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Determination of background concentrations of hydrochemical parameters and water quality assessment in the Akhuryan River Basin (Armenia)

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ABSTRACT

The determination of background values of hydrochemical parameters, to distinguish between natural concentration and anthropogenically-influenced concentrations, is highly relevant. In presented study, to estimate the background values of hydrochemical parameters in Akhuryan River Basin, log-normal probability functions on the hydrochemical parameters concentrations was applied. The study is carried out on the basis of hydrochemical data of surface water quality monitoring for the period of 2010–2013. This study highlights the usefulness of application of site-specific background concentrations for the evaluation, interpretation of surface water quality and for determination of pollution sources.

1. Introduction

Surface water quality is a matter of serious concern today. Anthropogenic influences (urban, industrial and agricultural activities, increasing consumption of water resources) as well as natural processes (changes in precipitation inputs, erosion, and weathering of crustal materials) degrade surface waters and impair their use for drinking, industrial, agricultural, recreational or other purposes (Carpenter et al., 1998). Increasing water pollution causes not only the deterioration of water quality but also threatens human health and the balance of aquatic ecosystems, economic development and social prosperity.

In Akhuryan River Basin sewage and communal wastewaters from the settlements are directly released into the environment, since there are non-operational treatment plants, and sewage and industrial pipeline networks are obsolete: 70–80% of pipes are out of order. As a result, all wastewaters, including communal, industrial and non-industrial, are discharged into the surface waters without treatment (River Basin Management, 2014).

In the assessment of the quality of surface waters the typical procedure is that the concentration of contaminants of the surface water is monitored and subsequently compared with their respective Maximum Permissible Concentrations (MPCs) (Ch et al., 2003). If the MPCs are not exceeded, then the water quality is considered to be safe. But can we be certain that this is true? In Armenia previous surface water quality system assessment was based on the MPCs for fishery inherited from the former USSR. The application of MPCs in Armenia is highly disputable. The same value of MPC of certain chemical indicator used for the water body of different geographical zones. The MPC did not provide any information about the pressure on the water body.

One of the complexities of water quality information is that hundreds of different substances can influence on water quality, the importance of each depending on local hydrological conditions, biophysical features (e.g., wetlands), natural geology of an area, and sources of pollution. Secondly, each of these substances fluctuates throughout the year, either above or below the levels that may be harmful. Consequently, monitoring programs produce an enormous amount of information that is difficult to grasp. In these situations, development of site-specific water quality objectives is usually warranted. Site-specific objectives are derived for individual watersheds or ecosystem types, which take into account natural background conditions and management targets (i.e., remediate to desired state or prevent current conditions from deteriorating) (Ch et al., 2003; Crommentuijn et al., 2000; Shah et al., 2011; Smith

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et al., 2003; Gałuszka, 2007).

Prior to determining the site-specific objectives for any river basin, the determination of "background concentration" is necessary.

What is background concentrations (BGCs)?

The EPA has determined that while BGCs can be influenced by human activities, these sources must be from 'minor pollution of everyday activities' and not from a defined incident, activity or source of pollution.

The EPA defines the conditions that contribute to the BGC as:

- Natural: this is the amount of naturally occurring chemical substances derived/originating from natural processes in the environment as close as possible to natural conditions, exclusive of specific anthropogenic activities or sources; and
- Ambient: the concentration of chemical substances in the environment that are representative of the area surrounding the site not attributable to a single identifiable source. These are typically from historic activities, widespread diffuse impacts fall-out from motor vehicles (EPA Guidelines, 2008).

In the literature, there are different methods to define the BGCs of physico-chemical elements. For example, mean value plus two standard deviations, 90th percentile value, the median value, geochemical, statistical, combined methods (Reimann et al., 2008).

In the presented work BGCs are calculated using the statistical method with the theoretical distribution function (Pekarova et al., 2008; Slovak Technical Standard STN 7221, 1999). This method is quite simple, and for its calculation long-term data of water quality are not required.

The aim of this study is the calculation of BGCs; the application of BGCs in the derivation of water quality assessment system for the Akhuryan River Basin; the assessment of water quality of Akhuryan River and its tributaries; and, the determination of pollutants and their pressures.

2. The study area: Akhuryan River Basin

2.1. Description of the river basin

Akhuryan River Basin is located in the western part of the Republic of Armenia. The total area of the river basin is 2784 km^2. The total number of population in the Akhuryan River Basin is about 297,000. Akhuryan River originates from Arpilich Reservoir. In the middle and lower reaches Akhuryan River is transboundary with the Republic of Turkey. Karkachun and Ashotsq are the observed largest tributaries of Akhuryan River in Armenia. The largest urban community in Akhuryan River Basin is Gyumri which is also the second largest city of Armenia, with a population of 146,122 (Fig. 1).

Agriculture is one of the leading branches of economy in Akhuryan River Basin. The main profiles of agricultural production in the river basin are crop and livestock productions. There are plenty of reserves of construction materials, which are mainly presented by tuffs, perlite, sands and scoria. In Akhuryan River Basin all wastewaters, including communal, industrial and non-industrial, are discharged into the rivers without treatment. The impact of sewage water was considered as point source pollution in Akhuryan River Basin and the assessment of the impact was conducted based on the number of population. Gyumri, Artik and Maralik cities are viewed as potential sources of significant pressures (River Basin Management, 2014).

2.2. Description of water quality monitoring sites

The dataset originates from 5 sampling sites along the main flow of Akhuryan River, 2 sampling sites along the flow of tributary Ashotsq and 1 sampling site of tributary Karkachun (Fig. 1). The sampling sites are located in representative sites, where specific water properties are controlled. The sampling site 31 (0.5 km upstream Amasia village) checks the Akhuryan river water quality in the upper section of river which is influenced by the quality of the tributary Ashotsq; the sampling site 32 (1 km downstream Amasia village) indicates the impact of the settlements of this region; sampling site 33 (0.8 km upstream Gyumri city) controls the river water quality before its entry to Gyumri city the largest urban community in Akhuryan River Basin. The sampling site 34 (5 km downstream Gyumri city) controls the river quality downstream Gyumri City, which is enriched by the wastewater of Gyumri city. The sampling site 35 (near Yervandashat village) is located near the mouth of the river, where Akhuryan River flows into the River Araqs. The sampling site 36 (0.5 km upstream Artashen village) is located in the upper sections of tributary Ashotsq far from significantly affected by human activities of urban and rural areas. The sampling site 37 (river mouth) and sampling site 38 (river mouth) describe accordingly the estuaries of Ashotsq River and Karkachun River before flowing into Akhuryan River.

3. Methods

3.1. Methodology of ***BGCs*** calculation

First of all, for the assessment of BGCs of hydrochemical parameters for the Akhuryan River Basin the location with natural or minimal anthropogenic influence, where water quality data are available, was chosen. From the existing monitoring sites in the Akhuryan River Basin the source of Ashotsq River (sampling site 36) was selected. For the calculation of BGCs water monitoring data for the period 2006–2010 were used.

Since in nature processes mainly are described by normal distribution function, and in mathematical statistics logarithmic variables rank, regardless of their distribution law, seeking to normality, it is accepted as a theoretical distribution function observed the logarithmic normal distribution function.

Logarithmic normal density function is given as follows:

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} exp\left(-\frac{1}{2}\frac{(ln(x)-\mu)^2}{\sigma^2}\right),\ x>0$$

where $\mu$and $\sigma$are the location and scale settings, respectively, which can be estimated as follows:

$$\hat{\mu} = \frac{\sum_{i=1}^{n} ln(x_i)}{n}, \quad \widehat{\sigma^2}\frac{\sum_{i=1}^{n}(ln(x_i)-\mu)^2}{n}$$

Logarithmic normal distribution function percentile is calculated as follows:

$$x_p = F^{-1}\left(\frac{p}{100}\right)$$

where F(x) is the log-normal cumulative distribution function.

If the theoretical logarithmic function is used instead of the empirical distribution function, which is estimated as follows:

$$F(x) = \frac{\#X \le x}{n+1}$$

where $\#X \le x$ shows the number of observations that are smaller than x or equal:

Percentiles for the empirical data are calculated as follows: