



Variation of groundwater salinity in the partially irrigated Amudarya River delta, Uzbekistan

Olov Johansson^a, Izzet Aimbetov^b, Jerker Jarsjö^{a,*}

^a Department of Physical Geography and Quaternary Geology, Stockholm University, SE-106 91 Stockholm, Sweden

^b Karakalpak branch of the Uzbek Academy of Sciences, 41 Prospekt Berdakh, 742000 Nukus, Uzbekistan

ARTICLE INFO

Article history:

Received 3 January 2007

Received in revised form 12 February 2008

Accepted 12 March 2008

Available online 13 August 2008

Keywords:

Aral Sea

Amudarya

Amu Darya

Irrigation

Land use

Surface water

Groundwater

Water systems

Salinization

Pollution

ABSTRACT

The Amudarya delta region contains surface and groundwater resources that discharge into the shrinking Large Aral Sea and ultimately control its future fate. These freshwater resources are prerequisites for sustaining the population of the region. However, salinization and pollution caused by agricultural irrigation is a key problem for these water systems. Here, we report results from a recent field measurement campaign conducted during April 2005 which included 24 monitoring wells located in an irrigated region of the Amudarya delta, thereby extending the historical data set of groundwater levels and salinity measurements. This data set is combined with corresponding data from a downstream, non-irrigated region that was formerly irrigated (together covering 16,100 km² between the Uzbek cities of Nukus and Muynak). This comparison shows that in the downstream region, which is currently not irrigated, shallow groundwaters are far more saline (average 23 g l⁻¹) than the currently irrigated region (average 3 g l⁻¹). We estimate that the unconfined aquifer within the 13,500 km² non-irrigated zone of study area contains 9 billion tons of salt, or almost as much salt as the entire Aral Sea (containing 11 billion tons of salt and covering an area of 20,000 km² in year 2000). Within the non-irrigated zone, there are statistically significant large-scale spatial correlations between groundwater salinity and distance to the Amudarya River, irrigation canals and surface water bodies when distance is measured along the modelled regional groundwater flow direction. Generally, groundwater salinities are lower downstream of surface water bodies in the non-irrigated zone. Annual fluctuations in groundwater salinity are too large to be explained by input from surface water (Amudarya) or wind-blown salt from the dried Aral Sea sediments. Salt transport by groundwater is the only plausible remaining explanation for these changes.

© 2008 Elsevier B.V. All rights reserved.

1. Introduction

The Aral Sea Crisis is one of the world's largest environment disasters, which has mainly been caused by an enormous expansion of agricultural irrigation within the Aral Sea Basin (ASB) during the 20th century. The sea's surface has decreased by 75% and its volume by 90% (Micklin, 2004) since the 1960s due to diversion of water of its tributaries for irrigation purposes. As a result, the sea is divided into two separate water bodies, the shallow Small Aral Sea in the north

and the southern Large Aral Sea. The shallow eastern basin and the deeper western part of the Large Aral Sea are currently connected by a narrow canal. This canal will dry up in the case of continuing sea level decrease.

Due to the considerably decreased surface water inflow, groundwater inflow has become a significant freshwater component of the water budget of the Larger Aral Sea (Jarsjö and Destouni, 2004). The discharge of the Syr Darya, which feeds the Small Aral Sea, is high enough to counterbalance the evaporative water loss of this lake. Additionally, discharge of water from the Small Aral Sea into the Large Aral Sea is restricted by an artificial dam. The groundwater discharge and the discharge of the Amudarya, which feed the Large Aral Sea,

* Corresponding author. Tel.: +46 8 164958.

E-mail address: jerker.jarsjo@natgeo.su.se (J. Jarsjö).

are not currently sufficient to prevent its ongoing salinization and shrinkage (e.g., Peneva et al., 2004; Friedrich and Oberhänsli, 2004; Benduhn and Renard, 2004; Gascoin and Renard, 2005). Zavialov et al. (2003) found that the salinities¹ of the western basin of the Large Aral Sea in 2002 ranged between 90 and 104 g l⁻¹, with the lower value representing conditions in the upper layer of the sea and the higher value representing conditions at the sea bottom. In 2005 the surface water salinity of the western basin reached above 109 g l⁻¹ (Zavialov et al., 2006). Due to the drastic change from the pre-1960 average salinity of 10 g l⁻¹ the Large Aral Sea has lost its former natural resource values, particularly its fish stocks which are not expected to recover in foreseeable future.

In contrast to the Aral Sea, artificial water reservoirs and small lakes within the adjacent Amudarya delta still possess realistic future potential for freshwater supply and fish production on the basis of an improved water resource management (Karimov et al., 2004). The United Nations Environmental Programmes Global International Waters Assessment (UNEP-GIWA) identified salinization and freshwater pollution as key problems hindering the development of the Aral Sea region (Severskiy, 2004). Today, the Amudarya River delta is severely affected by salinization, pesticide and nutrient pollution because it receives multiple irrigation waters from the catchment of the river. Additionally, the delta region receives influx of salt and pollutants from the dried sea floor by eolian deposition (Razakov and Kosnazarov, 1996). In order to understand the dominant processes that govern the spread of salt (and potentially also other pollutants), and to model these processes, detailed hydrogeological and geochemical data are needed. Furthermore, there is a need for the quantification of large-scale relationships between spatially varying land use-irrigation practices and downstream soil–water pollution and salinization development.

In (irrigated) arid areas with shallow groundwater tables, upward capillary water flow is the main cause for soil and groundwater salinization (e.g., Ceuppens and Wopereis, 1999; Northey et al., 2006). Understanding irrigation effects on large-scale salinity distribution is commonly limited by the availability of observational data, even though supporting analysis tools and models have been developed (see Utset and Borroto, 2001). Due to the clear environmental changes and existing monitoring sites and measurement data, the Amudarya delta region offers good conditions to investigate large-scale transport of salts and pollutants. Water quality data, including data on pesticide concentrations, are available for a long historical period at relatively high spatial and temporal resolution. Contaminant concentrations are often very high, which allows their detection over a large dilution range. Furthermore, as shown by e.g. Shibuo et al. (2006) and Alekseeva et al. (2009–this issue), the depth of the groundwater table is low. This means that analyses of surface topography and surface slopes can be used for quantification of hydraulic gradients, groundwater flows and near-coastal groundwater–sea water exchange (Shibuo et al., 2007; Jarsjö et al., 2008).

The major goals of our study are:

- Compilation of unpublished monitoring data of groundwater levels and groundwater salinity;
- Extending existing measurement series by our own measurements;
- Analysis of the spatial and temporal development of groundwater level and salinity in the Amudarya delta;
- Analysis of large-scale relations between land use-irrigation practices and downstream soil–groundwater–surface water salinization;
- Analysis of the causality of observed salinization trends of local groundwater and surface waters in the Amudarya delta and their consequences for the development of the Large Aral Sea.

2. Field investigation site and methods

2.1. Study area and field measurements

Fig. 1 shows the study area, which covers approximately 16,100 km². As part of the study we will investigate the top part (<5 m) of the unconfined aquifer, which is most likely to be affected by agricultural activities. The aquifer ranges in depth between 10 and 150 m (see e.g. summary of Shibuo et al., 2006). 90m Digital Elevation Data (Shuttle Radar Topographic Mission, National Aeronautics and Space Agency; <http://srtm.csi.cgiar.org/>, 2005-06-08) show that the elevation of the study area varies between – 18 and 255 m a.s.l., and most of the area is flat with an elevation of about 30 m a.s.l. A large part of the study area was formerly irrigated. Today, only the southern part is used for irrigated agriculture (Fig. 1). The surface waters of the study area contain a significant amount of irrigational return-waters from upstream areas, which in turn are again used for irrigation. The area comprises wetlands that are important reserves for the remaining flora and fauna (Verhoog, 2000; de Schutter and Dukhovny, 2003). Geologically, the area comprises dried-up sediments from the Amy Darya river on top of Quaternary deposits. The aquifers contain gravel, sand, sandstone and loamy sandy sediments. The soil salinity ranges between relatively low and high. When the salinity is moderate to high, the soils are called solonchaks and are commonly characterized by saline crusts (Singer et al., 2001).

The field campaign reported here is a continuation of the measurement series of the Karakalpak Hydromelioration Expedition (KHE). We used 24 groundwater monitoring wells (capped steel pipes with a diameter of 1 dm encased in concrete rings) that were also analysed in the monitoring program of the KHE and are located in the currently irrigated area (see Fig. 1). In order to obtain comparable results, the groundwater sampling procedures used were consistent with those used by the KHE. More than 500 wells are currently administered by the KHE. In previous hydraulic evaluations carried out by the KHE, the investigated 24 wells showed intact hydraulic connection with the surrounding aquifer. The depth to the groundwater table was measured using a floating weight on a graded string. Groundwater salinity was measured with a portable conductivity meter. The groundwater samples analyzed for conductivity were taken

¹ Volume-based units are used for consistency with our earlier work (e.g., Jarsjö and Destouni, 2004), noting that x g l⁻¹ corresponds to the mass fraction $x/(1+x/1000)$ g×kg⁻¹, yielding specifically 104 g l⁻¹=94 g×kg⁻¹ and 10.0 g l⁻¹=9.9 g×kg⁻¹.

Download English Version:

<https://daneshyari.com/en/article/4548814>

Download Persian Version:

<https://daneshyari.com/article/4548814>

[Daneshyari.com](https://daneshyari.com)