Turbidity Caused by the Construction of a Bridge in the Water Extraction Zone

V A Seleznev¹,², A V Rahuba¹, A V Selezneva¹
¹Institute of ecology of the Volga Basin RAS, Togliatti, Russia
²Togliatti state University, Togliatti, Russia

E-mail: seleznev53@mail.ru

Abstract. The article considers turbidity in a water storage basin during dredging in water extraction zones for household and drinking needs. Turbidity zones are calculated with the help of a math model based on the solution to the shallow water equations in the advective diffusion equation for impurity distribution. The model was verified on the basis of a field experiment in the Kuibyshev water storage basin. The data on additional turbidity in the water extraction zone collected with the help of a suction dredge shows that the turbidity is higher than the maximum allowed concentration (MAC), but when a crane boat is used, the calculated value does not exceed MAC.

1. Introduction

Bridge building across waterways and water bodies is one of the areas of economic activities that includes dredging. When a suction dredge or a crane boat with a gripper are used, significant amounts of bed soil is moved, which causes turbidity and poorer water quality and disturbs water ecosystems [1-3]. It is essential to assess additional turbidity where the works are conducted in the water bodies that are used for the needs of fisheries [4] and as drinking water for the population [5].

Patterns in turbidity distribution determined by currents in water bodies and waterways are studied quite well [6], practical recommendations are developed on turbidity calculation in dredging zones [7-10]. When currents are unstable in large water bodies, in order to calculate turbidity we recommend to use various mathematical models [11]. The models have empirical coefficients, which means that the reliability of the calculations depends strongly on the model verification quality based on the data collected during the field experiment in a specific water body.

The authors propose that in order to calculate the turbidity, the mathematical model "VOLNA" [12, 13] should be used, that is based on the shallow water equations and the advective diffusion equation for impurity distribution [14, 15]. The goal of the modelling is to calculate the additional water turbidity during dredging in water storage basin with daily, weekly and seasonal regulation regime for aqueous run-off.

2. The description of the research area and technologies employed

The Kuibyshev water storage basin was used as the object of the research where a bridge was built across the Volga river in 34 km from Zhigulevskaya dam. The length of the water storage basin is 750 km, and its surface is 6450 km². The width of the water storage basin in the area where the bridge was built was 3.5 km and the maximum depth was 41 km. The water storage basin has a daily, weekly and
seasonal regulation regime for aqueous run-off [16]. The bed deposits in the construction area is small-sized aleurite and clayed silt, and their depth can vary considerably from several millimeters to 120 cm [17].

Dredging should be conducted with a self-moving multi-bucket dredging machine (a suction dredge P-36) with a productivity rate of 750 m³/hour. The best depth of the developed soil is 7 m and the maximum one is 10 m. The breadth of the working area is 6 m, and the soil loss coefficient is 10%. In order to reduce the negative impact a crane boat with 16 t capacity and a 4 m³ gripper and with a productivity rate of 16.3 m³/hour should be used instead. The breadth of the working area is 1.5 m, and the soil loss coefficient is 1%.

The bridge is to be constructed in the 2nd public health zone (PHZ) for water extraction for drinking purposes of Toliatti. Water extraction cutwaters are in 370 m from the left river bank and are situated in the submerged bottomland. When the head water level (HWL) is normal in the water storage basin (53 m onshore facilities), the water is extracted from 18 m, and when it is minimal (45 m onshore facilities), it is extracted from 10 m [18].

3. The research method and input materials
A method of mathematical modelling and a method of a field experiment to verify the model were used to calculate the turbidity. The model of the Kuibyshev water storage basin was used to calculate the hydrodynamics and the distribution of suspended particles from the sources of impurities in water storage basins; and this model uses the shallow water equation and the advective and diffusion equation to calculate the distribution of the impurity. This model was chosen because the Kuibyshev water storage basin is a large shallow water body, where the horizontal movement is stronger than the vertical one.

A method of a field experiment was used to verify the model [19] that allowed to make a qualitative comparison between the modelled and real-life current and turbidity zones. Field studies for the purposes of the verification of the model were conducted in the area of the Kuibyshev water storage basin where a bridge is constructed and water is extracted. Measurement tools: a Hydrolab DSS5X monitoring system, a DW-800 portable spectrophotometer, a rotator, an echo meter and a GPS navigation system. The water samples were collected from three horizons by a Molchanov bathymeter, and was transported by car to the place where the chemical analysis was conducted. The bed sediment samples were obtained with the tube of the State Oceanographic Institute. The information on average monthly and daily water consumption in the cross section, where the construction was underway, was given by RusHidro PJSC, Zhigulevskaya HPP. The coordinates of the bank line and the morphometry of the floor of the Kuibyshev water storage basin were given according to the Atlas of the Unified Deep Water System for the European part of Russia. The floor of the water storage basin was additionally scanned in the construction area by an echo meter in the 2nd public health zone (PHZ) for water extraction [20].

4. Results and their discussion
Fraction analysis of samples from the bed sediment in the dredging area showed that clayed silt were deposited in small fractions with the diameter of particles (D) less than 0.1 mm that accounted for 90.8% (see Table 1). The granulometric size of the small fraction varies from 0.00098 - 0.43600 cm/s [21].

At the first stage the areas of currents were calculated for the whole water storage basin with the estimated net spacing of 200 m. At the second stage the map of currents was used to calculate the distribution of suspended particles in the water storage basin in the construction area with the estimated spacing of 0.5 m for the suction dredge and 1.5 for the crane boat.

There are generally accepted expressions for the coefficient of horizontal turbulent exchange and the coefficient of horizontal turbulent diffusion, and they were chosen during the verification process of the mathematical model in the Kuibyshev water storage basin. The field experiment was conducted
in the construction area, the current speed was measured and the turbidity concentration in the initial solution and in the cross section of the water extraction.

Table 1. Description of silt sediment in the construction cross section.

| D, mm | Fraction share, % | Hydraulic size, cm/s |
|-------|-------------------|----------------------|
| >0,1  | 9.2               | >0.43600             |
| 0,1-0,05 | 21.7             | 0.43600              |
| 0,05-0,01 | 30.9             | 0.07990              |
| 0,01-0,005 | 33.8             | 0.00308              |
| 0,005-0,001 | 8.9              | 0.00098              |

The results of the hydrodynamic calculations show that if the water level is 53.0 m (onshore facilities) and the water consumption is 6000 m/s, average speed of the outflow in the construction area was 0.2-0.4 m/s. The suction dredge and the crane boat were in 480 m from the water extraction cross section. The results of the calculation of the turbidity in the construction cross section by a suction dredge (Z₁) and by a boat crane (K₁), and in the water extraction cross section (Z₂), by a boat crane (K₂) are shown in Table 2.

Table 2. The turbidity in the construction cross section (Z₁, K₁) and the water extraction cross section (Z₂, K₂) with a suction dredge and with a crane boat for fractions, mg/dm³.

| D, mm | Z₁, mg/dm³ | Z₂, mg/dm³ | K₁, mg/dm³ | K₂, mg/dm³ |
|-------|------------|------------|------------|------------|
| 0,1-0,05 | 505.80    | 34.64     | 4.37       | 0.163      |
| 0,05-0,01 | 720.24    | 49.33     | 6.22       | 0.232      |
| 0,01-0,005 | 787.83    | 53.96     | 6.81       | 0.253      |
| 0,005-0,001 | 207.45    | 14.21     | 1.79       | 0.067      |
| Sum         | 2221.31   | 152.14    | 19.19      | 0.715      |

5. Conclusions

The results of the calculation showed that the turbidity concentration in the Kuibyshev water storage basin in the drinking water extraction zone for Toliatti would be the following:

- 152.14 mg/dm³ if dredging is performed with a suction dredge P-36 with the productivity rate of 750 m³/hour;
- 0.715 mg/dm³ if dredging is performed with a 16-ton crane boat with a 4m³ gripper with the productivity rate of 16.3m³/hour.

Additional water turbidity caused by the suction dredge in the water extraction area will violate the requirement for the I and II public health zone (PHZ) for public drinking water purposes (Sanitary Rules and Norms 2.1.4.1110-02).

References

[1] Bolotova N L, Zuyanova O V, Dumnich N V 1997 The effect of hydromechanized work on water ecosystems of the Vologda Oblast Scientific support of environmental protection and rational use of natural resources: materials of scientific-practical. conf. (Vologda) 19 pp 22-27
[2] Kondratyev T A, Zakharov S D, Khaliullina L Yu 2012 The effect of mining non-metallic building materials on the ecosystems of the Kuibyshev reservoir Bulletin of Kazan Technological University T 15 19 pp 116 - 119
[3] Selezneva A V, Bespalova K V, Seleznev V A 2013 The formation of water quality of the Volga reservoirs under abnormal weather conditions Water economy of Russia 5 pp 4-14
[4] Rusanov V V, Turitsyna O S 1979 The effect of clay suspensions on the early stages of fish ontogenesis (Sat scientific tr GosNIORH) issue 2 pp 122-127
[5] Vikharev A N, Dolgova I I 2013 Calculation of turbidity zones during dredging in the water intake area Actual problems of forestry
[6] 1987 Methodological foundations for assessing and regulating the anthropogenic impact on surface water quality Ed. A V Karausheva (L.: Gidrometeoizdat) 287 p
[7] Baula V A 1994 A simplified method for determining the boundaries of turbidity zones during the operation of dredgers On Sat scientific Proceedings of the Nizhny Novgorod Aviation Administration “Development of the Inland Waterways of Siberia and Sakha (Yakutia)” Publishing House: NGAVT, Novosibirsk pp 100-108
[8] 1986 Temporary guidelines for assessing the increase in turbidity during excavation work carried out to ensure transit navigation on rivers and taking into account its impact on water quality and the ecology of aquatic organisms (M.) 59 p
[9] RDS 2-2.6-97 2000 Practical guide on the calculation and assessment of additional turbidity and secondary pollution during mining and excavation work on inland waters of Russia Design and Research Institute Lengiprorechtrans CJSC (St. Petersburg)
[10] 1990 Methodology for calculating additional turbidity and secondary water pollution during dredging and LFM extraction on rivers and water bodies Ministry of the River Fleet of the RSFSR Lengiprorechtrans
[11] 2012 Extraction of non-metallic building materials in water bodies Accounting for the channel process and recommendations for the design and operation of channel open pits (St. Petersburg.: Publishing house "Globus") 140 p
[12] Rakhuba A V, Shmakova M V 2018 Numerical modeling of siltation of the dam of the Kuibyshev reservoir by river sediments Meteorology and Hydrology 1 p 35 to 48
[13] Rakhuba A V 2017 The experience of using the Hiton-Volna measuring and computing system in hydroecological studies of the coastal waters of the city of Tolyatti In the collection: Ecological problems of industrial cities Collection of the 8th International Scientific and Practical Conference (Saratov) pp 484-488
[14] Volzinger N E, Klevanny K A, Pelinovsky E N 1989 The long-wave dynamics of the coastal zone (L.: Gidrometeoizda) 271 p
[15] Klevanny K A, Matveev T V 1994 CARDINAL user guide (SPb.: Nevsky Courier Publishing House) 72 p
[16] 1978 Hydrometeorological regime of lakes and reservoirs of the USSR: Kuibyshev and Saratov reservoirs (L.: Gidrometeoizdat) 269 p
[17] 1991 Dynamics of landscapes in the zone of influence of the Kuibyshev reservoir (St. Petersburg: Nauka) 224 p
[18] Bespalova K V, Seleznева A V, Seleznев V A 2016 Sustainable water supply for the urban population in the conditions of “blooming water” on the Volga reservoirs (on the example of the city of Togliatti) Water treatment 6 pp 19-24
[19] Seleznев A V, Seleznева A V 1999 Evaluation of the impact of a point source of pollution on the quality of reservoir water Water Resources 3 pp 501-511
[20] SanPiN 2.1.4.1074-01 2002 Drinking water. Hygienic requirements for water quality of centralized drinking water supply systems Quality control. Sanitary and epidemiological rules and regulations (M.: Federal Center for Sanitary Inspection of the Ministry of Health of Russia) 103 p
[21] 2007 Technical reference for water treatment: in 2 volumes T.1: trans. with fr. (St. Petersburg: New Journal)