ANALYSIS OF ENVIRONMENTAL STATUS OF THE RIVERS AGHSTEV AND GETIK WITH ARMENIAN INDEX OF WATER QUALITY

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The water quality of rivers Aghstev and Getik was evaluated by Armenian Water Quality Index at first time. It was shown that from the source to the mouth of the river is observed to increase the value of the Armenian index that indicates a decline in the water quality of the rivers from the 1st to the 2nd class of pollution. It is shown that the cause of pollution is the high content nitrogen compounds and metals. It was established thet the Armenian index of water quality has a linear relationship with the water pollution index and unit-combinatorial index of water quality and has an inverse relationship with the Canadian Water Quality Index.

Keywords: rivers Aghstev and Getik water quality index, Armenian Water Quality Index, entropy, geoecological syntropy

The study of ecological status of Republic Armenia Rivers is importance both for evaluation of water quality of that objects and for their further rational use. Development of water quality assessment methods using conventional indicators comprehensively taking into account various properties of surface water is an important issue. The complex evaluation is an extremely difficult task that requires a simultaneous consideration of a variety of properties of the water object. For evaluation of water contamination degree the comprehensive indicators are used which take possible to evaluate the contamination of water at the same time on a wide range of quality indicators. Water Contamination Index (WCI), Canadian Water Quality Index (CWQI) and Specific-combinatorial Water Quality Index (SCWQI) are used for evaluation surface water quality in Republic of Armenia [3, 4, 7]. It must be noted that most developed complex characteristics of water object in one way or another connected with the existing maximum permissible concentration (MPC). In the last years we suggest Entropic Water Quality Index (EWQI) and Armenian Water Quality Index (AWQI) for evaluation surface water quality [8, 9].

Monitoring Positions cross-sections of the River Aghstev

The aim of presented paper is evaluation of River Aghstev and it's tributary Getik by Armenian Water Quality Index.

River Aghstev is right tributary of the Kura. Aghstev is 133 kilometres long with a drainage basin of 2,589 square kilometres [5]. It rises in the territory of Armenia, on the northwest slope of Mount Tezhler. The following takes place in a wider valley. The largest tributaries – Bldan, Voskepar, Getik. Two monitoring posts located on the river Aghstev: number 15–1,2 km above the city of Dilijan, number 16–0,5 km below the city of Dilijan, number 17–1,0 km above the city of Ijevan, number 18–8 km below the city of Ijevan Getik River – right tributary Aghstev. The river is 63 km [5]. On Getik river located positions: number 19–0,5 km above the city of Chambarak and number 20 – at the mouth of the river.

Determination procedure

In hydroecological systems there can be processes both with increase, and with entropy reduction. 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 must it must consume information from the environment and provide information environment for act and interact with environment. Shannon was the first who related concepts of entropy and information [6]. He was suggesting that entropy is the amount of information attributable to one basic message source, generating statistically independent reports. Get any amount of information entropy is equal to the lost. Information entropy for independent random event x with N possible states is calculated by the equation:

$$H = -\sum_{i=1}^{N} p_i \log_2 p_i,$$

where P_i – probability of frequency of occurrence of an event.

Entropy general equation of Shannon was been used at the first time by Mac-Artur in 1955 for evaluation of degree of structuring biogenesis [1]. In 1957, R. Margalef postulated theoretical concept that meets a variety of entropy for a random selection of species from the community [2]. As a result of these works widespread and universal recognition received index Shannon *H*, sometimes referred to as a Shannon information index of diversity [6]:

$$H = -\sum n_i / N \log_2 \left(\frac{n_i}{N} \right).$$

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 equation Shannon pi- probability of the number of cases of MPC excess of *i*-substance or water indicator of total cases of MPC – *N*, $P_i = n_i/N$.

$$H = \log_2 N - \sum n \log_2 n/N;$$

$$H = \log_2 N - I;$$

$$I = \sum n \log_2 n/N,$$

where *I* – geoecological syntropy [10].

The following computational algorithm is used for determination *I*, *H*, *EWQI* and *AWQI* values:

1. Determines the number of cases of MPC excess of i-substance or indicator of water – *n*.
2. Estimates the total amount of cases the maximum permissible concentration (*N*) – $N = \sum n$.
3. Computes $\log_2 N$, $n\log_2 n$ and $\sum n \log_2 n$.
4. Determines geoecological syntropy (*I*) and entropy (*H*):

$$I = \sum n \log_2 n/N \quad \text{and} \quad H = \log_2 N - I.$$

5. Then *EWQI* is determined: $G = H/I$.
6. Further, the total amount multiplicity MAC exceedances is estimated (*M*) – $M = \sum m$.
7. Computes $\log_2 M$.
8. Armenian Water Quality Index was obtained: $AWQI = G + 0{,}1 \cdot \log_2 M$.

Results of research and their discussion

It was established that the water of the Rivers Agstev and Getik regularly exceeded the value of BOD_5 and concentrations of nitrite and ammonium ions, due to water pollution by domestic wastewater. It was shown that water of Rivers Agstrv and Getik is also contaminated by some metals. Thus, in the river water is regularly increased MPC of copper, vanadium, aluminum, cobalt, manganese and selenium (Tables 1–4). For example, in 2012 year in the position № 16 of River Agstev BOD_5, NH_4^+, NO_2^-, V, Cu, Al and Mn number of MPC increasing cases is 4, 5, 6, 11, 11, 9 and 7 times, respectively. The amount of excess cases of MPC – $N = 53$, $\sum n \log_2 n = 159{,}309$; $I = 159{,}309/53 = 3{,}005$; $H = \log_2 53 - 3{,}005 = 2{,}72$, $G = 2{,}720/3{,}005 = 0{,}900$. The total amount of the multiplicity of MPC exceedances – $M = \sum m = 13{,}2$; $\log_2 M = 3{,}7$; $A = 0{,}90 + 0{,}37 = 1{,}270$ (Table 3)

Table 1

Entropic and Armenian Water Quality Indexes for River Aghstev and Getik (2009)

Positions	15		16		17		18		19		20	
Indicator	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$
NH_4^+	0	0	6	15,5	0	0	0	0	7	19,64	0	0
Cu	7	19,64	12	43	11	38,0	12	43,0	5	11,6	11	38,0
V	8	24	10	33,2	10	33,2	10	33,2	11	38,0	8	24
Al	12	43,0	12	43	12	43,0	12	43,0	11	38,0	11	38,0
Mn	0	0	5	11,6	9	28,5	6	15,5	4	8	0	0
N	27		45		42		40		38		30	
$\sum n\log_2 n$	86,64		146,3		142,7		134,7		115,24		100	
I	3,201		3,251		3,398		3,367		3,032		3,333	
H	1,551		2,238		2,00		1,95		2,213		1,571	
G	0,4845		0,688		0,5886		0,5796		0,7300		0,471	
$M = \sum m$	10,9		17,4		18		19		20,2		16,1	
$\log_2 M$	3,44		4,12		4,167		4,254		4,333		4,006	
AWQI	0,8285		1,109		1,0053		1,005		1,161		0,871	

Table 2

Entropic and Armenian Water Quality Indexes for River Aghstev and Getik (2010)

Positions	15		16		17		18		19		20	
Indicator	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$
NH_4^+	0	0	4	8	0	0	0	0	4	8	0	0
NO_2^-	0	0	5	11,6	0	0	0	0	3	4,75	0	0
Cu	6	15,5	10	33,2	10	33,2	10	33,2	6	15,5	11	38,0
V	9	28,5	12	43	10	33,2	11	38,0	9	28,5	11	38,0
Al	10	33,2	8	24	9	28,5	10	33,2	8	24	11	38,0
Mn	0	0	5	11,6	7	19,64	0	0	4	8	0	0
Se	3	4,75	4	8	4	8	3	4,75	0	0	3	4,75
N	28		48		40		34		34		36	
$\sum n\log_2 n$	81,96		139,17		122,547		109,18		88,75		118,75	
I	2,927		2,903		3,063		3,211		2,610		3,300	
H	1,877		2,678		2,555		1,873		2,474		1,867	
G	0,641		0,922		0,736		0,583		0,948		0,566	
$M = \sum m$	15,6		21,8		15,9		18,5		22		17,2	
$\log_2 M$	3,96		4,44		3,98		4,200		4,46		4,10	
AWQI	1,037		1,366		1,134		1,003		1,394		0,979	

Table 3

Entropic and Armenian Water Quality Indexes for River Aghstev and Getik (2011)

Positions	15		16		17		18		19		20	
Indicator	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$
BOD_5	0	0	4	8	6	15,5	0	0	0	0	8	24
NH_4^+	0	0	5	11,6	0	0	0	0	0	0	0	0
NO_2^-	0	0	6	15,5	0	0	5	11,6	0	0	0	0
Cu	0	0	11	38,0	9	28,5	10	33,2	0	0	10	33,2
V	10	33,2	11	38,0	10	33,2	11	38,0	7	19,64	0	0
Al	10	33,2	9	28,5	9	28,5	9	28,5	7	19,64	12	43,0
Mn	6	15,5	7	19,64	9	28,5	0	0	0	0	0	0
N	26		53		43		35		14		30	
$\sum n\log_2 n$	81,9		159,309		134,236		111,344		39,28		100,18	
I	3,15		3,005		3,121		3,181		2,80		3,339	
H	1,547		2,72		2,302		1,945		1,005		1,565	
G	0,491		0,900		0,737		0,611		0,358		0,468	
$M = \sum m$	6,9		13,2		10,7		10,2		4,4		10	
$\log_2 M$	2,78		3,7		3,4		3,34		2,14		3,32	
AWQI	0,769		1,270		1,077		0,945		0,572		0,800	

Table 4

Entropic and Armenian Water Quality Indexes for River Aghstev and Getik (2012)

Positions	15		16		17		18		19		20	
Indicator	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$	n	$n\log_2 n$
BOD_5	0	0	0	0	10	33,2	8	24	0	0	0	0
NH_4^+	0	0	9	28,5	0	0	7	19,64	0	0	0	0
NO_2^-	0	0	8	24	5	11,6	9	28,5	0	0	0	0
Cu	12	43,0	12	43	11	38,0	11	38,0	7	19,64	12	43
V	10	33,2	10	33,2	10	33,2	10	33,2	8	24	10	33,2
Al	11	38,0	10	33,2	10	33,2	10	33,2	8	24	10	33,2
Mn	8	24	8	24	10	33,2	8	24	4	8	0	0
Cr	0	0	4	8	6	15,5	6	15,5	5	11,6	5	11,6
Se	2	2	2	2	2	2	3	4,75	0	0	0	0
N	43		63		64		72		32		37	
$\sum n\log_2 n$	140,2		195,9		199,90		220,79		87,24		121,0	
I	3,256		3,109		3,123		3,066		2,726		3,270	
H	2,167		2,864		2,873		3,100		2,274		1,936	
G	0,666		0,921		0,919		1,011		0,834		0,592	
$M = \sum m$	13,5		21		17,6		19,7		27,3		14,6	
$\log_2 M$	3,752		4,390		4,135		4,298		4,768		3,865	
AWQI	1,041		1,351		1,3325		1,4408		1,311		0,9785	

Table 5

Entropic and Armenian Water Quality Indexes for Rivers Aghstev and Getic (2009-2012)

Positions	2009		2010		2011		2012	
	EWQI	AWQI	EWQI	AWQI	EWQI	AWQI	EWQI	AWQI
15	0,485	0,828	0,641	1,037	0,491	0,769	0,666	1,041
16	0,688	1,109	0,922	1,366	0,900	1,270	0,921	1,351
17	0,588	1,005	0,736	1,134	0,737	1,077	0,919	1,3325
18	0,580	1,006	0,583	1,003	0,611	0,945	1,011	1,4408
19	0,733	1,161	0,948	1,394	0,358	0,572	0,834	1,311
20	0,476	0,871	0,565	0,979	0,468	0,800	0,592	0,9787

$AWQI = (0{,}271 \pm 0{,}065) + (1{,}227 \pm 0{,}108) \cdot EWQI$; $R = 0{,}98481$; $N = 6$ (2009 year);

$AWQI = (0{,}351 \pm 0{,}033) + (1{,}094 \pm 0{,}044) \cdot EWQI$; $R = 0{,}99676$; $N = 6$ (2009 year);

$AWQI = (0{,}172 \pm 0{,}049) + (1{,}235 \pm 0{,}079) \cdot EWQI$; $R = 0{,}99191$; $N = 6$ (2009 year);

$AWQI = (0{,}309 \pm 0{,}075) + (1{,}133 \pm 0{,}090) \cdot EWQI$; $R = 0{,}98765$; $N = 6$ (2009 year)/

Analysis of obtained data indicate that AWQI has liner dependence with EWQI (Table 5).

The obtained data indicate that along the source to the mouth of the river water quality decreases. After the cities of Dilijan and Ijevan *AWQI* increases, this indicates a decline in water quality of River Voghji caused by water pollution by domestic wastewater.

Quality of Rivers Aghstev and Getik water also comprehensively evaluate by other indexes: *WCI, EWQI, CWQI, SCWQI* (Table 6).

Table 6

Water Quality Indexes for Rivers Aghstev and Getik (2009)

Index	AWQI	EWQI	WCI	CWQI	SCWQI
15	0,828	0,485	0,97	81,61	1,56
16	1,109	0,688	1,59	73,13	2,33
17	1,005	0,588	1,42	74,17	2,06
18	1,006	0,580	1,46	72,23	2,40
19	1,161	0,733	1,5	71,52	2,11
20	0,871	0,476	1,4	72,15	1,95

Analysis of obtained data indicate that *AWQI* has liner dependence with *WCI*, *SCWQI*, *EWQI* and an inverse dependence with *CWQI*:

$AWQI = (0{,}338 \pm 0{,}257) + (0{,}474 \pm 0{,}183) \cdot WCI$; $R = 0{,}79116$; $N = 6$;

$AWQI = (0{,}358 \pm 0{,}313) + (0{,}309 \pm 0{,}150) \cdot SCWQI$; $R = 0{,}71722$; $N = 6$;

$AWQI = (0{,}271 \pm 0{,}065) + (1{,}227 \pm 0{,}108) \cdot EWQI$; $R = 0{,}98481$; $N = 6$;

$AWQI = (2{,}631 \pm 0{,}977) - (0{,}022 \pm 0{,}013) \cdot CWQI$; $R = 0{,}64206$; $N = 6$.

For river Aghstev excellent correlation,

$AWQI = (0{,}408 \pm 0{,}074) + (0{,}426 \pm 0{,}053) \cdot WCI$; $R = 0{,}98468$; $N = 4$;

$AWQI = (0{,}417 \pm 0{,}207) + (0{,}273 \pm 0{,}098) \cdot SCWQI$; $R = 0{,}89146$; $N = 4$;

$AWQI = (0{,}181 \pm 0{,}119) + (1{,}377 \pm 0{,}203) \cdot EWQI$; $R = 0{,}97886$; $N = 4$;

$AWQI = (2{,}823 \pm 0{,}642) - (0{,}024 \pm 0{,}009) \cdot CWQI$; $R = 0{,}89661$; $N = 4$.

Conclusion

Thus, for the first time using *AWQI* the quality of Rivers Aghstev and Getic water evaluate. 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 Dilijan and Ijevan of *AWQI* increases, indicating a decrease in water quality due to pollution of water River Aghstev by domestic wastewaters. It was established the correlation between *AWQI* and other water quality indexes.

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