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ANALYSIS OF ENVIRONMENTAL STATUS OF THE RIVERS VOROTAN, SISIAN AND GORIS

A. G. SIMONYAN [*], G. P. PIRUMYAN [**]

Ecological Safety Centre YSU, Armenia

The water quality of the Rivers Vorotan, Sisian and Goris was evaluated by Armenian Water Quality Index (AWQI) for the first time. The increase of the value of AWQI was shown, which indicates a decline of the water quality in the Rivers. Some correlation between AWQI and other indecies estimating water quality is established.

***Keywords*:** Vorotan River, water quality index, Armenian water quality index, entropy, geoecological syntropy.

Introduction. Water is a nonrenewable resource and unreasonable exploitation of it almost everywhere led to a decrease in water quality. Urbanization, industrialization and other anthropogenic activities as well as some natural processes affect water resources badly. Unplanned resource consumption finally will become threat to the water ecosystem. Rivers are the most important natural resources for human development. The comprehensive indicators are used for evaluation of water contamination degree which makes possible to evaluate the contamination of water on a wide range of quality indicators at the same time. The study of ecological status of the Rivers in RA is important for evaluation of their water quality, as well as for their further rational use. The development of water quality assessment methods using conventional indicators with taking into account various properties of surface water is an important issue. It must be noted that most developing complex characteristics of water object in one way or another is connected with the existing maximum permissible concentration (MPC) [1]. Recently was suggested Entropic water quality index (EWQI) and Armenian water quality index (AWQI) for evaluation of surface water quality [2−6]. The evaluation of water quality in the Rivers Vorotan, Sisian and Goris by AWQI is the aim of presented paper.

Study Area. The River Vorotan originates from Artsakh Plateau and flows into the River Araz, has length of 178 *km* and river basin of 5650 km^2. It flows through the winding canyon and has drop 16 *m* to 1 *km*. Major tributaries are the Rivers Sisian, Lernashen, Goris, Akari. There are four monitoring posts on the Vorotan River: № 99 – 0.5 *km* above Gorayr; № 100 – 1.0 *km* above Sisian City; № 101 – 2.0 *km* below Sisian City; № 102 – 0.5 *km* downstream from village Vorotan. The River Sisian is 33 *km* in length, it is the right tributary of the Vorotan River. Two monitoring posts, № 103 – 0.5 *km* above the Arevis and № 104 – at the mouth of the river, are located on the river. The River Goris is 29 *km* in length, it is the left tributary of the Vorotan River [7].

[*] E-mail: Sim-simov@mail.ru [**] E-mail: gpirumyan@ysu.am

Two monitoring posts, № 106 – 3.0 *km* above Goris City, № 107 – 1.5 *km* below Goris City, are located on the Goris River.

Determination Procedure. The concept of entropy has many interpretations in various fields of human knowledge. The system interacts with the outside world as a whole. An open system can exchange energy, material and, which is not less important, information with environment. The system consumes information from the environment and provides information to environment by acting and interacting with it. Shannon was the first, who related concepts of entropy and information [8]. He suggested that entropy is the amount of information attributable to one basic message source, generating statistically independent reports. The amount of getting information entropy is equal to the lost.

Monitoring positions cross-sections of the Rivers Vorotan, Sisian and Goris.

Information entropy for independent random event *x* with *N* possible states is calculated by the equation:

$$H = -\sum_{i=1} p_i \log p_i,$$

where p_i is probability of frequency of an event occurrence.

MacArthur was the first who used the general equation of entropy for evaluating biogenesis structuring degree [9]. Margalef R. postulated theoretical concept that meets a variety of entropy for a random selection of species from the community [10]. As a result of these works widespread and universal recognition received the index of Shannon H, which sometimes refers to as Shannon information index of diversity [8]:

$$H = -\sum n_i / N \log(n_i / N).$$

Different processes in hydro-ecological systems both with increasing and decreasing of entropy can occur. Pollution of water systems can be represented as a system of the hydro-chemical parameters (elements), the concentration of which exceeds the MPC. Then in the Shannon equation p_i is probability of the number of cases of MPC excess of *i*-substance or water indicator of total cases of MPC (*N*), $P_i=n_i/N$.

Calculation of EWQI and AWQI was carried out according to the procedure which is described in detail in [2, 5]:

Results and Discussion. It is established that in the water of the Rivers Vorotan, Sisian and Goris regularly exceedes the concentration values of nitrite and ammonium ions, due to water pollution by domestic wastewater. It is shown that water of studied rivers is also contaminated by some metals. Thus, in the studied rivers MPC of Cu, V, Al, Cr, Mg and Se is regularly exceeded. For example, in 2009 in the post № 101 concentration of NO_2^-, Al, V, Cr, Mn and Se exceeded MPC 6, 5, 12, 3, 4, and 1 times, respectively. Data on all elements and ions, as well as the calculation of the EWQI and AWQI are given in Tabs. 1 and 2.

The obtained data indicate that along the source to the mouth of the river water quality decreases. After Goris and Sisian Cities AWQI increases, this indicates a decline in water quality of the Rivers Vorotan and Goris caused by domestic wastewater pollution.

Water quality of the Rivers Vorotan, Sisian and Goris has been comprehensively evaluated by other indexes, also. Water Contamination Index (WCI), Canadian Water Quality Index (CWQI) and Specific-Combinatorial Water Quality Index (SCWQI) are used for evaluation surface water quality in RA (Tab. 3) [1, 12–14].

Table 1

EWQI and AWQI for the River Vorotan (2009–2012)

Post / Ind.	№ 99				№ 100				№ 101				№ 102			
	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012
NH_4^+	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
NO_2^-	0	0	0	0	0	0	0	0	6	5	6	5	0	0	0	0
Al	11	11	6	10	5	10	6	8	5	10	6	8	11	10	10	11
V	12	11	7	10	12	10	9	12	12	10	9	11	12	11	11	12
Cr	3	–	–	0	2	–	–	4	3	–	–	4	2	–	–	5
Mn	0	–	0	0	4	–	0	0	4	–	3	3	3	–	3	4
Cu	0	4	0	0	0	0	0	8	0	0	5	8	8	7	10	12
Se	0	–	–	0	0	–	–	0	1	–	–	3	1	–	–	0
N	26	26	13	20	23	20	15	32	31	25	35	42	37	28	34	44
$\sum n\log_2 n$	85.8	84.06	35.15	66.4	64.61	66.4	44.03	98.95	82.88	78.00	91.42	115.1	111.8	90.87	109.2	143.6
I	3.29	3.232	2.70	3.32	2.81	3.32	2.935	3.09	2.67	3.12	2.612	2.74	3.02	3.245	3.211	3.26
H	1.41	1.465	0.998	0.99	1.711	0.99	0.969	1.90	2.28	1.52	2.514	2.64	2.186	1.559	1.873	2.196
EWQI	0.428	0.453	0.369	0.298	0.610	0.30	0.330	0.61	0.854	0.48	0.962	0.96	0.724	0.480	0.583	0.67
M	9.9	13.3	9.0	8.4	24.0	21.0	20.0	22.5	30.2	24.8	28.8	24	20.1	14.6	14.3	14.7
$\log_2 M$	3.305	3.731	3.168	3.068	4.596	4.389	4.319	4.489	4.913	4.629	4.845	4.582	4.327	3.865	3.835	3.875
AWQI	0.758	0.826	0.686	0.605	1.070	0.739	0.762	1.059	1.346	0.943	1.447	1.418	1.157	0.867	0.967	1.058

Table 2

EWQI and AWQI for the Rivers Sisian and Goris (2009)

River	Sisian		Goris			Sisian		Goris	
Post / Ind.	№ 103	№ 104	№ 106	№ 107		№ 103	№ 104	№ 106	№ 107
BOD_5	0	0	0	4	N	12	28	19	61
NH_4^+	0	0	0	12	$\sum n\log_2 n$	24.35	90.5	55.75	194.6
NO_2^-	0	0	0	12	I	2.03	3.231	2.934	3.190
Cu	3	8	0	11	H	1.55	1.57	1.311	2.737
V	0	11	12	12	EWQI	0.765	0.487	0.447	0.858
Al	5	9	4	4	M	12.7	10	16.4	39.2
Mn	4	0	0	0	$\log_2 M$	3.70	3.32	4.03	5.369
Cr	0	0	3	5	AWQI	1.135	0.819	0.850	1.395
Se	0	0	–	1					

Table 3

WQI for the Rivers Vorotan, Sisian and Goris (2009)

Index	AWQI	EWQI	WCI	CWQI	SCWQI
№ 99	0.7583	0.4278	1.42	86.69	1.08
№ 100	1.0696	0.610	4.36	73.30	1.67
№ 101	1.3457	0.8544	4.33	70.77	2.14
№ 102	1.1567	0.724	2.12	80.05	1.76
№ 103	1.135	0.765	0.80	83.77	1.30
№ 104	0.819	0.487	1.30	87.25	1.47
№ 106	0.850	0.447	2.88	79.99	1.45
№ 107	1.395	0.858	5.76	67.55	2.16

With the help of a computer program "Origin-6" is done an analysis of the linear relationship between AWQI and other WQI: AWQI =a + b (WQI).

A good correlation is obtained also when the Rivers Vorotan, Sisian and Goris are considered together:

AWQI=(0.8084±0.1362)+(0.0897±0.0410) WCI, R=0.66599, N=8;

AWQI=(0.1894±0.2161)+(0.5383±0.1296) SCWQI, R=0.86133, N=8;

AWQI=(0.2154±0.0751)+(1.3155±0.1125) EWQI, R=0.97875, N=8;

AWQI=(3.1810±0.5838)–(0.0269±0.0074) CWQI, R=0.82942, N=8.

For the rivers Sisian and Goris is got good correlation:

AWQI=(0.838±0.215)+(0.079±0.065) WCI, R=0.65178, N=4;

AWQI=(0.229±0.554)+(0.514±0.340) SCWQI, R=0.73018, N=4;

AWQI=(0.225±0.154)+(1.290±0.232) EWQI, R=0.96899, N=4;

AWQI=(3.082±1.044)–(0.025±0.013) CWQI, R=0.81023, N=4.

For the river Vorotan is got better correlation:

AWQI=(0.736±0.271)+(0.113±0.081) WCI, R=0.70050, N=4;

AWQI=(0.156±0.042)+(0.558±0.024) SCWQI, R=0.99807, N=4;

AWQI=(0.204±0.083)+(1.343±0.123) EWQI, R=0.99170, N=4;

AWQI=(3.361±0.973)–(0.029±0.013) CWQI, R=0.85675, N=4.

Thus, the correlation between AWQI and other WQI is established. Analysis of obtained data indicate that AWQI has liner dependence on WCI, SCWQI, EWQI and an inverse dependence on CWQI.

Conclusion. In the paper the quality of the Rivers Vorotan, Sisian and Goris water has been evaluated for the first time by AWQI. It was shown that from the source to the mouth of the river there is an increase in the value of the AWQI, which indicates the decline in the quality of water of the rivers from the first to the second class of pollution. After the cities of Goris and Sisian AWQI increases, indicating a decrease in water quality due to pollution of water in the Rivers Vorotan and Goris by domestic wastewaters. It is established correlation between AWQI and other WQI.

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