Geoecological Assessment of Resources of a Water Body for More Optimal Use

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Abstract. This paper presents a geoecological assessment of resources potentially available in or from shallow water bodies. It describes a case study as an example of how water bodies and coastal areas could be comprehensively analyzed, including microbiological testing, physical and chemical tests, testing water and bottom sediments for heavy metals, gamma spectrometry of soil samples, hydrological and hydroeconomic estimates. Experimental data is used to analyze the status of water bodies. Apparently, microbiological indicators are within the acceptable limits, and so are heavy metals. However, water sampled from Lake Oktyabrskoye has >10 times limit chromaticity and turbidity indicators, 10⁻¹¹ times the limit chemical oxygen demand (COD). This indicates severe pollution and high concentration of organic substances. The presented approach to resource assessment could be of use when devising measures for nature-friendly restoration of water bodies.

1. Introduction
Most lake and river systems have recently been exposed to intensive anthropogenic impact, which disturbs their hydrology, pollutes water with numerous toxicants, and boosts siltation and eutrophication, which may even result in the disappearance of a water body [15,16,17,21]. Shallow lakes are most vulnerable to anthropogenic impact. This is a pressing issue given that freshwater of appropriate quality is a dwindling resource. The relevance of this topic comes from investigating the resources of water bodies for the purposes of rational use thereof. Such studies shed light unto the actual state of the art and help determine the categories of water use for each specific body.

2. Research materials and methods
For resource assessment, the research team picked shallow lakes in the settlements of the Bryansk Municipality, Bryansk Oblast. They are man-made water bodies. To measure their pollution and to assess their resources, we tested lake water, bottom sediments, and soil from the adjacent areas for key quality indicators.

Research involved general theoretical methods (analysis and synthesis) coupled with experimentation. Reconnaissance surveying followed a set of predetermined routes and involved photography [10,12]. Water and soil were sampled by the known methods [1,2,8]. Chromaticity and turbidity were measured by photoelectric colorimetry [3,5], and COD was measured by the known method [4,14]. pH value of sampled water was measured using a pH-150M unit; for coastal gamma
surveying, we used a dosimeter based on gas-discharge counters: DRG-01T1, DBG-06t [6]. Besides, we made hydrological and hydroeconomic estimates per SP 33-101-2003. [9]

3. Results and discussion
Shallow open lakes were picked to evaluate anthropogenic impact. Figure 1 shows the condition of water bodies.

Lake Gosoma is elongated, the basin bottom is slightly sloped. Max depth is >3 m. On the east side, the coastline borders farmland. There is an industrial pumping station on the coast that withdraws water in spring and summer for agricultural use; this has reduced the water level by 1.0-1.5 m. In the northwest of the lake, there is a dam with a tubular reinforced-concrete water outlet tower [16,20]. The lake is becoming overgrown, which compromises its recreational quality.

Lake Oktyabrskoye has an elongated furrow-shaped basin with slightly sloped shores. The dam features shut-off valves in the lower pool. The lake is ~4 meters deep; however, it is growing shallower. Compared to 2015 data, its water level has dropped by 2-2.5 meters, and terraces overgrown with shrubs and herbaceous vegetation have emerged, see Figure 1b. Shallowing was caused by the degradation of the shut-off valves in the lower-pool drain of the dam.

Tests show a varying degree of anthropogenic impact. Lake Oktyabrskoye is affected the most, see Table 1.

| Sample no. | Chromaticity, units | Turbidity, units | COD, mg O₂/l | pH  |
|------------|---------------------|-----------------|--------------|-----|
| Lake Oktyabrskoye |
| 1          | 600                 | 15              | 182          | 6.96|
| 2          | 700                 | 14              | 326          | 7.16|
| 3          | 600                 | 15              | 250          | 6.54|
| 4          | 560                 | 13              | 310          | 6.43|
| 5          | 720                 | 14              | 290          | 6.62|
| 6          | 600                 | 13              | 300          | 6.82|
| Lake Gosoma |
| 1          | 10                  | 1.5             | 18.2         | 7.84|
| 2          | 12                  | 1.7             | 14.7         | 7.70|
| 3          | 15                  | 2.0             | 14.5         | 7.58|
| 4          | 10                  | 1.5             | 18.3         | 7.82|
| 5          | 10                  | 1.7             | 17.4         | 7.69|
| 6          | 12                  | 1.7             | 15.1         | 7.77|

Figure 1. Condition of the water bodies.
Chromaticity and turbidity readings are >10 times the acceptable limits [3], and chemical oxygen demand (COD) was also 10-11 times the limit [4]. This indicates severe pollution and high concentration of organic substances. Besides, the lakes are turning into swamps as indicated by their pH.

Water and bottom sediment samples were tested for heavy metals to determine the recreational quality of the water body and the feasibility of using sapropel as fertilizer. Lead and cadmium were found to be within acceptable limits in water and bottom sediments. Heavy metals have higher concentrations near the bottom due to the accumulation of pollutants in the bottom sediments. Still, heavy metals are within MPCs in the bottom sediments. This means such sediments could be used as an organic fertilizer.

The studied area is dominated by sod-podzolic gleysols. Physical and chemical tests reveal that clayey particles sized <0.005 mm make up for 20% to 30% of the tested samples, classifying the soil as a heavy loam [7] containing silts with a well-defined morphological structure. Upper horizons are heterogeneous with residual herbaceous vegetation and a peat substrate mixed with gleys.

Radiation level ranged from 10 to 12 μR/h, averaged at 11.2 μR/h. Measurement results follow normal distribution, i.e., 11.2 μR/h could be deemed characteristic of the entire area. Thus, the lakes do not exceed the levels of background natural radionuclides typical of the location, which is in line with the NRB 99/2009 requirements. Therefore, bottom sediments could be used as an organic fertilizer.

The microbiological community is dominated by Bacillus and Actinomyces soil bacteria. Their presence decreases as sampling depth goes from the surface (20 cm) to 1 m.

Pathogenic microflora tests revealed coliforms and enterococci to be within the acceptable limits (<1 CFU/g) in all tested areas [13].

Surface water bodies are often used for irrigation in agriculture. However, such usage tends to ignore the hydrological and hydroeconomic parameters of water bodies. With that in mind, the research team proceeded to estimate the hydrological and hydroeconomic parameters of Lake Gosoma using the methods specified in SP 33-101-2003. [9] Bathygraphic curves were plotted for Lake Gosoma, see Figure 2.

In order to define the degree of siltation, we calculated the annual runoff and siltation. Normal runoff as flow \( Q_0 \), m\(^3\)/s adjusted for the catchment area \( F \), km\(^2\), was found using the absolute value of runoff \( M_0 \), l/s per km\(^2\), whereas normal annual runoff, \( W_0 \), m\(^3\)/year was found by Eq. 2.

\[
Q_0 = \frac{M_0 F}{1000}, \quad W_0 = Q_0 t, \quad (1)
\]

where \( t \) is seconds in a year, 31.536 \( \times 10^6 \).

Thus, normal runoff would be \( Q_0 = 0.13 \) m\(^3\)/c, and normal annual runoff would be \( W_0 = 4.2 \times 10^6 \) m\(^3\)/year.

Annual runoff was calculated for a year with 50% confidence adjusted for the absolute coefficient \( K_r \) and the normal runoff:

\[
\begin{align*}
Q_{r-50\%} &= K_r Q_0 \\
W_{r-50\%} &= K_r W_0
\end{align*}, \quad (3)
\]

Siltation runoff volume \( V_{st} \), m\(^3\), was found as:

\[
V_{st} = \frac{\rho_0 W_{p-50\%}}{\gamma_{sed} 1000} (1 + m - \delta) \quad (5)
\]

where \( \rho_0 \) is the turbidity, g/m\(^3\); \( W_{p-50\%} \) is the annual runoff, m\(^3\)/year; \( \gamma_{sed} \) is the density of sediments, g/l; \( m \) is the proportion of bottom alluvia; \( \delta \) is the transit portion of alluvia [17]. From the collected data, siltation runoff \( V_{st} = 13.6 \) thous. m\(^3\)/year.
Acceptable siltation period for small lakes is 50 years [17]. According to the design documentation, the lake at the Gosomka River was made more than 50 years ago. During its lifetime, the water body gained a total alluvial volume $V_{a} = V_{st} \cdot 50 = 680$ thous. m$^3$ as adjusted for the siltation runoff. Such considerable siltation of the lake bed has caused the water body to shallow and overgrow, which compromises the habitat of aquatic animals and the resources of the lake.

Below are the authors-calculated hydroeconomic estimates that describe the condition of the lake from the economic standpoint, see Table 2.

**Table 2.** Hydroeconomic estimates.

| Indicators                                      | H level altitude, m | Water surface area $F$, thousand m$^2$ | Water volume $V$, thousand m$^3$ |
|------------------------------------------------|---------------------|----------------------------------------|-------------------------------|
| 1. Full volume of the pond, $V_{ful}$          | 169                 | 506.0                                  | 1362.0                        |
| 2. Pond bottom elevation                       | 164                 | -                                      | -                             |
| 3. Dead volume $V_{dv}$                       | 166                 | 267.0                                  | 222.5                         |
| 4. Water volume for water supply $V_{wat}=0.1V_{ful}$ | -                   | -                                      | 136.2                         |
| 5. Volume lost to evaporation, $V_{e} = ha \cdot F_{avg}$ | -                   | 386.5                                  | 228.3                         |
| 6. Volume lost to filtration, $V_{f} = hf \cdot F_{avg}$ | -                   | 386.5                                  | 231.9                         |
| 7. Total (exclusive of the full volume) $V_{dv}+V_{wat} + V_{e} + V_{f}$ | -                   | -                                      | 819.0                         |
| 8. Volume available for irrigation $V_{ir}=V_{ful}-(V_{dv}+V_{wat}+V_{e}+V_{f})$ | -                   | -                                      | 543.0                         |

These estimates could be of use for devising hydrotechnical projects seeking nature-friendly restoration of the lake.

**4. Conclusions**

This paper investigates a particular case to describe the principles and methods of physical, chemical, microbiological, and radiological testing of water and soil samples for geoecological assessment of water body resources.

It presents comprehensive analysis of the condition of shallow water bodies as well as hydrological and hydroeconomic estimates that indicate the anthropogenic impact and help determine the category of water use for each body.
The presented approach to resource assessment could be of use when devising measures for nature-friendly restoration of water bodies.

5. References

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