RIVER POLLUTION COMPONENTS MEAN ANNUAL VALUES ESTIMATION BY COMPUTER MODELING

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Abstract

The methods that allow with application of the computer modeling to estimate values of pollution ingredients discharged from the pollution sources during a year in the rivers are offered. With the help of the modeling results conclusions are made about distribution, change and provenance reasons of river pollutants values on the control sections

Key words and phrases: Modeling, pollution, river, control section, pollution sources.

1 Introduction

The purpose of the work is by computer modeling to estimate mean annual value of pollution components discharged from pollution sources working on river control sections. As an example are considered located in the western Georgia and running in The Black Sea four rivers of the river Khobistskali basin (which is one of basic pollution source of the Black Sea), which basic pollution sources are agricultural fields, cattle-breeding farms and small cities, located on these rivers. The data of the rivers pollution are received with the help of monthly measurements of the appropriate components during two years in sixteen control cross-sections of the rivers (see fig. 1, where by red triangles are marked the monitoring cross-sections, and by red circles are marked the cities located on the rivers). The length of the river Khobistskali that is the greatest river of the Khobistskali basin is - 74.8 km, the medium width is 68 m, and the medium depth is 1.035 m. The distances between six monitoring cross-sections located on it (see fig. 1) accordingly are: 23 km, 5 km, 15.5 km, 1.3 km and 30 km. The length of the river Chanistskali is 37.3 km, the medium width is 17.5 m, and the medium depth is 0.51 m. The distance between two monitoring cross-sections located on it (see fig. 1) is 37.3 km. The length of the river Ochkhomuri is 42.7 km, the medium width is 19 m, and the medium depth is 0.39 m. The distances between monitoring cross-sections located on it (see fig. 1) accordingly are: 11.7 km, 12 km and 19 km. The length of the river Choga is 12 km, the medium width is 7 m, and the medium depth is 0.18 m and the distance between monitoring cross-sections located on it (see fig. 1) is 11 km.

2 The results received by computer modeling

The modeling was realized with applied programs package for IBM-compatible personal computers for calculation of polluting substances concentration in any point of a river. It allow calculate the pollutants concentrations in any point of the river depending on pollution conditions from many sources. This package is developed by the authors of the given work [1, 2]. In it are realized spatially one -, two - and three - dimensional advective - diffusion models under different initial and boundary conditions [3 - 5]. In particular: a) with a not local boundary condition on the end of a controllable section with an allowance for the coefficient of natural self - purification of the river; b) with a boundary condition of full mixing at the end of the river controlled section; c) without the account of vertical advection with a not local boundary condition on the end of a controllable section with an allowance for the coefficient of natural self - purification of the river; d) without the account of vertical advection with a boundary condition of full mixing at the end of the river controlled section; e) diffusion equation with a not local boundary condition on the end of a controllable section with an allowance for the coefficient of natural self - purification of the river; f) diffusion equation with a boundary condition of full mixing at the end of the river controlled section.

It is supposed, that the researched section of the river contains some of dot or extended pollution sources. They can be, for example, ends of pipes, through which pollution sources dump in the river wastes, the underground sources or other rivers running into the researched river on a considered section. Exactly such sources are agricultural fields, cattle-breeding farms, on the rivers located built-up areas and comparatively small rivers, which run in the big rivers. It is supposed, that in the beginning of the given section the concentrations of polluting substances are known, i.e. their meanings are measured that have place in the considered case indeed. Modeling have carried out by basic biological parameters, nitrates (NO3) and phosphates (PO4), outgoing from agricultural fields and cattle-breeding farms. The monitoring results of 2002 and 2003 were used for modeling. The idea of modeling consists in the following. On the basis of the monitoring results are known the mean annual concentrations of the mentioned components in each control cross-sections of the rivers. If we admit, that on the given section of the river the pollution sources do not work, then existing in the top section of the river the pollution level should decrease in the bottom section at the expense of proceeding in the river of natural processes and ability of self purification. In reality for the Khobistskali's basin rivers this fact does not take place, as on each section of the river the appropriate pollution sources work. Therefore, if with the help of the developed mathematical models we calculate the polluting component concentration in the bottom section of the river on existing concentration in the top section and after a condition, that on this section of the river does not work any pollution source except of other river (if such runs in it on this section), then with a difference between measured and calculated concentrations we easily calculate polluting components values discharged in the river from pollution sources worked on this section. In considered concrete case for modeling was used one-dimensional mathematical model of pollution diffusion and transfer [3 - 7]. It is caused by the following circumstances: in first, on the geometrical sizes of the considered rivers (in a case, when length of that section of the river, which modeling is carried out, 10 times and more surpass its width, to provide width is not meaningful because of full mixing of water of the river on a considered section of the river; Also, if width of the river 10 and more time surpasses its depth, for the same reason, the taking into account of depth loses the sense [6]), and in second, because the average year data are used and the accuracy of model more high rank, in this case, loses the sense. The modeling results received by us for the Khobistskali's basin rivers with the help of one, two and three dimensional models, precisely have confirmed the mantioned reason. I.e. two and three dimensional models on all width and depth were given identical results with one-dimensional model that completely corresponds to the above-mentioned. The concentrations of NO3 and PO4 on all the lengths of the rivers Choga, Ochkhomuri, Chanistskali and Khobistskali are calculated through the identical steps. In case of the river Choga the length of the step is equal to 343,75 meters, in case of the r. Ochkhomuri the length of the step is equal to 1334,4 meters, in case of the r. Chanistskali the length of the step is equal to 1165,6 meters, and in case of the r. Khobistskali the length of the step is equal to 2337,5 meters. For the r. Choga the time of full updating of water, i.e. that time, which is necessary for runing of water from a source of the river up to its confluence in other river, is equal to 15 h 36 min. For the rivers Ochkhomuri, Chanistskali and Khobistskali this time are accordingly equaled to 39 h 12 min, 20 h 25 min, 9 h 27 min. Therefore, at modeling of the river through the appropriate interval of time it is possible taking of calculated value of concentration in any point of the river on all length, as it corresponds to the concentration in initial section recalculated by the appropriate model in the interesting point. In the tables 1, 2, 3, 4 are given the calculation results of mean annual values of the pollutants got from the appropriate sources in separate sections of the rivers during 2002, 2003. The calculation of mean annual values of pollutants discharged in the given section from above located pollution sources carried out as follows

$$S_{year}\,(kg/year) = (s_{mes} - s_{mod})\,(mg/\sec)\,vE\left(m^3\sec\right)60\,(\sec)\,24\,(hour)\,365\,(day)\,,$$

where

S_{year} - is mean annual value of a polluting component discharged in the given section of the river from sources working on this section;

S_{mes} - is measured mean annual value of concentration of a polluting component on the appropriate section;

S_{mod} - is mean annual value of concentration of a polluting component calculated by the model on the appropriate section;

vE - is the flow rate in the appropriate section of the river.

The calculated results by mathematical models are given in the tables 1, 2, 3 and 4. In the two last column of the tables are given by the considered rivers brought mean annual volumes of pollution components in places of them confluence calculated as by directly measurement results, and by direct summation of the calculated by model the appropriate values in separate sections of the rivers. On the basis of these results is concluded:

In 2002, 2003 r. Choga by parameter NO3 basically was polluted at sources, up to first cross-section. In 2002 by parameter PO4 the river was polluted in more to bottom part, i.e. between the first and second cross-sections. In 2003 the situation has changed also in parameter PO4 the river was polluted more up to the first cross-section. The pollution of the river by both considered parameters in 2003 is significant decrease after comparison with 2002: by parameter NO3 from 566,4 ton/years till 276,4 ton/years (2 times), and by parameter PO4 from 4,18 kg/years till 3,17 kg/years (1,32 times). A difference between measured and calculated values defined mean annual volumes of the polluting components brought by the river Choga in the r. Ochkhomuri, on our sight, specifies high quality of modeling, if take into account that circumstance, that the modeling was carried out on the basis of the defective initial data (because of absence of the better). For example, expenses of the river (as well as for other rivers of the Khobistskali's basin) completly was measured only in 2003, in 2002 only three times were measured the water expenses; exactly are not known the coefficients of diffusion and non conservativity etc. Despite of told the modeling and measurement results with acceptable accuracy coincide with each other, that specifies accuracy of the used technique.

The pollution of the river Ochkhomuri by parameter NO3 in 2002 in its all control sections was practically equally, except of last section, where the pollution 1,9 times is surpassed of the pollution of other sections. In 2003 the river is most of all polluted with mantioned parameter on initial and final sections. In 2002 the third section of the river is most of all polluted by parameter PO4, and in 2003 namely this sextion is polluted less of all. The r. Choga runs in the r. Ochkhomuri in this section. As already have noted in 2002 the pollution of the r. Choga by parameter NO3 2 times are surpassed the pollution of 2003, and by parameter PO4 - 1,32 times. The pollution of the r. Ochkhomuri on the last section (where the r. Choga runs in it) in 2002 2,7 times are surpassed the pollution of 2003 by parameter NO3 and 2,8 times - by parameter PO4. The mean annual volumes, calculated by model and directly by measured meanings, brought in of pollution components by the river Ochkhomuri in the river Khobistsksli practically are equal among themselves. Brought by the river Ochkhomuri in the river Khobistsksli the mean annual values of pollution components on both considered components considerably has decreased after comparison with 2002: by parameter NO3 from 7,119 ton/years till 3,685 ton/years (2 times), and by parameter PO4 from 36,212 kg/years till 33,661 kg/years (1,08 times).

The r. Chanistskali by parameters NO3 and PO4 both in 2002, and in 2003 is more polluted in the second section than in the first. In this section the river pollutes not only by the agricultural fields and cattle-breeding farms, but also by waste water of the city Tsalendjikha too. The pollution of the river by parameter NO3 in 2002 surpasses the pollution of 2003 and by parameter PO4 the pollution of 2002 lags from the pollution of 2003. In particular, at 2002 the mean annual volume of the component NO3 discharged in the river Khobistskali is equal to 18,026 ton/year, which on the volume of 2003, 11,197 ton/year, surpass 1,6 times, and mean annual volume of the component PO4 in 2002 is equal to 88,515 kg/year, which lags from mean annual volume of 2003, 123,018 kg/years, 1,4 times. Calculated by mathematical models and directly by measured values brought by the river Chanistskali in the river Khobistskali volumes of pollution components coincide with each other by very high accuracy. In our opinion, one of the reasons of such good result consists that calculation of self purification coefficient of the river for considered components was possible for data of the river Chanistskali, which were used for the other rivers too.

The river Khobistskali in 2002 is most of all polluted in the first and last sections. On these sections, except of agricultural fields and cattle-breeding farms the river accordingly becomes polluted by waste water of the cities Chkhorotsku and Khobi. On the next place by pollution there is the fourth section of the river, where the river Chanistskali runs into it. In 2003 the river is almost equally polluted in the first and fourth sections, i.e. the sections on which work the city Chkhorotsku and the r. Chanistskali. The last section, where on the river work the city Khobi, is one of least polluted. This fact is very much interesting, which one more time confirms the reason, that by the considered components the basic pollution sources of the rivers are agricultural fields and cattle -breeding farms. The pollution of the r. Khobistskali by the parameter NO3 in 2002 surpasses the pollution of 2003 and by parameter PO4 the pollution of 2002 lags behind pollution of 2003. In particular, by the river Khobistskali in the Black Sea introduced the mean annual volume of the component NO3 is equal to 62,772 ton/year, which surpasses the volume of 2003 43,605 ton/years 1,4 times, and the mean annual volume of the component PO4 for 2002 is equal 562,695 kg/year, which lag from the mean annual volume of 2003 673,473 kg/year 1,2 times. The calculated by the mathematical model and in direct by measured values brought by the river Khobistskali in the Black Sea volumes of pollution components coincide with each other with acceptable accuracy, especially if we lake into account the above mentioned (in case of the river Choga).

3 Conclusion

With application of the mathematical models, developed by authors of this work, and appropriate program realizations of transport in the rivers of pollution components have carried out the calculation of pollution components values discharged for 2002 and 2003 on sections of the rivers between the control cross-sections from appropriate pollution sources. By the help of these values: 1) have estimated a share of the pollution sources working on each of the section of the river in total amount of the river pollution; 2) have estimated a change of pollution components values discharged for 2002, 2003 on separate sections of the river, i.e. in the concrete the efficiency of those measures which were carried out in these years on the mantioned pollution sources in the appropriate region; 3) within the framework of those opportunities, which are given by division of the rivers into the monitoring sections, from each other have divided working on the river agricultural and others (for example, cities, located on the rivers; into them run other rivers) pollution sources; 4) developed and tested on the real data the mathematical models of rivers pollution are the component of ecologo-economic models of the considered agricultural region with which help possibly to calculate ecological loading coming on the environment, in particular, on closely laying river and agricultural fields from the single area of a farmer fild in view of its initial condition and brought in fertilizers, and also in the existing situation to calculate quantity and quality of expected harvest of concrete agricultural culture, on the basis of that will be appreciated the expected economic efficiency realized agricultural projects and to the farmers will be given the economically justified recommendations for action.

The table 1. The calculation results of pollutants mean annual meanings got from the appropriate sources in separate sites of the r. Choga during 2002, 2003.

R. Choga					
Year	The pollutant ingredient	Until the first section	Between the control section	Flow into the r. Ochkhomuri (by measuring)	Flow into the r. Ochkhomuri (by modeling)
2002	NO_3 kg/year	381,2	185,2	503,6	566,4
	PO_4 kg/year	1,68	2,5	3,8	4,18
2003	NO_3 kg/year	252,8	23,6	234,73	276,4
	PO_4 kg/year	2,2	0,972	2,814	3,172

The table 2. The calculation results of pollutants mean annual meanings got from the appropriate sources in separate sites of the r. Ochkhomuri during 2002, 2003.

R. Ochkhomuri							
Year	The pollutant ingredient	Until the first section	In the first site	In the second site	In the third site	Flow into the r. Khobistskali (by measuring)	Flow into the r. Khobistskali (by modeling)
2002	NO_3 ton/year	1,494	1,392	1,459	2,774	7,390	7,119
	PO_4 kg/year	9,170	8,316	15,663	3,063	36,375	36,212
2003	NO_3 ton/year	1,125	0,8844	0,537	1,140	3,894	3,685
	PO_4 kg/year	8,292	7,477	5,523	12,369	40,800	33,661

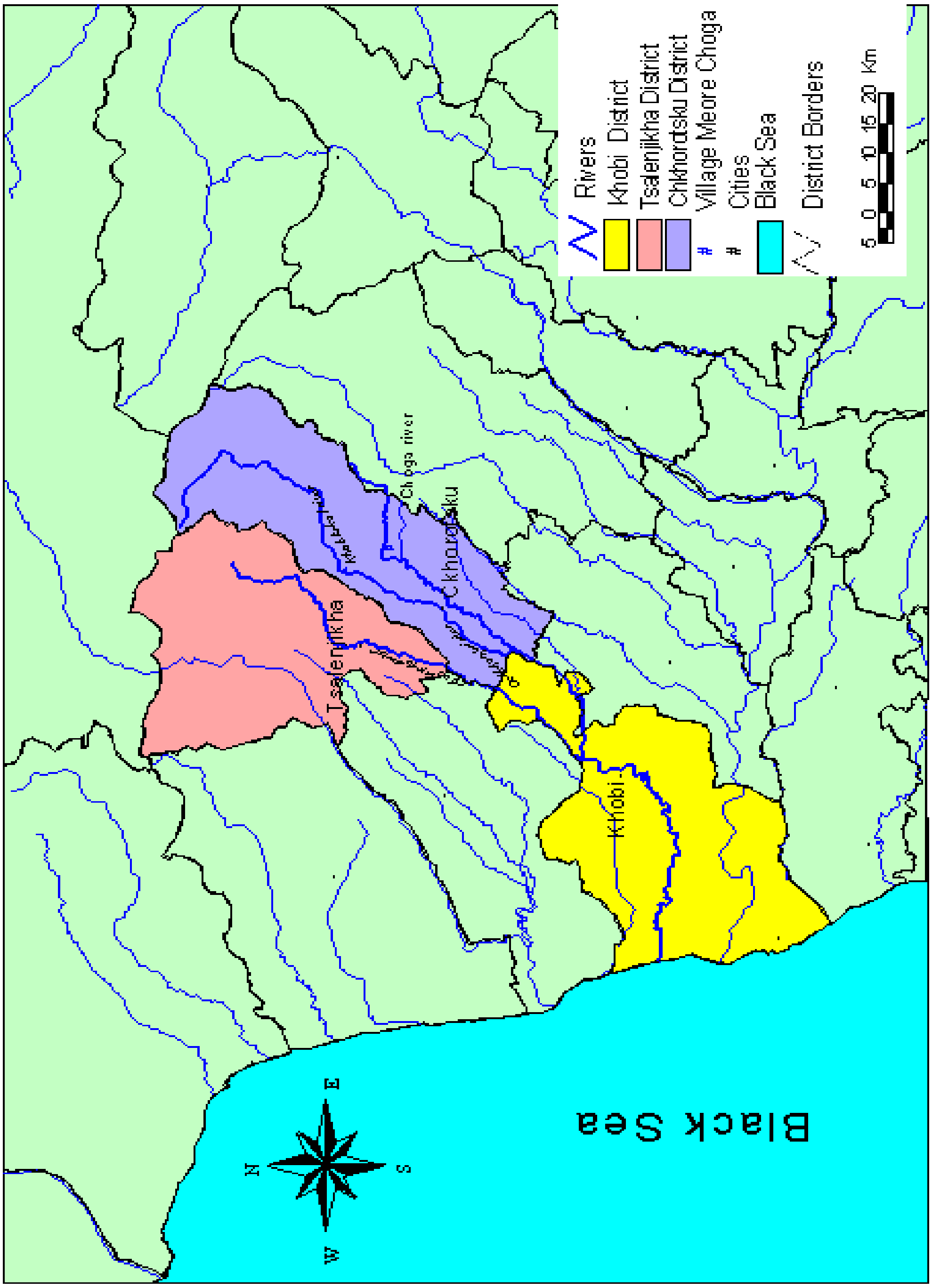
The table 3. The calculation results of pollutants mean annual meanings got from the appropriate sources in separate sites of the r. Chanistskali during 2002, 2003.

R. Chanistskali					
Year	The pollutant ingredient	Until the first section	Between the control section	Flow into the r. Khobistskali (by measuring)	Flow into the r. Khobistskali (by modeling)
2002	NO_3 ton/year	1,326	16,7	18,03	18,026
	PO_4 kg/year	9,5	79,012	88,683	88,515
2003	NO_3 ton/year	1,5	9,7	11,198	11,197
	PO_4 kg/year	20,749	102,269	122,872	123,018

The table 4. The calculation results of pollutants mean annual meanings got from the appropriate sources in separate sites of the r. Khobistskali during 2002, 2003.

R. Khobistskali									
Year	The pollutant ingredient	Until the first section	In the first site	In the second section	In the third section	In the fourth section	In the fifth section	Flow into the black sea (by measuring)	Flow into the black sea by sections (by modeling)
2002	NO3 ton/year	11,754	16,337	4,949	2,31	14,669	12,753	52,710	62,772
	PO4 kg/year	121,027	106,85	32,949	61,527	79,386	160,956	457,278	562,695
2003	NO3 ton/year	8,488	11,38	6,553	0,879	12,68	3,625	36,809	43,605
	PO4 kg/year	128,274	200,946	25,784	81,384	198,189	39,496	560,809	673,473

Fig. 1. The river Khobistskali's basin with control sections.



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