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System Optimization of Reservoir Pollution Prevention and Control Engineering under Deep Learning

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Abstract: At present, due to the eutrophication of the water body itself and the man-made discharge of pollutants, the large and small water bodies in many areas have been polluted, which is the main reason for the surface water pollution and soil erosion caused by over-exploitation of land in many areas. In many economically backward areas, low productivity, chemical fertilizer pollution or soil erosion can nourish water. To control reservoir pollution, it is necessary to consider the current emission level of indicators and point sources. In this paper, the Deep Learning (DL) algorithm was used to optimize the reservoir pollution control engineering system. This paper calculated the contribution value of each Pollution Source (PS) according to the classification of reservoir PS. On the basis of the contribution value of each PS, the DL algorithm was used to predict water quality pollution, and the water environment capacity model was established according to the pollution load prediction of the reservoir basin. The combination of water quality pollution prediction and water environment capacity model could monitor the reservoir pollution and control the water pollution in time. The experimental part studied the prediction effect of water pollution. The experimental results showed that the DL prediction algorithm had good water quality prediction ability. The error of reservoir pH (hydrogen ion concentration index) was less than 0.5, and the prediction error of COD (Chemical Oxygen Demand) content in water was less than 10%.

1. Introduction

At present, reservoirs in many areas have been seriously polluted, and water pollution is quite serious. Some areas have even experienced large-scale eutrophication, which is mainly due to man-made pollutants entering the reservoir. According to the survey, many reservoirs have led to eutrophication, low agricultural productivity and serious soil erosion. In addition, in order to reduce the cost of wastewater and waste gas treatment, companies around the reservoir directly add harmful substances to the reservoir. These problems have not been properly treated and controlled, and more wastewater has been discharged into the reservoir. The pollution of the reservoir is not optimistic, so relevant departments must pay high attention to it.

At present, many scholars have studied water pollution. Wikurendra Edza Aria analyzed the water quality of Pucang River and controlled water pollution [1]. He Mingjing studied the application of waste biochar in water pollution control and sustainable development [2]. Li Z. H. O. U conducted research on water pollution control of agricultural non-point PS [3]. Long Bui Ta explored the inverse algorithm of water pollution control based on the classic Streeter-Philps model [4]. Li Xiang studied the application of magnetic nanomaterials in water pollution control [5]. Martini Sri summarized the current research status of water pollution control membrane technology [6]. Although there were many studies on water pollution, the prevention and control of reservoir pollution needed to be continued.

There are many researches on DL in water resources. Sit Muhammed systematically reviewed the application of DL in water resources [7]. Barzegar Rahim developed an independent DL model to predict short-term water quality variables [8]. Zhang Han used the DL method to evaluate the water source bearing capacity [9]. Read Jordan S evaluated the role of DL model in lake water temperature prediction [10]. Venkataramana Y used DL algorithm to analyze lake water quality [11]. Khullar Sakshi introduced a dual-length short-term memory network model based on DL to predict the water quality factor of the Yamuna River in India [12]. Although DL was widely studied in the field of water resources, there was less research on reservoir pollution prevention and control engineering.

In order to improve the capability of reservoir pollution control, this paper used DL to optimize the reservoir pollution control engineering system. This paper first summarized the current situation of reservoir pollution. It then divided the reservoir PS into point PS and non-point PS, and calculated the pollution value of each PS in the reservoir pollution. On this basis, the DL algorithm was used to predict the water pollution. Finally, the pollution load of the reservoir was predicted and the water environment capacity model was established. The experiment part used the DL algorithm to predict the water quality, and compared it with the real value to study the prediction accuracy.

2. Current Situation of Reservoir Pollution

At present, the water quality of many lakes, reservoirs and small reservoirs is not optimistic. The eutrophication problem worsens with the reduction of water pollution, which is mainly due to the planting of nearby farmland and the discharge of fertilizer. Many pollutants in the water include chlorinated fertilizer, ammonia fertilizer and phosphate fertilizer. In addition to the reasons for releasing fertilizer from agricultural land, separate fish ponds are also included. Fish farming requires nitrogen. In the water body, the addition of phosphorus and other nutrients beneficial to fish farming would increase the nitrogen content. At the same time, due to the low exchange capacity of the reservoir and the slow flow of water, these nutrients accumulated, thus resulting in abundant algae in the water and long-term eutrophication of the reservoir [13].

At present, the inevitable consequence of water pollution and eutrophication is that cyanobacteria in the water body multiply in large numbers, which would cause certain damage to the water ecosystem [14].

3. Evaluation of Contribution Value of PS

3.1. Classification and Evaluation of PS

Various pollutants entering the reservoir from outside pollute the water quality of the reservoir. At present, due to the economic and social development of the river basin, there are few large industrial enterprises focusing on agriculture, and the tertiary industry has developed rapidly in recent years. Therefore, the pollutants in the basin come from scenic spots, urban living sewage, rural living sewage, etc. [15].

3.1.1. Point Source Pollution

There are almost no industrial enterprises around the reservoir, and the point PS are mainly from urban living PS. The pollution load of the reservoir area is divided into two types: the sewage pollution load of residents and the living pollution load generated by restaurants and hotels. The residents belong to the non-agricultural permanent population in the reservoir area.

3.1.2. Non-point Source Pollution

Reservoir non-point PS mainly occurs in livestock and poultry breeding, soil erosion, drainage pollution and other fields. Its pollution flow is closely related to precipitation, topographic conditions and the intensity of human activities in the reservoir area. The terrain on both sides of the reservoir area is high and the surrounding cultivated area is large. The slope is large and the amount of fertilizer is large, which is the direct or indirect cause of the current surface pollution in the reservoir area.

In addition to the partial pollution of the river directly flowing into the reservoir and the dust directly flowing into the reservoir, the other pollutants are mainly farmland fertilizer. Some nutrients are absorbed by crops. The rest are decomposed through surface runoff, infiltration and other processes, and finally pollutants (organic and nutrient substances) enter the water body of the basin.

3.2. Evaluation of Contribution Value of Various Types of Pollution

The formula for calculating living pollutants is as follows:

$$G = 365 \times N \times F \times 10^{-6} \quad (1)$$

G is the pollution load of pollutant i; N is the population; F is the emission coefficient of pollutant i.

Various pollutants in agricultural fertilizers cannot completely seep into the reservoir due to soil adsorption and other reasons, so the pollutants entering the reservoir are estimated to be 80% of the loss. The formula for calculating agricultural wastewater burden is as follows:

$$W_i = a_5 \times A \times L_5 \times 10^{-3} \quad (2)$$

i is a pollutant; W_i is the pollution load of agricultural runoff; A refers to cultivated land area; L_5 is the pollutant emission of planting area; a_5 is the agricultural flow coefficient of the river, which is 0.8 by default.

The formula for calculating the regional livestock and poultry pollution reduction is as follows:

$$P_i = a_4 \times N \times L_4 \times 10^{-3} \quad (3)$$

P_i is the pollution caused by animal husbandry; N is the number of existing animals and poultry; L_4 is the quality of pollutants produced by livestock and poultry production units; a_4 is the pollution input coefficient of animal husbandry, which is 0.10 by default.

Due to sediment, dust, water and other reasons, pollutants may directly enter the basin water, so the pollution of sediment and sediment is also the cause of reservoir pollution. The calculation formula of atmospheric dust fall is as follows:

$$Q = P \times A \times 10^{-3} \tag{4}$$

Q reflects the pollution of sand and dust storms on the water; P represents load capacity; A is the rainwater collection area.

The precipitation in the reservoir area directly transfers pollutants from rainwater to the reservoir area, which is also the reason for the increase of reservoir pollution. The calculation formula of rainfall pollution is as follows:

$$R_i = (P \times C) \times A \times 10^{-6} \tag{5}$$

R_i is the annual burden of surface rainwater pollution; P is the annual rainfall; C is the concentration of pollutants in sediment; A is the surface area of the reservoir.

4. Water Pollution Prediction Based on DL

The neural network model is determined by network topology, neural properties and learning plan. A three-layer feedback neural network model is selected. Each neuron activates S-type function, and the three-layer feedback neural network model is shown in Figure 1.

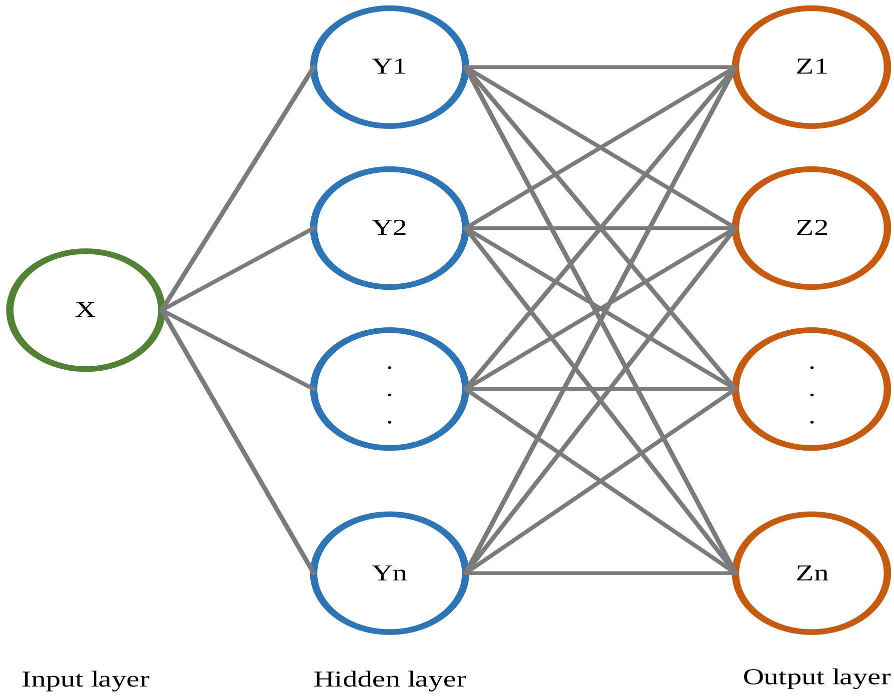


Figure 1. Feed-forward three-layer neural network model

The unsupervised learning algorithm of neural network is as follows.

According to the characteristics of the problem (the number of network layers, the number of network nodes in each layer), the network structure is designed and the network learning options are wisely selected.

Each connection weight and network threshold are defined, and the threshold is any number between [-1,+1].

Each data example includes an input vector x and an expected output value t_p, and the actual output of each network layer node is calculated by layer.

$$Y_j = f\left[\sum_{i=1}^{n} Wl_{ji} \cdot X_i + Ql_j\right] \tag{6}$$

$$O_p = f\left[\sum_{k=1}^{m} Wz_J \cdot Y_j + Qz\right] \tag{7}$$

$$f(x) = \frac{1}{1+e^{-x}} \tag{8}$$

Y_j is the output value of each node in the hidden layer; Wl_{ji} is the value of each node in the hidden layer; X_i is the value of each node in the input layer; Ql_j is the threshold value of each node in the hidden layer; O_p is the output value of the output layer P matrix; Y_j is the output value of each node in the hidden layer; Qz is the threshold value of each node in the hidden layer; Wz_J is the branch value of each node connected to the hidden layer by the output layer.

Network output error:

$$E = \frac{1}{k}\sum_{p=1}^{k}\left[\frac{1}{2}(t_p - O_p)^2\right] \tag{9}$$

The deviation signal of each node in the network is calculated by layer:

$$D = O_p \cdot (1 - O_p)(O_p) \tag{10}$$

D is the output layer node error.

$$\delta_j = Y_j(1 - Y_j)\sum_{k=1}^{m} D \cdot W_{zk} \tag{11}$$

δ_j is the output error of each node on the hidden layer.

Node weight and network connection threshold correction:

$$\Delta W_{zj}(t+1) = \eta D O_p + \alpha \Delta W_{zj}(t) \tag{12}$$

$$\Delta Q_z(t+1) = \eta D + \alpha \Delta Q_z(t) \tag{13}$$

$$\Delta WJI(t+1) = \eta \cdot \delta j \cdot Y_J + \alpha \Delta Wl_{ji} \tag{14}$$

$$\Delta Ql_j(t+1) = \eta \delta_j + \alpha \Delta Ql_{ji}(t) \tag{15}$$

Each learning sample P is processed as described above.

5. Calculation of Water Environment Capacity of Reservoir

The maximum allowable quantity of pollutants in the reservoir refers to the maximum quantity or quality of pollutants that the reservoir can absorb in a unit time after the water quality of the reservoir reaches the expected environmental objectives. A given water body can maintain the pollution amount lower than the established environmental target.

5.1. Basin Pollution Prediction

The prediction of population and socio-economic growth is the basis for formulating comprehensive pollution control plans and scientific control measures, which are helpful to predict the pollution of the river basin and the sea outlet. The main problem of basin load forecasting is the increase of pollution burden caused by population growth in the catchment area.

$$B_i = B(1 + r_i)^{t_i} \tag{16}$$

B_i is the population in the planning year; B is the base year population data; r_i is the average growth rate from the plan year to the base year.

5.2. Water Environment Capacity Model

Water flow can be expanded by surface calculation. For example, natural flow can be expanded through direct current. Complex basins can be simplified, and instantaneous flow can be reduced to stable flow. Factors affecting the water environment, such as tributaries, corresponding sewage and catchment areas, can also be simplified. If there are multiple sewers nearby, they can be simplified as central sewers. The water system map, regional management map and land use map are planned to divide the reservoir into several small watersheds of different sizes.

It is assumed that the reservoir water is completely mixed, the water flows into the reservoir and is immediately completely distributed in each area. According to the principle of mass balance, the formula is as follows:

$$V\frac{dC}{dt} = W_{in} - K \cdot C \cdot V - C \cdot Q_{out} \tag{17}$$

C represents the average concentration of total nitrogen and total phosphorus in the reservoir water; V is the reservoir capacity; W_{in} is the annual total phosphorus and total nitrogen reserves; Q_{out} is the annual outbound water volume.

$$C = \frac{W_{in}}{K \cdot V + Q_{out}} \tag{18}$$

$$V\frac{dC}{dt} = QC_o - QC + S_c + r(C)V \tag{19}$$

$$\begin{cases} S_c = W \\ r(C) = -KC \\ \frac{dC}{dt} = 0 \end{cases} \tag{20}$$

Formula (20) is carried into Formula (19):

$$U_{ij} = Q_{0ij} \times (C_{sij} - C_{0ij}) + 3.65 \times 10^{-4} \times k \times v_{ij} \times C_{sij} \tag{21}$$

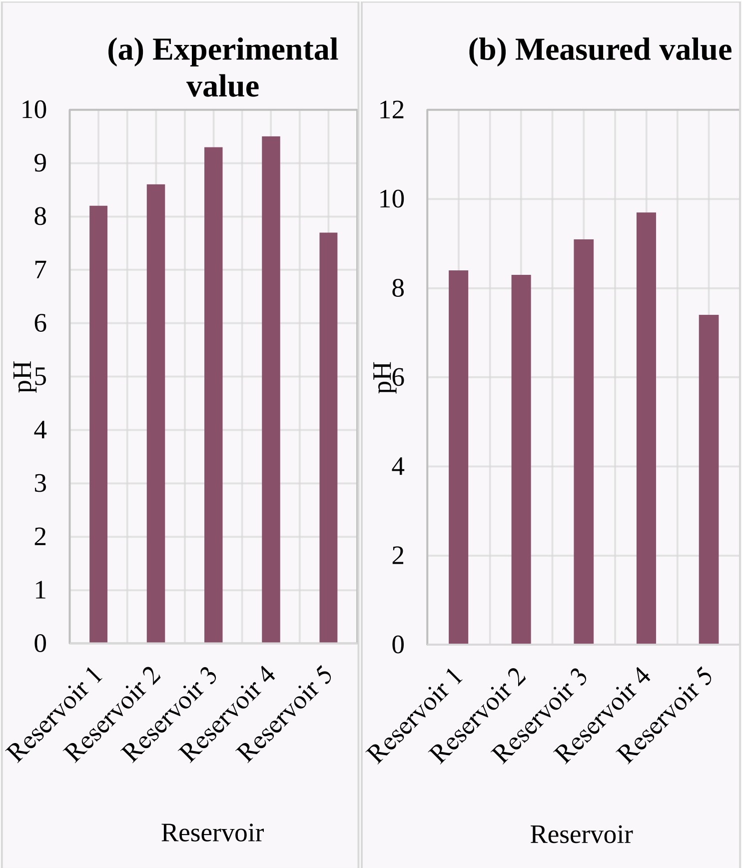
When calculating the water capacity in the reservoir environment, the allowable flow limit used in the previous calculation area, namely the water quality index, should be used as the basis for evaluating the water quality. When calculating water capacity, the water quality design objective of each control unit must conform to the functional planning of water resources.

6. Reservoir Pollution Prevention Experiment

The water pollution status of the five reservoirs was detected. The contribution value of the reservoir environment to the reservoir PS was analyzed, and the reservoir pollution situation was predicted using DL. The calculated results were compared with the real results to analyze the accuracy of the prediction of the reservoir pollution situation of the DL algorithm.

6.1. Reservoir pH

The experimental and measured pH values of the five reservoirs were shown in Figure 2.



(a) Experimental value of reservoir pH

(b) Measured value of reservoir pH

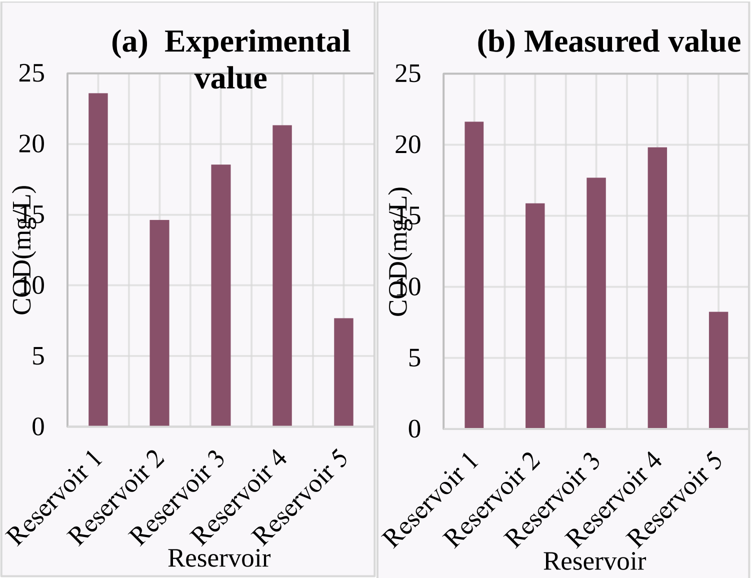
Figure 2. Reservoir pH

Figure 2 (a) showed the experimental value of reservoir pH, and Figure 2 (b) showed the measured value of reservoir pH.

The experimental pH value of reservoir 1 was 8.2, and the measured pH value was 8.4. The experimental pH value of reservoir 2 was 8.6, and the measured pH value was 8.3. The experimental pH value of reservoir 3 was 9.3, and the measured pH value was 9.1. The experimental pH value of reservoir 4 was 9.5, and the measured pH value was 9.7. The experimental pH value of reservoir 5 was 7.7, and the measured pH value was 7.4. It could be seen from the comparison data that the error between the experimental value and the measured value of the reservoir pH was within 0.5. This showed that the DL algorithm could better calculate the pH value of water in the reservoir, which was close to the measured value.

6.2. COD Content of Reservoir

The experimental and measured values of COD content in five reservoirs were compared and the Relative Error (RE) between them was calculated, as shown in Figure 3.



(a) Experimental value of COD content in reservoir

(b) Measured value of COD content in reservoir

Figure 3. Reservoir COD levels

Figure 3 (a) showed the experimental value of COD content in the reservoir, and Figure 3 (b) showed the measured value of COD content in the reservoir.

The experimental value of COD content in reservoir 1 was 23.58mg/L, and the measured value of COD content was 21.62mg/L. The RE between the two was 8.31%. The experimental value of COD content in reservoir 2 was 14.62mg/L, and the measured value of COD content was 15.88mg/L. The RE between the two was 7.93%. The experimental value of COD content in reservoir 3 was 18.54mg/L, and the measured value of COD content was 17.69mg/L. The RE between the two was 4.58%. The experimental value of COD content in reservoir 4 was 21.33mg/L, and the measured value of COD content was 19.82mg/L. The RE between the two was 7.08%. The experimental value of COD content in reservoir 5 was 7.69mg/L, and the measured value of COD content was 8.24mg/L. The RE between the two was 6.67%.

It could be seen from the comparison data that the DL algorithm could better predict the water quality in the reservoir, and the experimental value and measured value of COD content in the water were relatively close, with the prediction error of less than 10%.

7. Conclusion

This paper first classified the types of reservoir PS. It analyzed the pollution contribution of living pollution, farmland runoff pollution, livestock and poultry breeding pollution, atmospheric dust pollution, rainfall pollution and other PS, and then used the feedforward three-layer neural network model in DL to predict water quality pollution. The pollution caused by population growth in the reservoir basin was predicted, and then the water area was divided into different small areas. The water environment capacity model was established. The experiment part studied the accuracy of reservoir pollution prediction, and the experiment showed that DL had higher water quality prediction effect. Water quality could be monitored in time by using DL to predict water quality. The water environment capacity model could calculate whether the current water quality exceeded the water environment pollution capacity, and could better monitor and control the reservoir pollution.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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