THE ROLE OF RELATIVE DEPTH IN THE PREDICTION OF EUTROPHICATION OF LAKES AND RESERVOIRS

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INTRODUCTION

The morphology of water bodies is defined as the study of the characteristics of the form of the aquatic system. The measurement of these physical features is the field of study of the science called morphometry. The description of the form of rivers, lakes and reservoirs is made through the use of morphometric parameters. These can be divided into primary parameters (i.e. obtained directly from field researches or in the office) and secondary parameters, which are calculated indirectly from the primary ones. Examples of the first group are area, volume, maximum depth, length, breadth and perimeter. In the second group the most important are relative depth, shoreline development, volume development and surrounding factor (relationship between the drainage basin area and the surface of the water body). All these morphometric factors have a striking influence on the structure and function of the water body and consequently on its water quality (Cole, 1983). This is particularly true in the case of lentic systems (lakes and reservoirs). Since the water residence time is considerably higher in lentic systems than in rivers, the influence of the morphometry of the aquatic environment can be easier observed in these slow-flowing systems. One of the most significant morphometric parameters for describing and predicting the functioning of the aquatic environment is the relative depth. This paper discusses the limnological importance of this parameter and presents the results of a broad survey carried out by the author regarding the morphometric features of Brazilian lakes and reservoirs, particularly with reference to the distribution of values of relative depth. The paper stresses also the strong influence of this parameter on the water quality of lentic systems and the convenience of using this information in the prediction of the development of eutrophication. In a broad sense these considerations effectively contribute to the management of lakes and reservoirs, including the adoption of preventive and corrective measures for their conservation or restoration.

RELATIVE DEPTH

The relative depth \( Z_R \) is defined as the relationship between the maximum depth of the lake or reservoir and the mean diameter of the system. The mean diameter is the diameter of a circle that has the same area of the lake. The result is given in percent unities. Hence:

\[
Z_R = 88.6 \cdot \frac{Z_{\text{max}}}{A^{1/2}} \quad [\%]
\]

Deep water bodies with small areas present high values of relative depth. On the other hand large and shallow lakes and reservoirs have low relative depths. The main influence of the relative depth on the functioning of the aquatic environment is related with the circulation pattern of the water body, Lakes that are large, but shallow, have no difficulty in circulating vertically their waters. This means that, the upper layers, which are normally rich in dissolved oxygen, can frequently reach the bottom of the lake, contributing therefore to the oxygen supply in the deep layers. On its turn deep lakes with small areas are usually not able to provide oxygen to the deep waters, since vertical circulation is rarely complete. These lakes and reservoirs remain then with a part of their water volume completely isolated, leading to the establishment of permanent anaerobic layers. It can be easily concluded that the faculty of circulating or not the waters has a strong influence on the quality of the aquatic environment, determining also the convenience or limitation of uses. This is particularly important in the case of water supply reservoirs.
EUTROPHICATION

Eutrophication is characterized by the excessive growth of aquatic plants (algae and macrophytes) due to the water enrichment with nutrients. The so-called artificial eutrophication is caused mainly by discharge of untreated sewage in lentic water bodies. It is one of the most important pollution phenomena, leading to serious constraints in the use of the water. The development of eutrophication is closely related to the circulation pattern of the lake or reservoir. The influence of hydrodynamics (vertical circulations) can be considered under two aspects: in unpolluted water bodies vertical circulation is highly desirable, since it contributes to the oxygen supply of the system; on the other hand circulation in polluted aquatic systems can bring high loads of reduced compounds and even toxic materials from the bottom to the surface layers, with catastrophic consequences to the quality of the water body. The knowledge of the relative depth of the system can hence be very useful in predicting the development of eutrophication in polluted and unpolluted waters. Former models for defining critical levels of eutrophication considered mean depth (area divided by volume) as the main morphometric parameter (Vollenweider, 1976).

MORPHOMETRIC SURVEY OF BRAZILIAN LAKES AND RESERVOIRS

A broad survey about morphometric characteristics of Brazilian lakes and reservoirs was carried out by the author in the period 1994-97, with financial support from Brazilian Scientific and Technological Development Council (CNPq). About 700 lentic systems were analysed and relationships between morphometry and water quality were consistently developed.

Regarding relative depth the following distribution of values was found:

<table>
<thead>
<tr>
<th>$Z_R$ (%)</th>
<th>Distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 0,5</td>
<td>60</td>
</tr>
<tr>
<td>0,5 – 1</td>
<td>21</td>
</tr>
<tr>
<td>1 – 1,5</td>
<td>8</td>
</tr>
<tr>
<td>1,5 – 2</td>
<td>3</td>
</tr>
<tr>
<td>2 – 2,5</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 2,5</td>
<td>5</td>
</tr>
</tbody>
</table>

It can be seen that the absolute majority of surveyed lakes and reservoirs (about 80 %) present low relative depths, smaller than 1 %.

The five highest values of relative depth correspond to the following lentic systems:

<table>
<thead>
<tr>
<th>$Z_R$ (%)</th>
<th>$A$ (km$^2$)</th>
<th>$Z_{\text{max}}$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13,4</td>
<td>0,06</td>
<td>37</td>
</tr>
<tr>
<td>6,7</td>
<td>0,07</td>
<td>20</td>
</tr>
<tr>
<td>5,6</td>
<td>0,003</td>
<td>3,5</td>
</tr>
<tr>
<td>5</td>
<td>0,23</td>
<td>27</td>
</tr>
<tr>
<td>4,7</td>
<td>0,003</td>
<td>3</td>
</tr>
</tbody>
</table>
The lowest relative depths were found in the following lakes and reservoirs:

1. Peixe (State of Rio Grande do Sul) 0,004 43,7 0,3
2. Patos (State of Rio Grande do Sul) 0,005 9280 5
3. Mangueira (State of Rio Grande do Sul) 0,013 802 4
4. Cipó (State of Rio Grande do Sul) 0,02 2,7 1,6

All these water bodies are coastal lagoons, situated immediately close to the seashore. In the sequence there are 28 lentic systems whose relative depths oscillate between 0,02 and 0,1. It is interesting to observe that the highest values of $Z_R$ are always found in small water bodies, with areas rarely over 1 km$^2$. On the other hand low $Z_R$ values are easily found in both large and small systems.

**CONCLUSIONS**

The study of the distribution of relative depths in Brazilian lakes and reservoirs and their relationship with the water quality leads to following conclusions:

1. Aquatic systems with low relative depths show the prevalence of frequent vertical circulations; in the case of polluted lakes and reservoirs this can bring serious constraints to the water use;
2. Aquatic systems with high relative depths are usually not able to circulate completely; this means that the oxygen supply to the bottom layers is not adequate, bringing also difficulties for the proper use of the aquatic environment;
3. The majority of Brazilian lakes and reservoirs present low values of relative depth, generally under 1 %;
4. The sound utilization of lakes and reservoirs is most certainly achieved when these systems have mean values of relative depth (between 1 and 2 %);
5. The information about morphometric features of aquatic systems, specially with reference to relative depth, can effectively contribute to the important task of predicting the onset of stratification.

**BIBLIOGRAPHIC REFERENCES**
