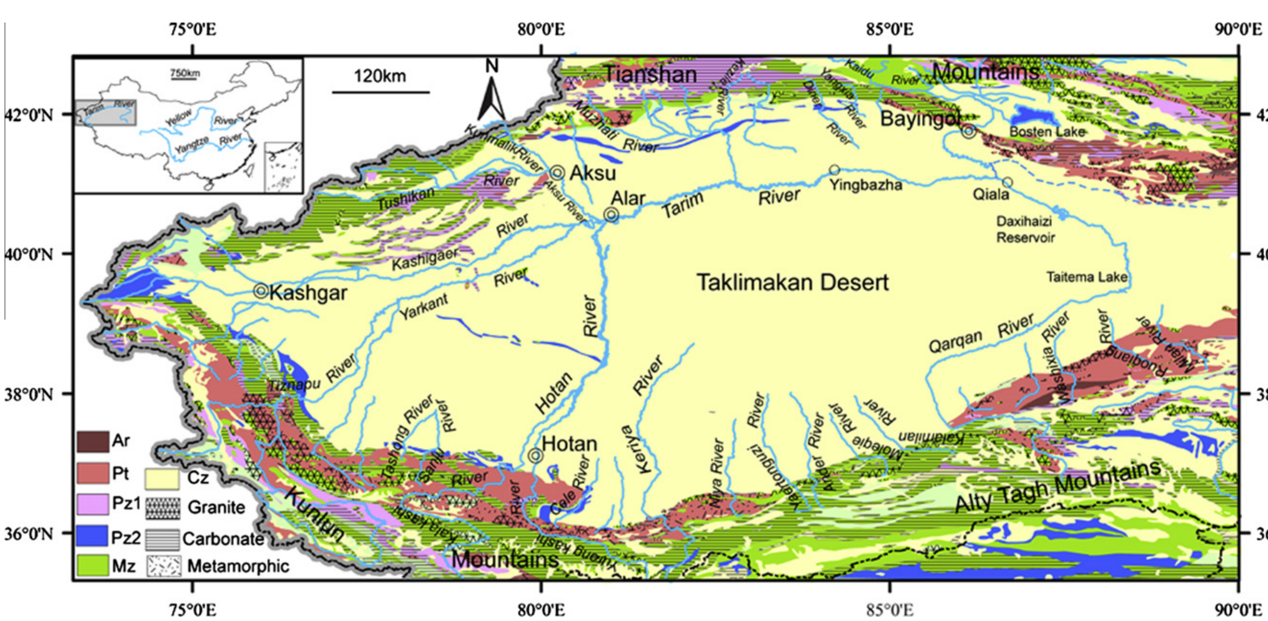

Fig. 1. Geologic map of Tarim River Basin on the northwestern Tibetan Plateau.