INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 08 Issue 07 July 2025

DOI: 10.47191/ijmra/v8-i07-13, Impact Factor: 8.266

Page No. 3851-3854

Numerical Assessment of Copper and Manganese Content in the Bottom Sediments of the Iori River

Nino Shushtakashvili[1], Leila Gverdtsiteli[2], Alexandre Surmava[3]

[1]Department of Environmental Engineering and Ecology, PhD Student in Chemical and Biological Engineering

[2]Department of Environmental Engineering and Ecology, Academic Doctor, Professor, Georgian Technical University

[3]Department of Environmental Engineering and Ecology, GTU, Monitoring and Forecasting Department of the Institute of Hydrometeorology, Doctor of Physical and Mathematical Sciences, Senior Scientific Researcher

ABSTRACT: The content of copper and manganese in bottom sediments at different sites of the Iori River and their changes over time have been determined by numerical integration of the equation for the time-dependent change in the concentration of sedimentary ingredients at the bottom.

It has been shown that the achievement of constant concentrations of copper and manganese in bottom sediments depends on two processes - gravitational sedimentation and turbulent diffusion.

KEYWORDS: Iori River, bottom sediments, numerical modelling, turbulent diffusion, manganese, gravitational sedimentation

I. INTRODUCTION

The Iori River is one of the main sources of fresh water in Georgia. It is intensively used for water supply, agricultural, industrial, domestic, and energy purposes. Therefore, assessing the level of pollution in the Iori water and protecting its cleanliness is an important ecological problem.

In recent decades, anthropogenic impact on surface water bodies, including rivers, has significantly increased. The diffuse sources of pollution in the Iori River basin can be considered agriculture, unauthorized landfills, discharge of untreated wastewater, as well as wine production, sand and gravel processing plants.

Heavy metal pollutants that enter river water as a result of anthropogenic impacts mainly end up in bottom sediments, which are characterized by their ability to accumulate significant amounts of these pollutants. As a result, bottom sediments can become a source of secondary water pollution due to subsequent redistribution processes. Therefore, high concentrations of heavy metals in bottom sediments pose a threat to water quality and consequently to human health.

From an environmental perspective, studying the changes in mass concentrations of heavy metals in bottom sediments is highly relevant for determining the water quality of the Iori River. Currently, optimal systems for surface water protection and management have been developed in the world's leading countries. These systems represent information-computational complexes for monitoring surface waters and are used to solve many practical issues.

II. METHODS

To study the level of pollution of the spread of impurities in individual rivers and relatively small rivers of Georgia and the sedimentation of heavy metals on the surfaces of bottom sediments, corresponding numerical models have been developed [9-16]. They take into account the hydrological characteristics of a particular water body, determine the concentrations of heavy metals in the ingredients and bottom sediments by numerically integrating the equation of transfer-diffusion of impurities in a continuous environment.

RESULTS AND DISCUSSION

A. Numerical Modelling of Heavy Metal Sedimentation in Bottom Sediments of Surface Waters – A Case Study of the Iori River

To mathematically determine the amount of heavy metals in bottom sediments along the Iori River section from the village of Tegerianebi to the city of Sagarejo, four points have been selected. It is assumed that the characteristic hydrological and hydro chemical parameters of the river at each point do not change with height: flow velocity, depth, impurity sedimentation rate, vertical turbulence, and total concentration of heavy metals in water remain constant. Their values equal the annual average values and are determined through field observations and experimental measurements. With these assumptions, the transport-diffusion equation of impurities in surface waters can be significantly simplified, and the change in concentration of sediment deposited on the river bottom over time can be determined by integrating the following equation:

$$\frac{\partial q_{s,i}}{\partial t} = \frac{w\, q_i}{H_i} + C\,|u_i|\,\frac{(q_i - q_{s,i})}{H_i^2}\,, \qquad (1)$$

where t is time, i is the number of the observation point selected on the river, qs,i is the concentration of impurities in bottom sediment, qi is the concentration of impurities in river water, u is the river flow velocity, w is the impurity sedimentation rate, Hi is the river depth at observation points, C is the characteristic parameter of vertical turbulent tension.

The initial moment is chosen after the flood when existing sediment has been washed away, a certain quasi-stationary state has been established, and the concentration of the studied ingredient in the bottom sediment is zero. Then the numerical approximation of equation (1) can be represented by the following algorithm:

$$q_{s,i}^{n+1} = q_{s,i}^{n} + \frac{\Delta t\, w\, q_i^n}{H_i} + \Delta t\, C|u_i|\frac{(q_i^n - q_{s,i}^n)^n}{H_i^2} \qquad (2)$$

where t is the temporal numerical grid, τ is the temporal grid step. The following parameter values were used for integration: w equals 0.09 m/s and 0.08 m/s for copper and manganese, respectively, C = 1.26* 10–5 m, and Hi and ui parameter values are taken from and given in Table 1.

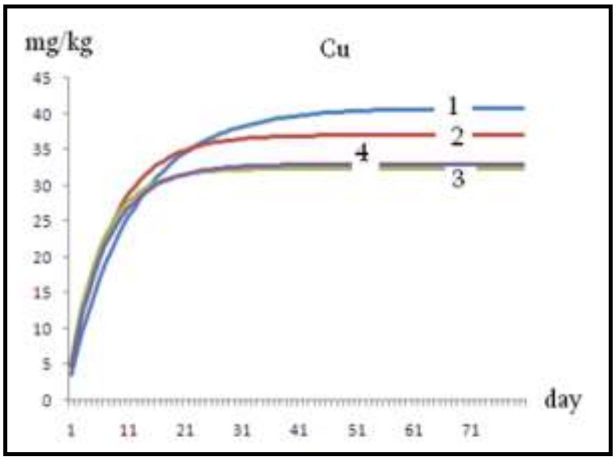
Laboratory measurements were carried out at field observation points 1-4 to determine the initial conditions for modelling. The measurement results and the values of the parameters used are given in Table 1. In the table, Qs,O,i represents the mass concentration values of copper and manganese in the sediment at observation points obtained by laboratory measurements, Qs,i = qs,i/ D represents the calculated mass concentration values of copper and manganese in bottom sediment on the 80th day after the start of modelling, D is the density of bottom soil.

Table 1 shows that the calculated values are close to field measurement values. The mass concentrations of deposited copper decrease from 40.7 mg/kg (village Tegerianebi) to 32.4 mg/kg (village Sartichala). The maximum relative error of 32.2% was obtained at Sartichala village, minimum 1.5% at Tegerianebi village. The mass concentrations of deposited manganese decrease from 1034.7 mg/kg (village Tegerianebi) to 823.1 mg/kg (village Sartichala). The maximum relative error of 16.0% was obtained at Sartichala village, minimum 4.9% at Sioni reservoir.

Table 1 Values of hydrological and hydro chemical parameters obtained by observations and calculations

Observation Point i	H_i (m)	U_i (m/s)	Cu			Mn		
			q_i (mg/l)	$Qs_{,i}$ (mg/kg) Calculated	$Qs_{,o,i}$(mg/kg) Observed	q_i (mg/l)	$Qs_{,i}$(mg/kg)Calculated	$Qs_{,o,i}$(mg/kg) Observed
1.Village Tegerianebi	0.55	0.5	0.0007	40.7	41.3	0.02	1034.7	976.5
2. Sioni Reservoir	0,4	0.4	0.0007	37.0	32.9	0.02	940.6	896.7
3. Village Sartichala	0.35	0.4	0.0007	32.4	24.5	0.02	823.1	979.5
4. Sagarejo	0.4	0.45	0.0007	32.9	28.6	0.02	836.1	927.0

Figure 1 -Time variation of the calculated mass concentration Qs,i (mg/kg) of deposited copper and manganese at observation points 1-4.



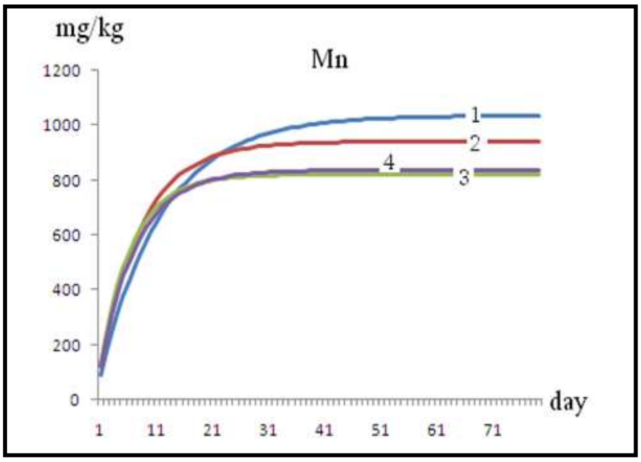


Figure 1 shows the change in mass concentration Qs,i (mg/kg) of copper and manganese obtained by calculations at observation points i=1-4. Figure 1 demonstrates that the change of copper and manganese concentration values over time proceeds qualitatively in the same way – in all four field observation points, a quasi-stationary distribution of concentration is established over 70 days, after which the concentration values in bottom sediments no longer change. There are quantitative differences, however. The constant values of copper and manganese concentrations in bottom sediments are achieved most quickly, in approximately 40 days, at the observation points near the villages of Sartichala and Sagarejo. At the Iori reservoir and near the village of Tegerianebi, constant concentrations are established after approximately 45 and 50 days, respectively.

The kinetics of the process is as follows: at the initial stage of sedimentation, gravitational deposition of the substance is prioritized. The sedimentation is also facilitated by the turbulent diffusion process. Since the concentration of copper and manganese in water is higher than in bottom sediments, the concentration of copper and manganese in bottom sediments increases. When the concentration of substances in the bottom sediment exceeds the concentration in water, turbulent diffusion causes the opposite process – the transfer of substances from bottom sediment to water. As a result, an equilibrium state is established, where the gravitational flow of substances directed toward the bottom equals the turbulent diffusion flow from the bottom to the water.

III. CONCLUSION

For the first time, experimental measurements and numerical modelling were used to assess how copper and manganese concentrations in bottom sediments change over time and space along the Iori River section between Tegerianebi and Sagarejo villages.

The change in copper and manganese concentration in bottom sediment over time was analysed. It is shown that the process is characterized by the establishment of a stationary distribution of substance concentration on the river bottom. It was determined that reaching constant concentrations of copper and manganese in bottom sediment occurs at different times and under conditions of different rates of concentration change, and depends on two processes - gravitational sedimentation and turbulent diffusion. The results of the calculations were compared with measurement data, and a satisfactory correlation between them was demonstrated.

REFERENCES

1) James, A. (Ed.). (1981). *Mathematical models of water pollution control*. Moscow: Mir.
2) Shlychkov, V. A., & Nabieva, O. R. (2003). Numerical model for describing local hydrological processes. In *Proceedings of the International Conference "Mathematical Methods in Geophysics - MMG-2003"* (pp. 395-399). Novosibirsk.
3) Global Water Partnership & International Network of Basin Organizations. (2009). *Handbook for water resources management in basins*. GWP, INBO.
4) Vanrolleghem, P. A. (2005). *Modeling aspects of water framework directive implementation*. London, New York: IWA Publishing.
5) Pryazhinskaya, V. G., Yaroshevsky, D. M., & Levit-Gurevich, L. K. (2002). *Computer modeling in water resource management*. Moscow: FIZMATLIT.

6) Loucks, D. P., & van Beek, E. (2005). *Water resources systems planning and management: An introduction to methods, models and applications*. Paris: UNESCO Publishing.
7) Pushistov, P. Y., Vtorushin, M. N., Romanenko, R. D., & Zemtsov, V. A. (2009). Development of an electronic registry-directory of information and computing tools for planning and managing the water resources system. In *Water problems of large river basins and ways to solve them* (pp. 546-557). Barnaul: Agency of Advertising Technologies LLC.
8) Pushistov, P. Y., & Danchev, V. N. (n.d.). *Information-computing complexes of water bodies of the Ob basin. Part 1 - IVK "Northern Sosva". Part 2 - IVK "Lake Teletskoye"*. Retrieved from https://www.lap-publishing.com/catalog/
9) Surmava, A. (2015). Numerical simulation of distribution of contaminants discharged to Kura River. *Bulletin of the Georgian National Academy of Sciences, 9*(1), 78-84.
10) Surmava, A., Intskirveli, L., & Buachidze, N. (2015). Theoretical investigation of ammonium ion pollution of the Mtkvari River. *Georgian Chemical Journal, 14*(1), 192-196.
11) Surmava, A., Gverdtsiteli, L., & Bagrationi, N. (2016). Numerical simulation of distribution of arsenic discharged to Tskhenistskali and Lukhuni rivers from industrial waste. *Proceeding of the Georgian National Academy of Sciences, Chemical Series, 42*(3), 410-415.
12) Kachiashvili, K., Gordeziani, D., Lazarov, R., & Melikdzhani, D. (2007). Modeling and simulation of pollutants transport in rivers. *Applied Mathematical Modelling, 31*(7), 1371-1396. https://doi.org/10.1016/j.apm.2006.02.015
13) Surmava, A., Rostomashvili, I., & Kerkadze, J. (2022). Numerical modeling of the temporal change in iron content in the bottom sediments of the Orkhevi River using field measurements and experimental data. *Collection of Scientific Works of the Georgian Technical University, 3*(525), 150-156.
14) Nikuradze, T. R., Surmava, A. A., & Gverdtsiteli, L. V. (2020). Chemical analysis of the riverbed sediments of Khrami River and its main tributaries, Debeda and Mashavera rivers. In *International Scientific Conference Sustainable Development and Protection of Environment* (pp. 260-262). Tbilisi: Georgian Technical University.
15) Bagrationi, N., Gverdtsiteli, L. V., Surmava, A., & Gvakaria, V. (2020). The numerical model of arsenic extract from industrial waters in the sediment of the river Tskenitskal. In *International Scientific Conference Sustainable Development and Protection of Environment* (pp. 143-145). Tbilisi: Georgian Technical University.
16) Nikuradze, T. R., Surmava, A. A., & Gverdtsiteli, L. V. (2022). Numerical model for the distribution of heavy metals in the water and bottom sediments of the Khrami River. *Georgian Engineering News, 95*(1), 100-106.