Application of Water Quality Index in the Evaluation of an Abandoned Mine Areas of Xunwu, China

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Abstract. Within the display think about, an surrendered ion-type rare soil mine contains a tremendous affect on the encompassing water environment contamination in Xunwu, Jiangxi Province, China. Since the usage of coordinates remediation innovation and extend in 2018, its natural quality has been enormously moved forward. In arrange to encourage assess the environmental remediation impact, a altered water quality index strategy (WQI) is proposed. Concurring to the grid method, 16 water quality examining focuses were set within the surrendered mine remediation extend, and 9 key assessment records such as NH\textsubscript{4}+-N and heavy metals were chosen for principal component analysis (PCA) and factor analysis (FA), in arrange to comprehensively assess the worldly and spatial changes of different contamination variables within the deserted mine environmental remediation range. The results uncovered that the water quality of the surface water has been slowly progressed, and the generally water quality has been getting superior, among which the water quality in August is clearly superior than that in July, and the progressed water quality index is successful for the classification of water quality and the assessment of the transient and spatial changes of water quality within the remediation of surrendered mines.

Keywords: water quality index, mine restoration, water quality assessment, principal component analysis and factor analysis

1. Introduction
The surrendered ionic uncommon soil mine caused avalanche, flotsam and jetsam stream, at the same time the lake wonder happens, water misfortune and soil disintegration and water contamination due to the long mining and expansive generation in mining region. soil disintegration scale, about 99% of the arrive within the neglected, genuine danger to the mining range close the masses of drinking water security and water system issues \cite{1}. So to fathom over issues, and in 2018 the execution of environment and biodiversity assurance, waterway bowl water environment security and redesign, mine natural reclamation, soil and water misfortune, arrive recovery and soil enhancement five ventures.

The natural quality of surrendered mines has been enormously progressed after the execution of coordinates remediation innovation and designing. Be that as it may, biological rebuilding of ionic mining ranges could be a long-term errand after all, so more successful logical strategies ought to be received to comprehensively evaluate the environmental quality of such mines, and after that viable
measures ought to be taken to screen and treat the remediation of uncommon soil mines [2].

By water quality observing and collecting a huge number of information containing natural, physical and chemical factors, preparing these factors and applying multivariate measurable strategies, such as central component investigation and figure examination, the potential key components can be impartially distinguished [3]. WQI may be a broadly utilized degree completely different parts of the world to illuminate issues of information administration and to assess the triumphs as well as disappointments of administration procedures for progressing water quality [4]. The WQI has been considered as one basis for surface water classifications based on the utilize of standard parameters for water characterization [5]. Hence, endeavors have been made to create a adjusted WQI to form it a more viable strategy [6]. For instance, the trapezoidal dim social degree strategy was utilized to make strides and assess the water quality of New Tong yang Canal. The results indicate that the water quality of New Tong yang Canal disintegrated with the increment of precipitation and progressed with the diminish of precipitation [7]. The water quality index (WQI) was utilized to assess the regular and spatial changes of water quality amid the observing period of south-to-North water redirection venture. The results appeared that the water quality condition remined steady at the "excellent" level [8]. At show, small is known approximately the biological rebuilding impacts of the surrendered ion-type uncommon soil mine in Xunwu. To this conclusion, testing overviews were conducted within the three administration offers for the reclamation of the deserted ion-type uncommon soil mine, and the factors related to the water environment quality were decided through multivariate factual investigation of the water quality observing database [9]. And utilize the progressed water quality index strategy to comprehensively assess and analyze the worldly and spatial alter characteristics of the water environment quality of each offered segment after the rebuilding of the ion-type surrendered mine.

2. Materials and Methods

2.1. Overview of the Study Area
Located at the southeastern conclusion of Jiangxi Province (24°30’40” N, 115°21’22” E), Xunwu District is one of the most creating districts of ionized uncommon earths. There are numerous streams within the domain, counting the Dongjiang river system which streams into the Pearl River Basin, xiangshui Stream framework which streams into the Ganjiang Stream bowl and Hanjiang Stream Framework which streams into the Hanjiang Waterway Bowl. Hilly region less, warm and muggy climate, rich arrive, wealthy water asset, for the birthplace of the Dongjiang. Xunwu Province could be a subtropical rainstorm climate, the yearly average temperature is 18.9°C, the yearly normal precipitation is 1650.3 mm. Among the 8 rare earth producing counties (cities) in southern Jiangxi, Xunwu County was the first county (city) to start rare earth mining in 1976, wealthy mineral assets, has found minerals incorporate: tungsten, tin, copper, molybdenum, lead, zinc, rare earth, niobium tantalum, iron, cobalt, gold, granite stone, phosphorus, crystal, gypsum, clay, mineral water, uranium and other more than 30 sorts, counting the advantage of China uncommon soil minerals. Wenfeng Township is found within the suburb of Xunwu District, Ganzhou City, Jiangxi Territory, approximately 8.5km south of Xunwu District to the north. This paper is found in Keshutang, south of Shangjia Town, Wenfeng Township, and west of Qinglong River. It is found within the surrendered mine of Keshutang, Wenfeng Township, with a treatment range of 0.146km2, and the particular area is appeared in figure 1.

2.2. Water Quality parameters and Chemical Examination
Collect, transport and analyze water tests concurring to SL187-96, specialized Controls for Water Test Testing. The surface water (0 ~ 20 cm) was collected with a water collector, collected in polyethylene plastic bottles, and put away at 4 °C. In this paper, all the water tests were analyzed concurring to the Surface Water Natural Quality Standard GB-2002 and the conventional water quality checking report. The water temperature and PH esteem were measured on location by PH METER AS-PH8, and alkali
nitrogen was measured by the Nasser reagent Colorimetric strategy GB 7479 – 1987. COD and heavy metals Mn, Pb, AL, Mg, Co, Cu, Sn, Sb, TL, Sh, Li, Cd, and Cr were analyzed. The reagents utilized were all immaculate chemical reagents of national standard investigation.

2.3. Determination and Arrangement of Factors

The water environment system could be a complex framework with numerous water quality affecting variables acting together [10]. The coordinate assessment of water quality will result in certain deviation of the assessment comes about. Appropriate determination of factors can move forward the exactness of water natural quality assessment results [11]. Therefore, through the foremost component figure examination strategy to decide the water quality in fundamental ingredients of commitment, to select driving calculate, to assess water quality with the strategy of central component calculate examination, and utilizing the spearman rank relationship coefficient strategy to analyze all factors, the direct relationship coefficient (r≥0.9) said related or totally. The chosen factors are normalized through z-scale changes to maintain a strategic distance from investigation mistakes from values and dimensional contrasts [12-13]. All scientific and factual calculations were performed utilizing Microsoft Exceed expectations 2010 program and SPSS 23.0 computer program.

2.4. Revised WQI Index

2.4.1. Classification Criteria. In this consider, for each variable is put forward from I to V five classification benchmarks as appeared in table 1. These guidelines are based on the Natural Guidelines for Surface Water (GB3838-2002), Comprehensive Gushing Release Benchmarks (GB8978-1996) and the information set of ceaseless information observing in this consider.
Table 1. Limits of environmental quality guidelines for surface water.

| Grade limits of environmental quality guidelines for surface water |
|---------------------------------------------------------------|
| Standard value \ Classification | I    | II    | III   | IV    | V    |
| PH                           | 6-9  | 6-9  | 6-9   | 6-9   | 6-9  |
| T(°C)                        | 22   | 18or26 | 14or30 | 10or30 | 6or30 |
| COD(mg/L)                     | 15   | 15   | 20    | 30    | 40   |
| NH4⁺-N (mg/L)                 | 0.15 | 0.50 | 0.1   | 1     | 1    |
| Mn(mg/L)                      | 0.05 | 0.05 | 0.1   | 0.05  | 0.1  |
| Pb(mg/L)                      | 0.01 | 0.01 | 0.05  | 0.05  | 0.1  |
| Al(mg/L)                      | 0.2  | /    | /     | 3.0   | /    |
| Cu(mg/L)                      | 0.01 | 1    | 1     | 1     | 1    |
| Sb(mg/L)                      | 0.05 | 0.05 | 0.05  | 0.1   | 0.1  |
| Cd(mg/L)                      | 0.001| 0.005| 0.005 | 0.005 | 0.01 |
| Cr(mg/L)                      | 0.01 | 0.05 | 0.05  | 0.05  | 0.1  |

2.4.2. Principal Component Analysis and Factor Analysis. Numerous factors are changed over into some autonomous comprehensive variable sets through vital component analysis, known as PCs [14]. Each central component could be a direct combination of the first variable and cannot reflect the quality of the relationship between the variable and its characteristics. The unused variable gotten by pivoting the greatest fluctuation strategy utilizing figure examination strategy is called the driving calculate (LFs) [15]. Observable factors incorporate undetectable factors and idle factors (common characteristics of perceptible factors), taken after by direct combinations. The condition can be communicated as:

\[ y = a_1x_1 + a_2x_2 + \cdots + a_ix_i \]  
\[ LF_k = \sum_{k=1}^{n} y_k \]

Where \( y \) is the measured esteem of LF, \( A \) is the calculate stack, \( X \) is the standardized concentration factor, \( I \) is the overall number of factors, and \( LF_k \) is the esteem of PC, \( y_k \) is the measured esteem of LF, and \( k \) is the number of LFs.

2.4.3. Calculation of the Revised Water Quality Index. After calculating the variables, the adjusted WQI is gotten by increasing the weight of the variogram (rate of fluctuation) and their values, and after that including them up. The calculation equation is as takes after:

\[ WQI = \sum_{k=1}^{n}(W_kLF_k) \]

Where, WQI is the comprehensive water quality score, and \( W_k \) is the weight (% of variance) of the LF.

The reexamined water quality list values are calculated utilizing the flat limits of the water quality factors chosen within the condition (as appeared in table 2). Based on the over condition, the changed water quality file isolates water quality into five grades, to be specific extraordinary (\( \leq 0.5 \)), destitute (0.5-0.75), medium (0.75-0.95), exceptionally great (0.95-1.75) and fabulous (>1.75), as appeared in table 2. The bigger the number of WQI, the superior the water quality.
Table 2. WQI Water Quality assessment grades after modification.

| WQI             | The water quality situation | Water quality assessment grade |
|-----------------|----------------------------|--------------------------------|
| WQI > 1.75      | good                       | I                              |
| 0.95 < WQI ≤ 1.75 | Very good                  | II                             |
| 0.75 < WQI ≤ 0.95 | medium                     | III                            |
| 0.5 < WQI ≤ 0.75 | poor                       | IV                             |
| WQI ≤ 0.5       | poor                       | V                              |

3. Results and Discussion

3.1. Describe Statistics and Choice
A expressive measurable examination of water quality factors was performed on 288 add up to watched values (16 sectional focuses, 9 water quality pointers and 2 testing times), summarized as appeared in table 3, which gi

In this study, relationship examination was utilized to dispense with unessential factors to move forward the exactness of examination. The results appear the relationship as appeared in table 4. The results appeared no critical relationship between PH and other factors. Be that as it may, PH values surpassed the ordinary run, whereas Cu, Sn, Sb, TL, Sb, Li and Cr did not surpass the typical extend. Hence, COD, Cu, Sn, Sb, TL, Sb, Li and Cr are not considered as water quality restricting factors [17]. The over pointers are avoided within the ensuing investigation, but PH esteem ought to be considered as a variable influencing water quality. All the relationship coefficients were inspected for four multi collinearity. In this think about, it was found that the relationship between AL and Mg, Mg and Co was more than 0.9. Among these nine factors, alkali nitrogen, temperature, PH and overwhelming metal Mn, Pb, AL, Mg and Co were chosen as the examination pointers.
Table 4. Use spearman rank correlation coefficient as the correlation between variables in the non-parametric test.

|         | PH   | T(℃)   | NH₄⁺-N (mg/L) | COD (mg/L) | Mn (mg/L) | Pb (mg/L) | Al (mg/L) | Mg (mg/L) | Co (mg/L) |
|---------|------|--------|----------------|-------------|-----------|-----------|-----------|-----------|-----------|
| PH      | 1.000|        |                |             |           |           |           |           |           |
| T(℃)   | 0.689| 1.000  |                |             |           |           |           |           |           |
| NH₄⁺-N | 0.451| 0.296  | 1.000          |             |           |           |           |           |           |
| COD (mg/L) | 0.055 | 0.084 | 0.903 | 1.000 |
| Mn (mg/L) | 0.900 | 0.600 | 0.794 | 0.479 | 1.000 |
| Pb (mg/L) | 0.603 | 0.071 | 0.288 | 0.506 | 0.276 | 1.000 |
| Al (mg/L) | 0.837 | 0.760 | 0.054 | 0.455 | 0.536 | 0.695 | 1.000 |
| Mg (mg/L) | 0.900 | 0.614 | 0.026 | 0.358 | 0.623 | 0.824 | 0.963 | 1.000 |
| Co (mg/L) | 0.805 | 0.276 | 0.025 | 0.318 | 0.540 | 0.956 | 0.796 | 0.924 | 1.000 |

3.2. Multivariate Statistical Analysis of Water Quality

Foremost component examination may be a multivariate factual strategy to ponder the relationship between different factors (values) [18]. This strategy is based on the ordinary conveyance of the first data, and on the prefecture of guaranteeing the least misfortune of the initial data, the dimensionality decrease scientific strategy is used to turn the related factors into a number of autonomous comprehensive factors (foremost components), so as to attain the impact of highlight extraction. In this ponder, standardized water quality data were analyzed by central component analysis. Secondly, in arrange to decide the characteristics of water quality, the turn figure of the greatest fluctuation is taken as the eigenvalue within the calculate examination strategy, and the most impacting variables of water quality are decided [19-20]. The results appear that diverse coefficient sets of variety are gotten for each inspecting zone, as appeared in table 5.

Table 5. Load of water quality variables in three blocks of the abandoned mining area.

| Variable | LF1   | LF2   | LF3   |
|----------|-------|-------|-------|
| The first bid |       |       |       |
| PH       | 0.957 | 0.286 | 0.028 |
| T (℃)    | 0.661 | 0.267 | 0.701 |
| NH₄⁺-N (mg/L) | 0.175 | 0.978 | 0.116 |
| COD (mg/L) | 0.224 | 0.933 | 0.265 |
| Mn (mg/L) | 0.735 | 0.670 | 0.091 |
| Pb (mg/L) | 0.762 | 0.482 | 0.433 |
| Al (mg/L) | 0.943 | 0.192 | 0.267 |
| Mg (mg/L) | 0.988 | 0.150 | 0.001 |
| Co (mg/L) | 0.900 | 0.230 | 0.369 |
| Total | 5.228 | 2.774 | 0.978 |
| % of variance | 58.092 | 30.817 | 10.870 |
| Cumulative % variance | 58.092 | 88.908 | 99.778 |
| The second bid |       |       |       |
| PH       | 0.869 | 0.492 | 0.049 |
The results of principal component analysis showed that the main variable groups in the three sampling areas were heavy metals and NH$_4$-$\text{N}$, and NH$_4$-$\text{N}$ was the main pollutant. In this study, natural temperature and PH were also distinguished as the main contributors to water quality. They straightforwardly or indirectly influence the water environment and therefore natural conditions are also part of the assessment of water quality and environmental quality in the mine wastewater remediation area.

The results appear that LF1 accounts for 58.092% of the full fluctuation for the data set of a square locale, and contains a strong positive stack on Mg and Al. LF2 accounts for 30.817% of the entire change and contains a solid positive stack on NH$_4$-$\text{N}$ and COD. LF3 accounts for 10.87% of the entire fluctuation and had a solid positive stack on Pb. The major poisons for the primary stage are Mg and Al, taken after by NH$_4$-$\text{N}$, LF1 accounts for 65.798% of the overall change of the information set within the second bid, and contains a solid positive stack on NH$_4$-$\text{N}$ and Pb. LF2 accounts for 32.158% of the whole fluctuation, includes a solid positive stack on temperature and COD, LF3 accounts for 2.044% of the whole change, and contains a solid positive stack on temperature and Co. The major poisons for the primary stage are Mg and Al. LF1 accounts for 71.203% of the whole change and encompasses a solid positive stack on temperature and COD, LF2 accounts for 12.72% of the entire change, includes a solid positive stack on Mg and Pb. LF3 accounts for 10.764% of the entire change, and incorporates a strong positive stack for temperature and Co. Section III and Area I are comparative in that the most poisons are overwhelming metals, taken after by NH$_4$-$\text{N}$.

The results of vital component investigation appeared that the most variable bunches within the three examining ranges were heavy metals and NH$_4$-$\text{N}$, and NH$_4$-$\text{N}$ was the main pollutant. In this ponder, normal temperature and PH were too recognized as the most donors to water quality. They straightforwardly or by implication influence the water environment and so common conditions are
too portion of the evaluation of water quality and natural quality within the mine wastewater remediation region.

3.3. Modification of WQI Index
The WQI examination in this consider was based on other distributed WQI thinks about [21-23]. We adjusted WQI in three ways: (1) diminished the factors from 9 to 8; (2) Decided the weight of each figure concurring to the characteristics of nearby water quality contamination; (3) Gotten the WQI esteem with a bigger extend through z-score change (not constrained to $< WQI < 1$). In expansion, through the advance investigation of the information itself, the weight of the driving figure was decided [24-25]. At that point all coefficients of variety are summarized to assess water quality more naturally. Figure 2 appears the WQI esteem of each point of the three areas, in which the water quality of the ionized surrendered mine has self-evident worldly and spatial contrasts. But for the third segment, the water quality file of the other two segments changes from "destitute" to "medium", and the water quality record in Admirable comes to the level of "exceptionally great". At distinctive testing time focuses, water quality in parts 1, 2 and 3 was for the most part more regrettable in July and superior in Admirable (show in figure 2A). The negative water quality information of area 3 may be related to the area of the center of the mine and the moo territory. This can be because (1) the third area is found within the center of the ionized surrendered mine; (2) The third segment is the region with the biggest treatment range within the ion-type surrendered mine; (3) The third area is the zone with less wetland region within the ion-type surrendered mine. In expansion, sharp changes in water quality were watched in segment 3, showing that WQI can completely reflect spatial-temporal changes in water quality in numerous inspecting zones and times [26].

![Figure 2. WQI values of the testing destinations.](image)

4. Summarize
In this ponder, a add up to of 9 factors with critical relationship were chosen for foremost component examination. Distinguish potential variables for 58-72% of the overall fluctuation of each fragment. The most components influencing the water quality of the surrendered mine are overwhelming metals manganese lead and smelling salts nitrogen. The worldly and spatial variety of water quality in surrendered mines was assessed by utilizing the made strides WQI investigation strategy. These comes about give reference for understanding the complex changes of water quality in surrendered mines and are supportive for mine rebuilding and administration.

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