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Fusion Chaos Neural Network Algorithm to Control Water Pollution Prevention in Mine Reconstruction Projects

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Abstract: In recent years, the mining and utilization of large-scale mineral resources and the promotion of mine reconstruction projects have led to the increasingly serious problems of heavy metal pollution and water pollution (WP) in mine waters, which have posed potential threats to the health of the residents in and around the mines. Therefore, it is of vital importance to study the pollution characteristics of water bodies in mining areas to improve the water environment in mining areas. In this study, three mine alterations are used as the research objects to initially study the current WP status of surface water and groundwater in the watersheds near the mines, and to make a preliminary evaluation of the water environment quality using chaotic neural network algorithm (CNNA), so as to clarify the WP situation under the influence of mine alterations. This study has some application value for the practice of WP prevention and control engineering in mine reconstruction projects.

1. Introduction

Water is the source of life and the basis of the ecological environment, but the current environmental problems are becoming more and more serious, especially in the WP has gradually become one of the most worrying environmental problems in the world, the research work on the groundwater environment near the mines is also getting more and more attention, and the evaluation system and evaluation methods are becoming more and more perfect, so the research on water quality evaluation and WP prevention and control has also become the focus of global research.

Many scholars have studied and analyzed the current situation of WP in mine areas and the causes of pollution. Due to the large number of coal mines, the massive mining of coal mines as well as the long mining history has formed mine pit drainage, gangue piles and thus collapse ponds, resulting in varying degrees of soil and water pollution (including conventional components and heavy metal pollution), which can even affect the water environment and water ecology in mining areas, and it is very difficult to study the elimination of regional soil and water pollution [1]. Although some previous studies have been carried out, the mechanism of soil and water pollution under mining conditions and the mode of pollution are not yet clear, but there is an urgent need to study the mechanism of heavy metal pollution from coal mining and to assess, predict and analyse the pollution status in order to provide reference material for further studies on water pollution in mining areas later [2]. Numerous studies have been conducted by domestic scholars on the practical application of numerical simulations and the conversion of results to characterise the hydrogeological features of the study area. The development process of the seabed water flow system has been analysed through mining water flow system simulation to provide suitable conditions for seabed water resources assessment [3]. For example, some scholars have simulated groundWP in a basin through three-dimensional groundwater flow and contaminant transport in an open pit mine after mine closure shaft, found the contaminant transport pattern after coal mine closure and proposed corresponding preventive measures, and some people have conducted a study for the impact of coal mining on the complex structure area of groundwater system with numerical simulation and application [4-5]. At present, China has made remarkable achievements in the utilization and protection of water resources in mining areas, making outstanding contributions to the economy, society and human well-being.

This paper firstly introduces the concept of chaotic optimization algorithm and proposes a transient CNNA model, then uses this algorithm model to calculate the pollution indices of surface water and groundwater in the rainy and dry seasons during the reconstruction process of three mines A, B and C to evaluate their watershed pollution, and finally proposes several WP prevention techniques for water resources protection in mine areas.

2. Related Algorithms

2.1. Chaotic Optimization Algorithm

The characteristic of random variation of chaotic optimisation variables is the most unique feature of the algorithm, and this property may enable the algorithm to find the optimal solution faster than other optimisation algorithms. If the algorithm can randomly search for the global optimal solution in the first step of the calculation, it basically does not need to spend a lot of time to find the optimal solution, and the search time later will be reduced. However, due to the randomness of chaotic motion, when the chaotic variables are close to the global optimal solution, they are suddenly searched randomly, thus wasting a lot of search time [6-7]. It can be argued that randomness is the main property that drives the algorithm to jump out of the local optimum, but it also tends to make the search process unnecessarily time-consuming.

2.2. Transient Chaotic Neural Networks

Adding simulated annealing to the gradient descent solving process can effectively avoid the optimization process from falling into local minima to a certain extent; meanwhile, chaos enriches the dynamic performance of the network because it has the traversal property that helps the comprehensive search of the optimization process [8]. The combination of the two is added to Hopficld neural network to propose the Transicntly Chaotic Neural Network (TCNN) with chaos simulated annealing property. However, since the chaotic dynamics used in the transient chaotic neural network has a completely deterministic property, the network is not guaranteed to always find a globally optimal or near-optimal solution to the optimization problem [9]. The mathematical expression of the chaotic neural network model is given below.

$$d_{j,k}(t) = \frac{1}{1+\exp(-w_{j,k}(t)/\varepsilon)} \quad (1)$$

$$w_{j,k}(t+1) = \eta w_{j,k}(t) + \alpha\left(\sum_{\substack{m=1,n=1 \\ m\neq j,n\neq k}}^{J} g_{jk,mn} d_{m,m}(t) + I_{j,k}\right) - Z \quad (2)$$

$$Z = z_{j,k}(t)(d_{j,k}(t) - I_{j,k}) \quad (3)$$

In the above equation, $d_{j,k}(t)$ and $w_{j,k}(t)$ denote the output and input of neuron j, k at moment t, respectively; $g_{jk,mn}$ denotes the connection weights from neuron m, n to neuron j, k and $g_{jk,mn} = d_{m,n}$; $I_{j,k}$ denotes the input bias of neuron j, k; α is the coupling factor of neural network; ε denotes the steepness coefficient of Sigmoid function; η denotes the neural membrane damping factor; z(t) denotes the self-feedback connection weight.

3. Analysis of WP Status of Mine Reconstruction Project Based on CNNA

In this section, CNNA is used to evaluate the pollution status of surface water and groundwater in the nearby watershed caused by the process of mine reconstruction in A, B and C. The results are as follows.

3.1. Surface WP Evaluation Results

Table 1. Surface WP index in rainy season

	COD	TP	Cr	Cu	Zn	Cd	Comprehensive Index
A	1.45	1.16	0.06	0.32	0.04	0.07	1.04
B	1.27	0.33	0.89	0.81	0.11	0.05	1.53
C	1.62	0.85	0.27	0.13	0.09	0.03	1.12

As shown in Table 1 and Figure 1, during the rainy season, the pollution index of COD in the nearby watersheds of A, B and C mines exceeded 1, and its highest COD index was 1.62 in C mine. the pollution index of TP was 1.16, 0.33 and 0.85, respectively, and the watershed of A mine was most seriously polluted by TP. Zn and Cd in the water bodies were the least polluted. From the comprehensive index, among the three mines, the watershed of mine B is moderately polluted, and mines A and C are lightly polluted.

Figure 1. Pollution index values

Table 2. Surface water dry season pollution index

	COD	TP	Cr	Cu	Zn	Cd	Comprehensive Index
A	0.65	1.36	0.11	0.34	0.08	0.04	0.73
B	0.37	0.55	0.48	0.32	0.06	0.08	0.54
C	0.41	0.87	0.07	0.10	0.07	0.09	0.51

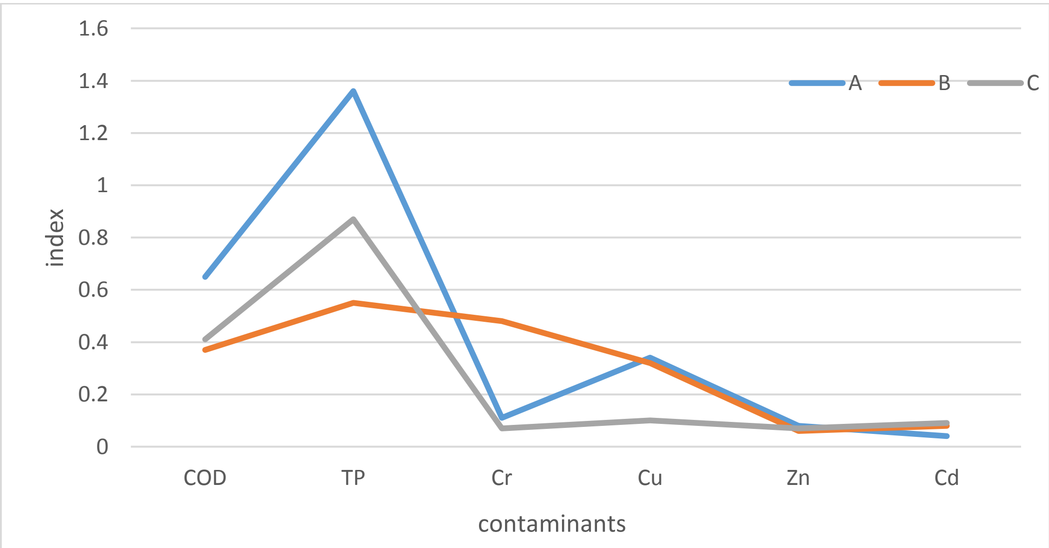

Figure 2. Surface WP

As shown in Table 2 and Figure 2, the COD index was relatively low during the dry season, but the TP index was higher than in the rainy season, but not much higher, and the heavy metal pollution indices of Cr, Cu, Zn, and Cd were all below 0.5. The combined pollution index also did not exceed 1, i.e., none of the three mining watersheds showed pollution.

3.2. Ground WP Evaluation

Table 3. Ground WP indices in the dry and rainy seasons

		TDS	NO_3	As	Hg	Comprehensive Index
A	Dry season	0.17	0.21	0.30	2.64	1.72
	Rainy season	0.36	1.43	0.26	5.23	2.35
B	Dry season	0.08	0.18	0.06	1.08	0.24
	Rainy season	0.14	3.45	0.23	1.12	0.68
C	Dry season	0.05	0.13	0.02	0.97	0.21
	Rainy season	0.09	3.32	0.07	0.85	0.54

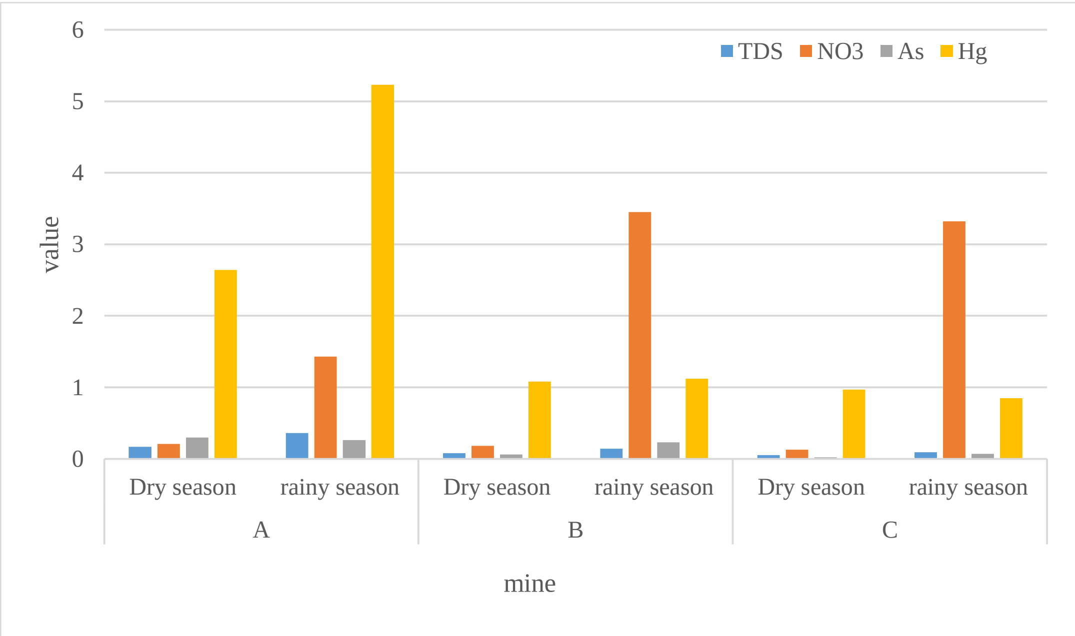

Figure 3. Comparison of pollution indices during the dry and wet seasons

From Table 3 and Figure 3 , it is known that the dissolved solids pollution index of groundwater in the nearby watersheds from the alteration of three major mining areas, A, B and C, did not exceed 1 in either the dry or rainy seasons, indicating that the dissolved solids meet the national groundwater standards and do not cause harm to humans. The As pollution index was low in all three regions. Relatively speaking, the pollution index of nitrate in the mining basin is high, in which the nitrate index of groundwater in B and C mining basin is 3.45 and 3.32 in the rainy season, but only 0.18 and 0.13 in the dry season, indicating that the nitrate pollution of groundwater in B and C mining basin is more serious in the rainy season. In addition, the Hg pollution index of groundwater in the watershed of mining area A is high and there is heavy pollution. In general, from the comprehensive pollution index, the groundwater in B and C mine basins is in light pollution, and the groundwater in A mine basin is in moderate pollution level.

4. Key Technologies for WP Prevention in Mine Reconstruction Projects

4.1. Source Reduction Control Technology of the Main Recharge Water Source in the Mining Area Based on Mine Water Infusion Recharge

The source of water recharge in the mining area comes from the infiltration recharge of the water layer in the upper watershed on the one hand, but mainly from the massive and rapid infiltration recharge of the underground dark river. Therefore, by filling and blocking the recharge sources and recharge channels of the ponded water in the mining area, in order to minimize the amount of water recharge in the mining area and achieve the purpose of source reduction control of recharge sources [10-11].

4.2. Key Spillover Channel Control Technology for Contaminated Water in the Extraction Area Based on Point Source Pollution Characteristics

Mine watershed pollution channel for the development of karst pipes in the top plate of the mining area fissures leading to the watershed aquifer, so that mine pollution water mixed into the river through the karst pipes. Therefore, the top plate tectonic fissure conduit at the end channel location of the mining area is grouted and sealed to control the contaminated water overflow from the mining area and realize the contaminant migration control [12].

4.3. End Pollution Channel Curtain Blocking Technology Based on Pipeline Flow Pollution Characteristics

The regional pollution near mine alteration has significant pipeline flow characteristics. By blocking the channel of polluted water into the karst pipeline through curtain blocking, the flow of pollution can be separated and the path of pollutants into the mine karst pipeline can be controlled [13].

4.4. Emergency Response Pumping Treatment Technology Based on "U-Tube Effect" Hydrodynamic Field Control

When encountering heavy rainfall, the underground dark river water pours into the mining area in large quantities and rapidly, causing the water level of the mine to rise and destroying the hydraulic relationship between the overlying aquifer and the mine water. By constructing drainage boreholes in the mining area and emergency pumping out treatment to control the mine water level rising too fast, keep the hydraulic relationship between the overlying aquifer and mine water basically unchanged, control the polluted water overflow, and realize the river water body not being polluted under extreme weather conditions [14-15].

4.5. Artificial Wetland Process

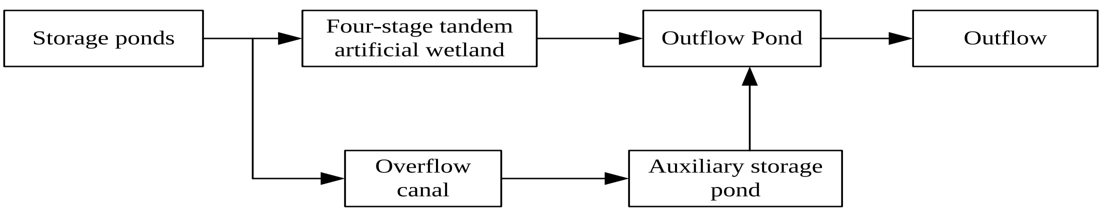

Figure 4. Process flow diagram

The artificial wetland process is used to degrade WP in the mine area, and the surface runoff collected from the mine area first enters the storage pond along the original river channel, and the volume of the storage pond is designed in accordance with the standard of three days inlet and three days discharge. At the inlet of the pond, a diversion wall is set up at the entrance to avoid the impact on the embankment when the water volume is large and to enable the sediment suspended in the water to be better deposited when passing through the pond [16]. After the preliminary sedimentation of the transfer pond, the volume and quality of the larger solids and suspended matter have been removed in large quantities of water in the transfer pond side of the role of the water distribution wall, the surface runoff to be treated evenly into the four-stage tandem artificial wetland treatment, and finally discharged into the downstream river through the outlet pond, each level of wetland between the secondary water distribution facilities, can significantly improve the hydraulic retention time and avoid the emergence of dead space, the maximum function the maximum function of the artificial wetland purification role. When the water volume exceeds the design standard of the artificial wetland, it will be discharged directly downstream through the overflow channel next to the water distribution wall to avoid scouring the wetland plants [17-18]. The detailed arrangement of the artificial wetland is shown in Figure 4.

4.6. Recycling of Groundwater

As the soil has the effect of self-purification, some inorganic substances in groundwater, organic substances can be absorbed and converted by the soil to improve groundwater quality so that it can meet some kind of use standard and thus be reused by human beings. Sometimes mine water can be used without purification treatment, and some contaminated water needs strict purification treatment before it can be used [19]. The wastewater discharged from mines should be treated to meet certain discharge standards and then reused.

5. Conclusion

With the acceleration of industrialization around the mine site and the increase of the population gathered in the mine area, as well as the improvement of people's living standard, the demand for water resources in the surrounding areas is increasing. In particular, heavy metal pollution in water bodies caused by mining is increasing, and the process of mine reconstruction has caused more serious groundWP in mining areas. In order to promote the sustainable use of groundwater resources in mines, it is necessary to protect the valuable groundwater resources before mine alteration. By studying the impact of mine alteration on the water environment of watersheds and analyzing various WP indices, it provides a convenient condition for assessing groundwater resources.

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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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