Response to Referee #2's comments on the manuscript (HESS-2024-387) **"Mapping mining-affected water pollution in China: Status, patterns, risks, and implications"** by Ziyue Yin, Jian Song, Dianguang Liu, Jianfeng Wu*, Yun Yang, Yuanyuan Sun, and Jichun Wu

Note that the following text in Arial Narrow font denotes Referee's comments and in Times New Roman font denotes our response to the comments in the review.

The manuscript aims to provide a comprehensive assessment of mining-affected water pollution across China by compiling a large dataset (8433 water samples from 298 mines). The study evaluates spatial patterns, assesses both carcinogenic and non-carcinogenic risks to human health, and discusses management implications for both coal and metal mining areas. While the work is well supported by extensive data and robust methodologies, questions remain regarding the novelty of the contribution, as the manuscript does not clearly delineate how its findings significantly extend beyond previous studies.

[Response] We sincerely thank you for your constructive and conscientious suggestions. Hereby we have fully incorporated and addressed all the comments in the revised manuscript and given a point-by-point response as below. In particular, a more explicit statement of our novel contributions relative to the existing literature (*e.g.*, Cheng, 2003; He et al., 2013; Hu et al., 2013; Feng et al., 2014; Sun et al., 2025) has been added to the **Conclusion** to address your concern that "the manuscript does not clearly delineate how its findings significantly extend beyond previous studies".

"It is noteworthy that previous studies predominantly concentrated on localized water pollution from individual coal or metal mines, while national-scale assessments have primarily addressed impacts exclusively attributed to coal mining activities. The new and unique contributions of the current study are: (i) establishing a national-scale high-quality database covering 8,433 surface water or groundwater samples (6,175 coal mine water samples and 2,258 metal mine water samples) from 298 mines (211 coal mines and 87 metal mines) in 26 provinces/autonomous regions of China; and (ii) filling the gap of the nationwide spatial patterns of water pollution and associated health risks from both coal and metal mining activities for the first attempt. Specifically, eight heavy metals (*i.e.*, Cr, Ni, Cu, Zn, As, Cd, Hg, and Pb) are considered in the current study based on a national-scale high-quality hydrochemical database. The new results show that Zn, Ni, and Cu are the predominant contaminations contaminants of both coal and metal mines in China. The detectable concentrations of several heavy metals are higher in most metal mines than in coal mines, especially in mining-affected water with low pH (< 6.5). The order of detectable median values of water affected by coal mining is Zn (0.4211) > Ni (0.1796) > Cu (0.0431) > Cr (0.0080) > Cd (0.0036) > As (0.0034) > Pb (0.0023) > Hg (0.0004), while that of water affected by metal mining is Zn (7.200) > Cu (1.7325) > Ni (0.2142) > Pb (0.1498) > Cr (0.0500) > Cd (0.0383) > As (0.0281) > Hg (0.0090). In terms of spatial patterns, the pollution hotspots and potential risks of mining-affected water (with low pH, high sulfate, Fe, Mn, and heavy metals) are pronounced in the southern regions, especially in Guizhou, Guangdong, Fujian, Jiangxi, Hunan, and Guangxi provinces/autonomous regions. These phenomena are closely linked to the underlying mechanisms, such as climatic conditions, geological factors, and mining practices. Accordingly, the findings of the study yield critical insights for designing differentiated management measures and formulating spatially-adaptive pollution control strategies across three key dimensions, including geographic scales (site-specific scale, provincial scale, or national scale), mine types (coal or metal), and mining status (active or abandoned). This multidimensional framework enables policymakers to strategically balance the trade-off between green mining activities and human health priorities."

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Sun, Y.J., Guo, J., Xu, Z.M., Zhang, L., Chen, G., Xiong, X.F., Hua, J.F., Mu, L.J., and Wu, W.X.: Spatial distribution characteristics of mine water quality in coal mining areas of China and technological approaches for mine water treatment. J. China Coal Soc., 50(1), 584-599 (in Chinese with English abstract), https://doi.org/10.13225/j.cnki.jccs.YG24.1547, 2025.

Novelty and Original Contribution

Strengths: The study assembles a large national dataset and applies risk assessment models to evaluate health impacts, which is commendable. The spatial mapping of contamination hotspots and risk distribution provides valuable insights for policy-making.

[Response] No change needed. Thank you for your positive comments.

Concerns: One key issue is that the manuscript does not sufficiently highlight what is new compared to earlier studies. Although the scale of the data collection is impressive, the paper lacks a clear statement of its novel contributions relative to existing literature. The authors could enhance the manuscript by emphasizing unique aspects—such as new methodological approaches, previously unreported spatial trends, or innovative risk assessment strategies—that set this work apart.

[Response] The point is well taken. We have incorporated your concerns into the revision and a more explicit statement has been added to the revised **Conclusion**, highlighting the novelty and practical implications of our manuscript relative to the existing literature. See also the response to your general comment above.

Methodological Rigor and Data Quality

Strengths: The methodology is generally robust, with clear criteria for data quality control and appropriate use of standard risk assessment models (e.g., those provided by the US EPA). The division of water samples (acidic vs. neutral/alkaline) and the differentiation between coal and metal mines are well executed.

[Response] No change needed. Thank you for your positive comments.

Suggestions: To further strengthen the paper, the authors should elaborate on how potential biases (e.g., variations in sample density among regions) were addressed. Additionally, more detailed statistical tests comparing water quality parameters between different mining types (such as using non-parametric tests) could provide further evidence for the observed differences.

[Response] Comment accepted. Indeed, there are potential biases caused by variations in sample density among regions. Therefore, our future in-depth research will attempt to address the biases by (i) combining the data mining and field sampling methods to investigate the potential contamination levels in more coal and metal mines across China; (ii) balancing the sampling density within each zone using bias correction techniques (*e.g.*, kernel density estimation and stratified spatial resampling) to ensure the data representation; and (iii) incorporating spatial uncertainty into the criteria to improve the spatial robustness for the assessments of mining-affected water pollution. Furthermore, we have added the results of non-parametric tests (*i.e.*, Mann-Whitney U-test and Spearman's rank correlation) to further support the differences observed in our study based on your suggestions:

"Non-parametric tests do not rely on assumptions about the distribution of the data and are suitable for non-normally distributed datasets or those containing outliers (Cardew, 2003). These methods statistically compare central tendencies, typically represented by medians, rather than means. The result of the Mann-Whitney U-test ($p < 0.05$) shows a statistically significant difference in the critical parameters (except Fe) of mining-affected water based on the different mine types (coal mine vs. metal mine), indicating the differences caused by geological factors, mining practices, surrounding environment, etc. Besides, Fig. S7 shows the Spearman correlation coefficients between the hydrochemical compositions in the mining-affected water. It can be seen that strong negative correlations are observed between pH and SO_4^{2-}, Fe, Mn, Al, and heavy metals while positive correlations are observed between SO_4^{2-} and metal components, implying that the spatial consistency of acid water, high sulfate, high Fe and Mn, and high heavy metal mining-affected water."

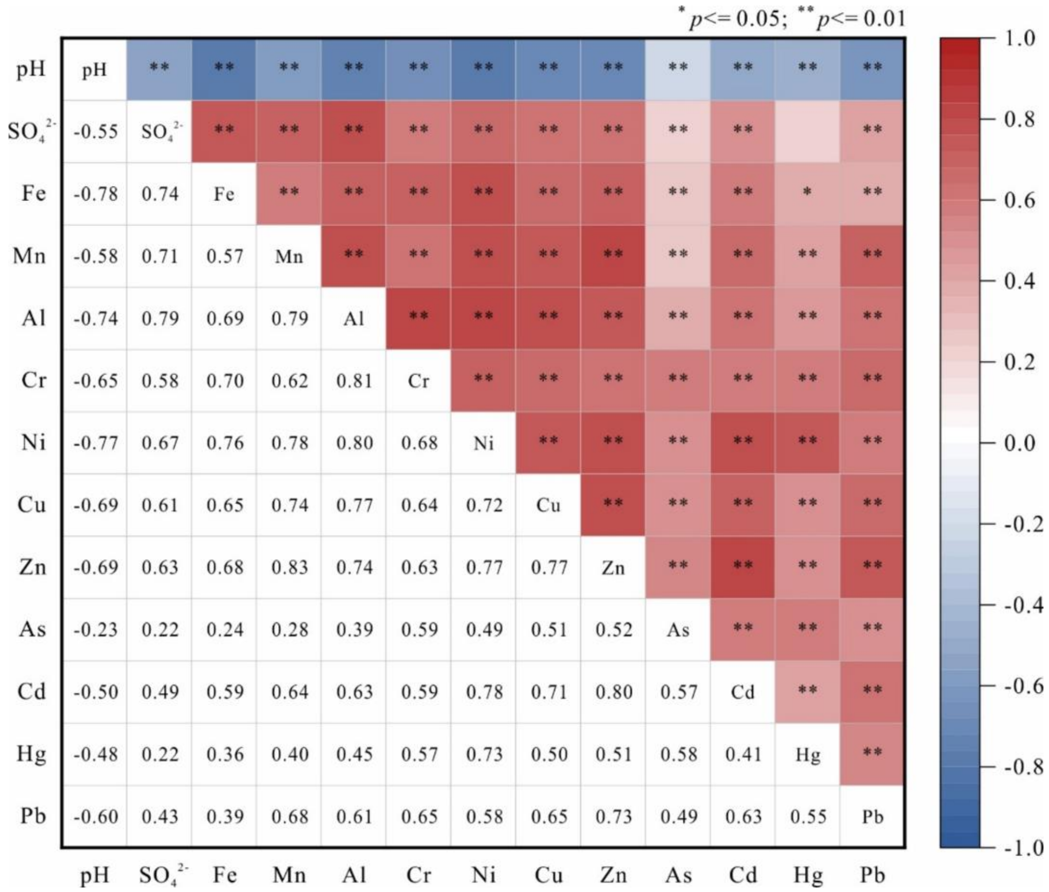

Figure S7. The Spearman correlation coefficient between the hydrochemical compositions in the mining-affected water.

Cited Reference:

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Presentation and Interpretation of Results

Strengths: The results are logically presented, starting from the basic water quality parameters, moving on to spatial distribution patterns, and culminating in detailed risk assessments for different populations. Figures (e.g., maps and boxplots) support the textual description and help visualize the trends effectively.

[Response] No change needed. Thank you for your positive comments.

Suggestions: Although the numerical details are extensive, the manuscript may benefit from a more concise presentation. For example, summarizing key quantitative findings in a table could improve clarity. Additionally, while the spatial patterns are well described, a deeper discussion on the underlying geochemical or environmental processes that cause these trends would better contextualize the results.

[Response] Thank you for your insightful comments. To improve the clarity of the manuscript, key quantitative results (*e.g.*, statistics of critical parameters for acid and neutral/alkaline water across different mines) have been summarized in Table 1 in the revised manuscript and Table S4 in the **Supplement**. Moreover, a further elaboration of the underlying mechanisms (*e.g.*, geochemical conditions and environmental processes) driving the spatial patterns of mining-affected water pollution in China, especially in the highly polluted southern regions, has been added in Section 4.1 of the revised manuscript:

"The underlying mechanisms, including climatic conditions, geological factors, and mining practices, determine the spatial patterns of mining-affected water pollution in China, especially in the highly polluted southern regions. In terms of climatic conditions, the average temperature of the coldest month is > 0°C, while that of the hottest month is > 22°C, and the annual average precipitation is generally > 1,000 mm in South China. The high temperature and precipitation create a synergistic accelerator for mine water acidification. Elevated temperatures stimulate acidophilic microbial communities (*e.g.*, *Acidithiobacillus ferrooxidans*), which enhance enzymatic activity that catalyzes sulfide mineral oxidation. Combined with high levels of precipitation, rainfall infiltrates abandoned mines, tailings ponds, and exposed ore bodies, creating a sustained water-oxygen exchange that drives sulfuric acid formation and iron oxidation processes."

"In terms of geological factors, the unique geo-environmental settings of South China, characterized by rugged topography, widespread sulfur-rich strata, and high background value of metallic minerals, result in mining-affected water with high acidity and elevated concentrations of sulfate, Fe, Mn, and HMs (Sun et al., 2022). The coal-forming periods of different mines in the South China coalfields are diverse, mainly Triassic, Neoproterozoic, etc., of which the sulfur enrichment exhibits strong links to marine-land interactions. The sustained seawater intrusion-regression cycle results in elevated sulfur contents (predominantly medium and high-sulfur coals) (Ai et al., 2023; Sun et al., 2025). As illustrated in Fig. S2, the coal fields in China exhibit sulfur contents ranging from 0.02% to 10.48%, with South China's coal-bearing areas showing the highest weighted average sulfur content (2.35%), including 29.63% of high-sulfur coal. Comparatively, those weighted average sulfur contents of coal-bearing areas in Tibet-Western Yunnan, North China, and Northeast China are 0.94%, 0.88%, and 0.86%, respectively (Tang et al., 2015). In addition, as shown in Fig. S3, the metal mineral resources are abundant in the southern region of China, and the water affected by mining practices is often highly toxic, with harmful HMs such as Cd, Pb, Hg, Cr, As, Cu, and so on, endangering the surface water and groundwater systems (Sun et al., 2022)."

"As to mining practices, especially those involving sulfide-bearing metalliferous ore deposits and sulfide-rich coal mining, are intrinsically associated with AMD. Acid drainage can occur wherever sulfide minerals are excavated and exposed to atmospheric oxygen. The main sulfide minerals in mine wastes are pyrite (FeS_2) and pyrrhotite ($Fe_{1-x}S$), while other associated sulfides are prone to oxidation and release toxic elements, including Al, As, Cd, Co, Cu, Hg, Ni, Pb and Zn, into the water flowing through the mine tailings (Blowes et al., 2014). The oxidation of FeS_2 by atmospheric oxygen can be expressed by Eqs. (1) - (4). Moreover, underground mining is the primary exploitation method in China. Substantial mined-out areas are formed after mining activities, inducing the accumulation of groundwater and the formation of acid mine water. In recent years, the phenomenon has intensified because a number of mines are abandoned without proper closure measures (Jiang et al., 2020)."

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+ \quad (1)$$

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O \quad (2)$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ \quad (3)$$

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad (4)$$

Table 1. The statistics of mining-affected water in China (Units are mg/L except pH).

Item	Acid mining-affected water				Non-acid mining-affected water			
	Min	Median	Ave	Max	Min	Median	Ave	Max
pH	1.20	3.52	4.04	6.50	6.51	7.80	7.85	12.60
Na^{+}	0.00	15.60	55.39	1613.00	0.23	156.01	403.20	9371.00
K^{+}	0.00	3.30	6.41	172.00	0.00	3.11	7.10	419.00
Ca^{2+}	0.83	284.80	284.33	987.97	0.00	64.10	119.76	4841.70
Mg^{2+}	0.01	75.33	388.36	10992.00	0.00	19.01	52.85	12752.00
Cl^{-}	0.00	3. 50	35.50	3097.40	0.00	51.68	314.21	26265.00
SO_4^{2-}	0.56	1580.16	4648.54	181000.00	0.01	181.27	621.24	52915.00
HCO_3^{-}	0.00	1.89	48.65	769.00	0.00	253.23	343.13	4976.61
NO_3^{-}	0.00	0.80	16.46	735.60	0.00	3.78	16.02	1774.95
F^{-}	0.00	0.69	4.17	238.34	0.00	0.81	1.91	100.00
Fe	0.0020	103.3000	520.4396	65250.0000	0.0000	0.1700	3.9788	495.4300
Mn	0.0050	8.1080	71.1849	5050.0000	0.0000	0.2164	1258.9853	200000.0000
Al	0.0077	53.9000	304.9210	13679.0000	0.0001	0.0350	0.5306	25.0000
Cr	0.0000	0.0200	0.7725	52.2700	0.0001	0.0031	0.0081	0.3100
Ni	0.0001	0.2166	1.6396	216.0000	0.0001	0.0050	0.0159	0.2260
Cu	0.0002	0.8010	85.6400	9777.7700	0.0001	0.0100	0.0678	2.5600
Zn	0.0026	2.3685	46.6335	1834.0000	0.0007	0.0391	0.5292	39.3000
As	0.0000	0.0108	6.4969	641.7000	0.0001	0.0034	0.1362	13.0000
Cd	0.0000	0.0220	0.6552	110.0000	0.0000	0.0004	0.0108	0.6677
Hg	0.0000	0.0038	0.6997	13.3600	0.0000	0.0003	0.0196	0.7833
Pb	0.0000	0.0700	0.5090	35.6800	0.0000	0.0012	0.0307	1.2200

Table S4. The statistics of mining-affected water in China (Units are mg/L except pH).

Item	Acid mining-affected water						Non-acid mining-affected water					
	Coal mine			Metal mine			Coal mine			Metal mine		
	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
pH	1.90	4.50	6.50	1.20	3.10	6.50	6.51	7.82	11.51	6.51	7.70	12.60
Na^+	0.02	18.55	1305.33	0.00	13.72	1613.00	0.23	234.75	7594.32	0.55	27.30	9371.00
K^+	0.04	3.50	37.00	0.00	2.99	172.00	0.00	2.84	164.42	0.20	3.80	419.00
Ca^{2+}	0.83	277.84	987.97	1.70	310.00	893.00	0.00	61.38	689.10	0.01	80.20	4841.70
Mg^{2+}	0.01	59.60	1665.00	0.10	89.52	10992.00	0.00	19.09	485.44	0.10	18.54	12752.00
Cl^-	0.06	2.51	477.24	0.00	9.20	3097.40	0.00	65.20	6462.75	0.35	19.00	26265.00
SO_4^{2-}	15.00	1381.59	17870.00	0.56	2982.00	181000.00	0.01	193.51	10110.00	0.09	157.41	52915.00
HCO_3^-	0.00	0.00	532.96	0.00	15.51	769.00	0.00	280.60	4976.61	0.62	169.50	2482.00
NO_3^-	0.00	0.55	143.65	0.00	1.45	735.60	0.00	3.00	356.97	0.00	11.00	1774.95
F^-	0.00	0.67	238.34	0.01	0.80	67.40	0.00	0.91	11.65	0.01	0.72	100.00

Item	Acid mining-affected water						Non-acid mining-affected water					
	Coal mine			Metal mine			Coal mine			Metal mine		
	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median	Max
Fe	0.0000	77.4100	2331.8560	0.0000	113.7700	65250.0000	0.0000	0.2500	205.0000	0.0000	0.0320	495.4300
Mn	0.0000	3.5000	88.4000	0.0000	15.8200	5050.0000	0.0000	0.0204	5.0200	0.0000	0.7612	200000.0000
Al	0.0000	12.8700	440.0000	0.0000	152.0000	13679.0000	0.0000	0.0200	25.0000	0.0000	0.0500	2.0900
Cr	0.0000	0.0080	0.1900	0.0000	0.0500	52.2700	0.0000	0.0022	0.3100	0.0000	0.0041	0.0909
Ni	0.0007	0.1796	2.7290	0.0000	0.2142	216.0000	0.0001	0.0040	0.2260	0.0000	0.0059	0.1200
Cu	0.0000	0.0431	18.5000	0.0000	1.7325	9777.7700	0.0001	0.0010	2.5600	0.0000	0.0180	1.1390
Zn	0.0026	0.4211	23.0000	0.0000	7.2000	1834.0000	0.0000	0.0048	0.9840	0.0000	0.0617	39.3000
As	0.0000	0.0034	2.1590	0.0000	0.0281	641.7000	0.0001	0.0016	0.3660	0.0001	0.0040	13.0000
Cd	0.0000	0.0036	0.1945	0.0000	0.0383	110.0000	0.0000	0.0000	0.0253	0.0000	0.0010	0.6677
Hg	0.0000	0.0004	0.0051	0.0000	0.0090	13.3600	0.0000	0.0001	0.7833	0.0000	0.0003	0.0050
Pb	0.0000	0.0023	7.4300	0.0000	0.1498	35.6800	0.0000	0.0003	1.2200	0.0000	0.0064	0.9400

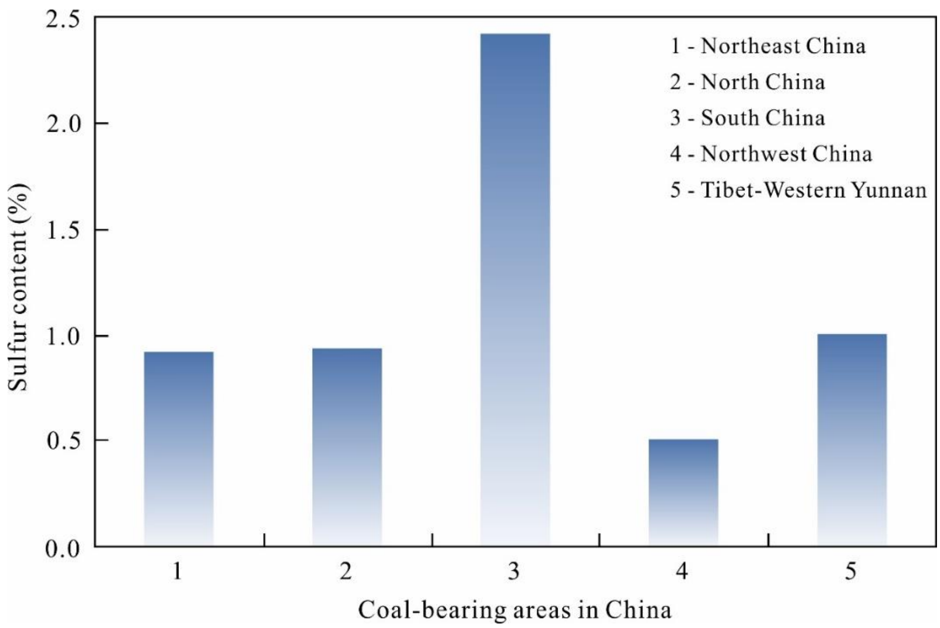

Figure S2. The total sulfur content in different coal-bearing areas in China (adapted from Tang et al., 2015).

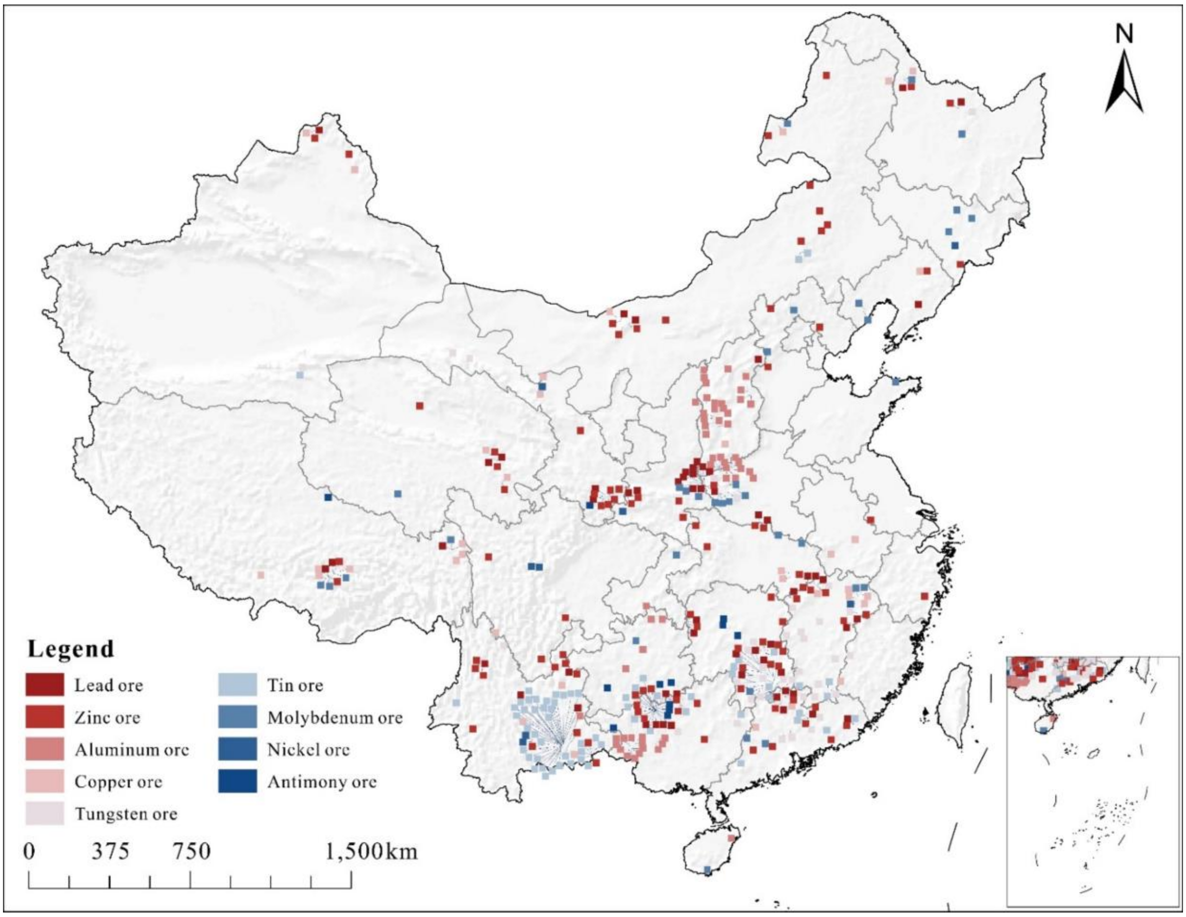

Figure S3. The spatial distribution of the major non-ferrous mineral resources in China (adapted from China Natural Resources Atlas, China Geological Survey, 2015, https://www.cgs.gov.cn/xwl/dzzl/201603/t20160309_304269.html).

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Structure and Coherence of the Argument

Strengths: The manuscript follows a conventional structure (introduction, methodology, results, discussion, conclusion) that makes it easy to follow. The discussion ties the findings back to the broader context of water pollution management.

[Response] No change needed. Thank you for your positive comments.

Suggestions: The transition between sections—especially from the results to the discussion—could be smoother. Explicitly linking how each result addresses the stated objectives would reinforce the coherence of the argument. Also, highlighting the novelty and practical implications of the work in the conclusion would help reinforce the manuscript’s contribution.

[Response] Comment accepted. We have rewritten the transition between sections to reinforce the coherence of the argument. Moreover, a detailed discussion of the novelty and practical implications of our manuscript has been supplemented in the **Conclusion** to highlight the unique contribution and valuable addition to the field of environmental hydrology. See also the response to your general comment above.

Figures, Tables, and Visual Aids

Strengths: Visual aids are generally clear and provide a good overview of the data distribution and risk maps. The integration of detailed figures (such as spatial distribution maps and risk assessment graphs) adds significant value to the manuscript.

[Response] No change needed. Thank you for your positive comments.

Suggestions: Ensure that all figures have clear legends and consistent formatting. It might be beneficial to include a summary table that aggregates the key findings (e.g., median values of critical parameters across different mine types) to enhance readability.

[Response] Thank you for your constructive suggestions. We have reviewed/revised all figures to ensure that they have clear legends and consistent formatting. To improve overall readability, the summary tables (*i.e.*, Table 1 in the revised manuscript and Table S4 in the **Supplement**) showing the statistics of critical parameters for different mine types have been added to the current revision. See also the response to your comment on 'Presentation and Interpretation of Results' above.

Language and Style

Strengths: The manuscript is written in clear, professional English with an appropriate academic tone. Technical terms are defined upon first use, and the text is generally free of major grammatical errors.

[Response] No change needed. Thank you for your positive comments.

Suggestions: A few sentences could be simplified to improve readability. In particular, some complex sentences in the introduction and discussion might be broken into shorter, more digestible statements. Maintaining consistency in terminology (for instance, ensuring that terms like “differentiated management” are clearly defined) will also help in reinforcing the manuscript’s clarity.

[Response] Comment accepted. We have simplified some complex sentences in the **Introduction** and **Discussion** to improve the readability of the manuscript. Moreover, a clear definition of terms like "differentiated management" has been added in the revised manuscript to reinforce the manuscript's clarity:

"The differentiated management mentioned in the current study is an optimized regulatory paradigm that customizes strategies to mine types (coal vs. metal) and operational status (active vs. abandoned) based on hydrogeological conditions, pollution source characteristics, and multi-system sustainability requirements. The initiative aims to implement targeted intervention and precise prevention/control to mitigate pollution risks, restore and enhance ecological functions, while concurrently safeguarding human health."

Conclusion

The manuscript presents an extensive dataset and a rigorous analysis of mining-affected water pollution in China, offering useful insights for environmental management and policy-making. However, the work would benefit from a more explicit discussion of its novelty compared to previous studies. Clarifying and emphasizing the unique contributions—whether in data scale, methodological advancements, or new insights into spatial and health risk patterns—would significantly strengthen the paper. With these revisions, the manuscript could represent a valuable addition to the field of environmental hydrology.

[Response] We sincerely appreciate your conscientious and constructive comments. A more explicit discussion of the novelty compared to previous studies has been added to the revised manuscript, to provide new insights into the spatial patterns and health risks of mining-affected water pollution at the national scale, and to clarify and emphasize the unique contributions of our study. We believe that your insightful comments on 'Novelty and Original Contribution', 'Methodological Rigor and Data Quality', 'Presentation and Interpretation of Results', 'Structure and Coherence of the Argument', 'Figures, Tables, and Visual Aids', and 'Language and Style' have led to significant improvements of the revised manuscript.