Physical and chemical characteristics of suspended sediment in plain river network

Xueqi Tian (894082347@qq.com)
Hohai University
Hua Wang
Hohai University
Zilin Shen
Hohai University
Weihao Yuan
Hohai University
Yichuan Zeng
Hohai University
Yuanyuan Li
Hohai University

Research Article

Keywords: Particulate Matter, Lakeside River Network, Flow Zones, Enrichment Capacity, Elemental Characteristics

Posted Date: April 19th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1427602/v2

Abstract

The suspended clay in plain river network is the main part of river transport. The suspended clay particles also affect the relevant movement of water pollutants. Taking the lakeside river network in Wuxi as an example, through the correlation division of velocity zone, comparing particle characteristics (geometric mean particle size GD, roundness RO and roughness FD) in different flow zones. On this basis, the influence of the flow characteristics of the river network on the physical properties and enrichment capacity of suspended clay particles was assessed; the differences in elemental species and content between waters with different flow velocities were analysed; and the influence of physical and chemical properties on the sorption capacity of particulate heavy metals was assessed. The results show that (1) the particle GD (5.77), roundness (1.32) and roughness (1.080) are the largest in the waters of the strong flow zone, and the particle roughness does not vary significantly between the different zones. (2) The average percentage content of the characteristic elements in the different flow velocity regions is in the same order from highest to lowest, with Mg being the characteristic element with the highest average percentage content in each region. (3) The GD, FD and RO of suspended clay particles are independent of TN, TP, V and SSC and are positively correlated with flow rate, with larger particle size and more spherical shape at higher flow rates. (4) The use of the defined enrichment factor AE=aF1(GD, RO, FD) is a better representation of the sorption capacity of suspended clay particles for heavy metals than considering only the GD factor.

1. Introduction

Changes in river overhanging banks and streambed sediments have environmental, ecological and social significance (Yang et al., 2018). Riverine sediments are becoming a global concern due to their important role in fluvial geomorphology, biogeochemistry, engineering and land-sea interactions (Dai et al., 2009). Suspended sediment is a natural part of river systems and plays an important role in constructing landscapes, creating ecological habitats and transporting nutrients. It is also a common management problem, with changes in sediment quantity and quality negatively affecting ecological communities, increasing flood hazards and shortening the life span of infrastructure (Mohammadi et al., 2021). In addition, the importance of suspended sediment in rivers can be attributed to its impact on water system quality and, more importantly, on pollution control (Martinez et al., 2009). Appropriate management strategies by quantifying SS transport link these transport dynamics to in-channel and wider catchment drivers in order to accurately predict suspended clay transport on management-relevant time scales (Garcia-Ruiz et al., 2015). The stochastic nature of sediment transport and the non-linear nature of sediment transport variables need to be considered in the prediction process (Safari et al., 2019). Sediment in suspended motion in the plain river network is a major component of river clay transport, and suspended clay undergoes a correlated movement while influencing the movement of pollutants in the water column. The study of suspended matter in the plains river network is always of interest.

Current research on sediment particles has focused on the variation in the composition of suspended clay particles, such as the fractal characteristics of suspended sediment particle composition (Zhao et al., 2010). The effect of porous media size distribution on the transport and deposition of polydisperse suspended particles at different flow rates (Ahfir et al., 2017). The particle size characteristics of suspended sediment in water basins are closely influenced by seasonal alternations in precipitation, wind and water action, and by the nature of surface materials (Xu, 2000). Coupling effects of ionic strength, particle size and flow rate on the migration and deposition of suspended particles in saturated clay (Bennacer et al., 2017). To quantify suspended sediment in medium and large clay bed rivers, analyze the different dual-mode particle size distributions, wash load and suspended clay ratio, and water level of the river, as well as the related effects of human activities on the river (Ahfir et al., 2017; Jehanzaib et al., 2020). Some scholars have separated river suspended sediments into different particle sizes to examine the distribution of radioactive elements with particle size information (Kondolf et al., 2014). A study was conducted using framework petrography, heavy mineral and grain size analysis (Wang et al., 2015). Current studies on sediment particle morphology mostly focus on one rivers, investigating the particle size driven environmental impacts for a particular river, or investigating the patterns of physical transport and microscopic sorption of several particle shapes in a river, investigating the particle size distribution and heavy metal concentrations in surface sediments of river basin streams and lakes, and using statistical and geochemical methods to determine their sources (Wang et al., 2015). The physical and chemical properties of suspended clay particles have an important influence on the transport of energy and the adsorption, migration and transformation of pollutants in the river network, and further research on them in the plain river network has important theoretical reference value and practical application significance for estimating the environmental impact of pollutants (Tiyasha et al., 2020).

The river network is an important part of the city and its important value is reflected in a number of ways: developing irrigation, providing water for industry and drinking water sources, providing an environment for the growth of aquatic plants and animals, and improving the regional ecological environment (Park et al., 2022; Qingming et al., 2022; Zhang et al., 2020). In this study, the urban lake-connected river network in Binhu District of Wuxi City which drives water from Taihu Lake was selected as the example and the following four aspects of research are proposed: (1) To classify the flow velocity zones of the plain river network and the coastal lake network; (2) To compare the physical particle characteristics (geometric mean particle size GD, roundness RO, roughness FD) and chemical characteristics of the different flow velocity zones of the plain river network and the coastal lake network; (3) To compare the differences in elemental species and contents between different flow velocities. (4) To evaluate the influence of river network velocity characteristics on the physical and chemical properties and enrichment capacity of suspended clay particles; (5) To combine various influencing factors to fit equations to characterize the sorption capacity of suspended clay particles for heavy metals.

2. Materials And Methods

2.1 Survey Region

Located in the lower reaches of the Lake Tai basin, the Lake Tai is the third largest freshwater lake in China, with a catchment area of 36,500 km^2 and a surface area of 2,338.1 km^2. It plays an important role in flood control, water supply and fisheries, and since the rapid industrial and economic development around it, the lake network has become heavily polluted. The plain river network is relatively flat and has a low gradient of 0.003-0.005, so the effect of river gradient is not considered in the course of this study.

In this paper, suspended clay particles in the water environment of the river network located in the eastern part of Meiliang Bay in the Taihu Lake basin, within the Lihu New Town area of Binhu District, Wuxi City, were studied. Wuxi Binhu District is bordered by lakes and rivers, with a dense network of internal rivers, forming a pattern of connected river and lake systems, referred to as the Binhu River Network. The river network reaches Caowangjing in the south, Liangxi river in the north, Wuli Lake in the west and Jinghang Canal in the east. The main river channels are Jinghang Canal, Liangxi River, Caowangjing and Cangli Port. The average suspended matter concentration was 53.15 mg/L and the average velocity was 0.204 m/s. The fluctuation range of heavy metal concentration varies greatly with season, and gradually decreases in dry season, normal season and wet season. The concentration of heavy metals in overlying water of lakeside river network is relatively small in wet season, which is lower than that in normal season and dry season.

2.2 Sample collection and determination

In this survey, the samples were collected in situ at 28 points 0.5m away from the water surface in the lakeside river network during the dry season in 2019. The water velocity was monitored by YH-S7, 0-3cm/s, 3-5cm/s and 5-15cm/s were defined as slow, gentle and strong velocity zones,

and three representative points were selected for analysis in different velocity regions. The sample was stored for experimental treatment. 500-1000ml of the sample was pumped and filtered by Brucellofer funnel (Shan et al., 2022). The filter membrane was acetate fiber membrane, and 0.45μm was filtered. After filtration, the membrane was dried to a constant weight (DeLaune et al., 2016), and the larger particles and impurities were screened out with 150μm. The contents under the sieve were encapsulated with tin foil paper and put into sealing bags, and stored for testing. The samples to be tested were sent to modern Analysis Center of Nanjing University for SEM-EDS detection. SEM images of suspended particles were obtained by taking 250mg samples and using S-3400N scanning electron microscope. The types of suspended clay elements were detected and quantitatively analyzed by ex-250 energy spectrometer attached to scanning electron microscope. The Myratek portable suspended matter /TSS meter was used to average the results of multiple vertical planes successively collected along the cross section of the monitoring station to obtain the suspended sediment concentration of each monitoring point (Allison et al., 2012). 1 g of dried suspended clay was dissolved with HCl, HNO3, HClO4, and HF under high temperature and pressure, and then the Ni content in the suspended clay was determined by inductively coupled plasma mass spectrometry (ICP-MS).

In this study, two-dimensional suspended clay graininess analysis was carried out using image processing software Image Pro Plus (IPP) for SEM images of different flow velocity zones within the Lake Shore network. Image-pro plus (IPP) is a top-notch 2D and 3D image analysis software developed by Media Cybernetics, which combines image acquisition, processing and analysis functions for a wide range of applications in fluorescence imaging, quality control, materials imaging and many other scientific, medical and industrial applications (Yu et al., 2013). The software is not only powerful in image processing and analysis, but also has a wealth of measurement capabilities (Zhang et al., 2015). To ensure measurement accuracy and avoid errors, ten electron microscope photographs of each point at different angles and magnifications were selected for analysis (Chen et al., 2022; Yang and Liu, 2020). Manual analysis of particle morphology, avoiding the influence of non-suspended particles such as algae and microplastics, averaging the same particle three times to avoid errors caused by manual outlining, and achieving accurate measurements of the projected area (A), profile perimeter (P), geometric mean particle size (GD), roundness (RO) and roughness (FD).

2.3 Statistical analysis

The descriptive statistical analysis method arithmetic mean (AVG) was used to quantitatively assess the morphological characteristics of the suspended clay particles (Zhou et al., 2022), the standard deviation (S.D) was used to measure the inhomogeneity of the particle morphology at each point, and the uneven level (UEL) was used to express the inhomogeneity of the particle morphology in each area.

$$uneven\ level = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{p-P}{P}\right| \quad (1)$$

In the formula: p is the mean value of a morphological parameter at a point in the plain river network; P is the mean value of a morphological parameter within the waters of the plain river network; n is the number of points in the study area.

3. Results And Discussion

3.1 Differences in physical characteristics

In this paper, the morphological characteristics of suspended clay particles are compared in terms of both particle size and shape, and the geometric mean grain size (GD) is used to measure the suspended clay grain size. Fewer materials are deposited in the faster flowing waters of the plain river network, and the water column is dominated by materials with large particles, and the larger particles are more gravitational and less likely to be carried along with the flow of water. Conversely, in the slower flowing waters of the plain river network, it is difficult for the river to carry small particles to flow because of the slower flow and the relatively high amount of sedimentary material. Therefore, on the whole, the average particle size (AVGGD) in the slow flow area (5.15μm) is smaller than the average particle size in the flat flow area (5.56μm) and smaller than the average particle size in the strong flow area (5.77μm); the standard deviation of the particle size (S.D) ranges from 5.1 to 6.1, and the corresponding S.D values are smaller at the points with smaller GD in the lake network, i.e. the particle size is relatively concentrated and uniform. For example, the smallest GD value at the slow-flowing area of the river network is 3.95 μm at the Lu Dian Qiao Bin, and the corresponding S.D value is 4.91.

Roundness (RO) and roughness (FD) were used to measure the shape characteristics of the suspended clay particles. The uneven level roundness (UELRO) between 0.15 and 0.21. The roughness (FD) values of the suspended clay particle population ranged from 1.077 to 1.080, with small differences in roughness (FD) values within each flow velocity zone, and the average roughness (AVGFD) in the slow flow velocityt zone (1.078) was smaller than the AVGFD in the advection velocity zone (1.079) and smaller than the AVGFD in the strong flow velocity zone (1.080), the standard deviation roughness (S.DFD) of the particle population ranged from 0.017 to 0.020, and The uneven level roundness (UELFD) between points within each zone ranged from 0.001~0.003.

The K-S significance tests for GD, RO, FD in each flow zone of the riverine network were all below 0.001, so the geospatial variability of GD, RO, FD was highly significant. According to the statistical analysis of particle shape, in the waterfront river network, the heterogeneity of physical properties within a point is S.DFD<S.DRO<S.DGD; the heterogeneity of physical properties between points is also UELFD<UELRO<UELGD; combined with the results of the inter-regional variability analysis, it is clear that with the refinement of the evaluation of the physical properties of particles from GD, RO to FD, the variation of particle morphological properties The variation between regions, although still different, tends to be the same overall.

3.2 Differences in chemical properties

The mineral content of the analysed areas was used to derive the chemical composition of the sediments within the three flow areas. From the SEM-EDS analysis, it is clear that geospatial differences result in different minerals being present in different areas of the riverine network. The abundance in the slow-flow and strong-flow areas of the riverine network is relatively similar, with some points containing the minerals C, O, Al, Si, Mg, Fe and Na, and the sediments containing mainly Mg, Fe, Na and K. The abundance in the advective zone is relatively high, containing the minerals C, O, Al, Si, Mg, Fe, Na and K. Therefore, the sediments in the advective zone contain mainly the special elements Mg, Fe, Na and K. Overall, the sediments in the advective zone contain mainly Mg, Fe, Na and K. The K-S test for differences in the elemental content of suspended clay particles between the flow velocity zones showed that the level of significance of the differences between the strong, flat and slow flow velocity zones was less than 0.05, so that the three flow velocity zones were different and very significant.

There are significant differences in the elemental species within the zones, with the basic elements C, O, Al and Si being present within the different flow rates. In the strong flow zone, both Hongqiao and Liqiao of the Liangxi River contain the special elements Mg, and Qingqi Bridge of the Liangxi River contains the special elements Mg, Fe and Na; in the flat flow zone, Caowangjing Dongjiang Bridge contains only the basic elements at the point, and Liangdong Bridge and Caowangjing Dongjiang Bridge of the Panbu Bridge contain the special elements Mg, Fe, Na and K in addition to the basic elements. In the slow flow zone, the Rao Xiu Bridge site at Lu Dian Qiao Bang contains only basic elements, while the Wenge and Han Cui Bridge sites at Lu Dian Qiao Bang contain Mg, Fe and Na special elements in addition to basic elements. The points containing fewer elements are all located at the connection of lakes and rivers, while the points containing more specific elements are mostly located in the middle of the river network, and these differences in location lead to large differences in element types between points.

The K-S test of elemental content within the regions shows a large variation in elemental content within the three flow velocity regions. The highest abundance and the highest content of characteristic elements were found in the flat velocity zone, and the average percentage content of characteristic elements were Mg (0.25%), Na (0.15%), Fe (0.14%) and K (0.13%). The average percentages of the characteristic elements in the slow-flowing zone are Mg (0.17%), Na (0.07%) and Fe (0.05%) in descending order, while the average percentages of the characteristic elements in the strong-flowing zone are Mg (0.32%), Na (0.08%) and Fe (0.05%) in descending order. The average percentages of the characteristic elements in the different flow velocity zones are in the same order from highest to lowest, with M being the characteristic element with the highest average percentage content in each zone.

3.3 Reason for variance

In this paper, the reasons for the spatial differences of suspended clay particles and elements were analyzed from hydrology and water quality conditions and characteristics of eroded soil. The plain river network is relatively flat and has a low gradient of 0.003-0.005, so the effect of river gradient is not considered in the course of this study. Hydrological water quality conditions are the main reason for the difference in suspended clay particle morphology. The parameters related to hydrological water quality conditions include total nitrogen (TN), total phosphorus (TP), flow velocity (V) and suspended particle concentration (SSC). The Pearson correlation test was conducted between the parameters related to hydrological and water quality conditions and the morphological parameters of suspended clay particles (GD, FD, RO), and the test results showed that the GD, FD, RO of suspended clay particles were positively correlated with the flow velocity, in which the FD of suspended clay particles was significantly positively correlated with the flow velocity. The GD, FD and RO of suspended clay particles were not correlated with TN, TP, V and SSC. This means that the particle population is larger and more spherical in shape at high flow rates in the waters of the lakeside network.

Particle size is one of the most important factors affecting the content of metallic elements in the particulate state (Vandecasteele et al., 2002), and Al is the most abundant metallic element in the earth's crust. It has been shown that the content of Al in particulate matter increases linearly with decreasing particle size, therefore the content of Al in particulate matter can reflect the size of the particle size (Hill and Aplin, 2001). The influence of particle size effects on the elemental content of metals in the particulate state was investigated in the water system of the Lake Shore network by studying the correlation between the elemental content of Al contained in the particulate matter and the content of the remaining metal elements. The results show that the elemental content of Al shows a strong correlation with the elemental content of Mg and Si.

As soil is an important source of suspended clay in water bodies, the influence of eroded soil properties on the elemental composition of suspended clay particles is considered here (Du et al., 2022). In terms of soil particle size, the lowest gravel content was found in the estuary of the flat-flow velocity zone and the highest in the estuary of the slow-flow velocity zone; the difference in gravel content between the two was four to eight times, which was a significant difference. The gravel content in the study area ranged from 571.1 to 650.5 g/kg, all of which were greater than 500 g/kg, and the gravel content in the estuary of each flow velocity zone was slightly higher than that in the near-shore sites, and the particle size of the soil was larger. The clay and clay content in the estuaries of the low-flow zones are comparable, both being about 110 g/kg, while the clay content in the estuaries of the flat-flow zones is slightly lower than the clay content, and the difference in clay content between the low-flow and flat-flow zones is significant, making the flat-flow zones more abundant than the slow-flow and strong-flow zones, and having special elements K.

3.4 Heavy metal adsorption capacity

Particulate matter is the main carrier of pollutant diffusion in the water column, the reasons for this phenomenon include the strong sorption of heavy metals and nutrients. The sorption capacity of suspended clay particles for pollutants is not only influenced by the physical characteristics of the particles (particle size, etc.) and the chemical environment of the water column (ph, salinity, organic matter, etc.), but the ability of suspended clay particles to sorb Zn and Ni heavy metals also has a significant positive correlation with the particle Al content (R_2>0.69), i.e. the elemental characteristics of suspended clay particles are related to the sorption capacity of Zn and Ni.

Heavy metals present in the water column as ions are readily adsorbed, complexed or co-precipitated by sediments or particulate matter suspended in the water column. In this paper, the influence of the two-dimensional morphology and elemental properties of suspended clay particles on the enrichment capacity of heavy metals is explored using Ni as an example.

Metal enrichment factors (EFs) are often used to help assess whether metals are enriched in natural concentrations. The calculation of EFs usually involves normalizing metal concentrations to Fe or Al. Al was chosen for geochemical normalization in this study because it has low yield variability, is considered a clastic component of sediments, and is the most frequently used element in coastal and estuarine environments (Kersten and Smedes, 2002; Maanan et al., 2015). Normalization of conserved elements explains the diagenetic and sedimentary inputs of elements of interest, enhancing the prediction of anthropogenic contamination by enrichment factors (Duodu et al., 2016).

Studies have shown that the sorption capacity of heavy metals is related to the particle size, specific surface area and surface roughness of the particles. In previous studies, only the particle size of the particulate matter was considered, and the smaller the particle size, the stronger the heavy metal adsorption capacity. This research approach approximates the particulate matter as a smooth sphere for analysis, ignoring the influence of factors such as the surface roughness of the particulate matter on the adsorption capacity. In this study, the particle size, roundness and roughness are taken into account to fit the shape function of the particles, thus proposing a comprehensive shape function model that affects the Ni enrichment capacity.

$$SP = F_1(GD,RO,FD) = k_1RO + k_2FD + k_3/GD + k_4 \qquad (3)$$

In the formula: SP is the shape factor; k_1, k_2, k_3, k_4 are the parameters.

In this study, four particle physicochemical characterisation factors, GD, RO, FD and Al content (Al%), were used as analytical variables, and the enrichment factor AE was used to characterise the sorption capacity of suspended clay for Ni in order to remove the interference of soil background values.

Based on the data of particle roundness, roughness and mean particle size, multiple regressions were carried out in combination with the functional model (3) to obtain the integrated shape function for each region. Combining the regional integrated shape functions with the functional model (4), the function AE was obtained for the influence of the physical and chemical properties of suspended clay particles on the sorption of heavy metals as follows:

$$AE = aF_1(GD,RO,FD) + bF_2(Al) + c \qquad (4)$$

Where: AE is the ability of suspended clay particles to enrich for heavy metals; F_1 is the effect of morphological properties; F_2 is the effect of elemental properties; a, b and c are parameters. To consider the practical significance, the constraints a>0 and b>0.

A comparison of the linear fit of the Ni enrichment factor EF with particle AE, SP, GD and 1/GD in each region shows that the interpretation of particle shape in the riparian network is improved by considering the particle shape factor compared to the effect of particle size only (EF-GD or EF-1/GD). A combination of particle shape factors (RO, FD) and Al content (EF- AE) gives the most accurate interpretation of Ni sorption by particles.

Considering lakeside river network area, the parameters of high, moderate velocity (a, b, c, d, k_1, k_2) average processing to $\overline{AE}$, this value can better evaluate the suspended sediment particles of Ni concentration skills.

The comparative analysis of EF, AE and GD at each site showed that the AE values at each site in the Lake Shore network fit better with the EF values relative to the GD values, while the suspended clay values were proportional to the EF values in all areas except for the Wenge Bridge in the Lake Shore network.

Therefore, the AE values are better able to assess the sorption of Ni by suspended clay at each point in the area than the GD values (Fig 6-d). The highest Ni sorption by suspended clay particles was found in the slow-flowing plain river network (EF= 4.28; AE= 4.42).

4. Conclusion

Suspended clay particles play an important role in pollutant migration and transformation, but little attention has been paid to the spatial differences of suspended clay particles morphology and element composition and their impact on the environment. In this paper, based on the actual SEM-EDS measurements, a large number of particle measurements were processed in an attempt to find the differences in the two-dimensional morphological characteristics (GD, RO, FD) and elemental properties of suspended clay particles in typical waters in the slow, flat and strong flow areas of the coastal lake network, to analyse the reasons for the differences, and to establish a coupled function model of suspended clay particle morphology and elements, which can scientifically reflect the differences in the Ni enrichment capacity of suspended clay particles in the waters. Analysis of the mean and standard deviation of GD, RO and FD of the suspended clay population in typical waters, as well as the heterogeneity within the area, shows that the smallest particle size, roundness and roughness are found in the slow flowing river network and the largest particle size, roundness and roughness are found in the strong flowing river network. With the refinement of the physical properties of particles from GD, RO to FD, the change of particle shape characteristics tends to be stable. Although there are still differences between regions, the overall trend is the same. In different flow rate regions, the average percentage content of characteristic elements is basically the same from high to low, and Mg is the highest average percentage content of characteristic elements in each region. The clay content of the estuary is slightly lower than the viscous content in the flat velocity zone, and the difference in viscous content between the low velocity zone and the flat velocity zone is significant, which makes the abundance in the flat velocity zone greater than that in the slow and strong velocity zones, and has a special element K. The integrated shape function model SP was fitted to influence the Ni enrichment capacity, and the enrichment factor AE was used to characterize the Ni sorption capacity of suspended clay. Compared with particle size, the integrated shape function model SP can better reflect the enrichment capacity (AE) of suspended clay for Ni in the watershed. The AE values therefore provide a better assessment of the amount of Ni sorbed by suspended clay between sites in the region than does GD (Fig 6-d). The highest Ni sorption by suspended clay particles (AE=3.65; EF=4.74) was found in the slow-flowing plain river network. This model provides an idea for quantitative analysis of heavy metal enrichment capacity difference of suspended sediment between point sites by SEM-EDS. However, the current work at the macro-basin scale may lead to error and does not adequately consider the effects of wind direction and flocculation of the suspended clay itself.

Declarations

Ethical Approval

I certify that: the research will be undertaken in line with all appropriate, University, legal and local standards and regulations. I have attempted to identify the risks that may arise in conducting this research and acknowledge my obligation to (and rights of) any participants. no work will begin until all appropriate permissions are in place.

Consent to Participate

All the participants would like to take part.

Consent to Publish

All the participants would like to publish.

Authors Contributions

Hua Wang: Methodology, Conceptualization, Supervision.

Xueqi Tian: Writing-Reviewing & Editing, Visualization, Software, Validation, Formal analysis.

Zilin Shen: Supervision, Writing-Reviewing & Editing, Software.

Weihao Yuan: Data acquisition, Investigation.

Yichuan Zeng: Writing-Original draft preparation, Conceptualization.

Yuanyuan Li: Data curation.

Funding

This work was supported by the National Natural Science Foundation of China (No. 52179064), water conservancy science and technology project of Jiangxi Province (202023ZDKT12), and the Fundamental Research Funds for the Central Universities (No. 2016B06814), and the CRSRI Open Research Program (2-D spatial-temporal investigation on water quality decoupling in the Yangtze River Estuary, CKWV2017504/KY);

Competing Interests

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work，there is no professional or other personal interest of any nature or kind in any product，service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.

Availability of data and materials

The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (No. 52179064), water conservancy science and technology project of Jiangxi Province (202023ZDKT12), and the Fundamental Research Funds for the Central Universities (No. 2016B06814), and the CRSRI Open Research Program (2-D spatial-temporal investigation on water quality decoupling in the Yangtze River Estuary, CKWV2017504/KY);

References

Ahfır, N.-D., Hammadi, A., Alem, A., Wang, H., Le Bras, G. and Ouahbi, T. 2017. Porous media grain size distribution and hydrodynamic forces effects on transport and deposition of suspended particles. Journal of Environmental Sciences 53, 161-172.

Allison, M.A., Demas, C.R., Ebersole, B.A., Kleiss, B.A., Little, C.D., Meselhe, E.A., Powell, N.J., Pratt, T.C. and Vosburg, B.M. 2012. A water and sediment budget for the lower Mississippi-Atchafalaya River in flood years 2008-2010: Implications for sediment discharge to the oceans and coastal restoration in Louisiana. Journal of Hydrology 432, 84-97.

Bennacer, L., Ahfır, N.-D., Alem, A. and Wang, H. 2017. Coupled Effects of Ionic Strength, Particle Size, and Flow Velocity on Transport and Deposition of Suspended Particles in Saturated Porous Media. Transport in Porous Media 118(2), 251-269.

Chen, C., He, M., Chen, Q., Zhang, J., Li, Z., Wang, Z. and Duan, Z. 2022. Triple collocation-based error estimation and data fusion of global gridded precipitation products over the Yangtze River basin. Journal of Hydrology 605.

Dai, S.B., Yang, S.L. and Li, M. 2009. The sharp decrease in suspended sediment supply from China's rivers to the sea: anthropogenic and natural causes. Hydrological Sciences Journal-Journal Des Sciences Hydrologiques 54(1), 135-146.

DeLaune, R.D., Sasser, C.E., Evers-Hebert, E., White, J.R. and Roberts, H.H. 2016. Influence of the Wax Lake Delta sediment diversion on aboveground plant productivity and carbon storage in deltaic island and mainland coastal marshes. Estuarine Coastal and Shelf Science 177, 83-89.

Du, X., Silwal, G. and Faramarzi, M. 2022. Investigating the impacts of glacier melt on stream temperature in a cold-region watershed: Coupling a glacier melt model with a hydrological model. Journal of Hydrology 605.

Duodu, G.O., Goonetilleke, A. and Ayoko, G.A. 2016. Comparison of pollution indices for the assessment of heavy metal in Brisbane River sediment. Environmental Pollution 219, 1077-1091.

Garcia-Ruiz, J.M., Begueria, S., Nadal-Romero, E., Gonzalez-Hidalgo, J.C., Lana-Renault, N. and Sanjuan, Y. 2015. A meta-analysis of soil erosion rates across the world. Geomorphology 239, 160-173.

Hill, D.M. and Aplin, A.C. 2001. Role of colloids and fine particles in the transport of metals in rivers draining carbonate and silicate terrains. Limnology and Oceanography 46(2), 331-344.

Jehanzaib, M., Shah, S.A., Yoo, J. and Kim, T.-W. 2020. Investigating the impacts of climate change and human activities on hydrological drought using non-stationary approaches. Journal of Hydrology 588.

Kersten, M. and Smedes, F. 2002. Normalization procedures for sediment contaminants in spatial and temporal trend monitoring. Journal of Environmental Monitoring 4(1), 109-115.

Kondolf, G.M., Gao, Y., Annandale, G.W., Morris, G.L., Jiang, E., Zhang, J., Cao, Y., Carling, P., Fu, K., Guo, Q., Hotchkiss, R., Peteuil, C., Sumi, T., Wang, H.-W., Wang, Z., Wei, Z., Wu, B., Wu, C. and Yang, C.T. 2014. Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents. Earths Future 2(5), 256-280.

Maanan, M., Saddik, M., Maanan, M., Chaibi, M., Assobhei, O. and Zourarah, B. 2015. Environmental and ecological risk assessment of heavy metals in sediments of Nador lagoon, Morocco. Ecological Indicators 48, 616-626.

Martinez, J.M., Guyot, J.L., Filizola, N. and Sondag, F. 2009. Increase in suspended sediment discharge of the Amazon River assessed by monitoring network and satellite data. Catena 79(3), 257-264.

Mohammadi, B., Guan, Y., Moazenzadeh, R. and Safari, M.J.S. 2021. Implementation of hybrid particle swarm optimization-differential evolution algorithms coupled with multi-layer perceptron for suspended sediment load estimation. Catena 198.

Park, E., Loc Ho, H., Van Binh, D., Kantoush, S., Poh, D., Alcantara, E., Try, S. and Lin, Y.N. 2022. Impacts of agricultural expansion on floodplain water and sediment budgets in the Mekong River. Journal of Hydrology 605.

Qingming, W., Shan, J., Jiaqi, Z., Guohua, H., Yong, Z., Yongnan, Z., Xin, H., Haihong, L., Lizhen, W., Fan, H. and Changhai, Q. 2022. Effects of vegetation restoration on evapotranspiration water consumption in mountainous areas and assessment of its remaining restoration space. Journal of Hydrology 605.

Safari, M.J.S., Ebtehaj, I., Bonakdari, H. and Es-haghi, M.S. 2019. Sediment transport modeling in rigid boundary open channels using generalize structure of group method of data handling. Journal of Hydrology 577.

Shan, K., Ouyang, T., Wang, X., Yang, H., Zhou, B., Wu, Z. and Shang, M. 2022. Temporal prediction of algal parameters in Three Gorges Reservoir based on highly time-resolved monitoring and long short-term memory network. Journal of Hydrology 605.

Tiyasha, Tran Minh, T. and Yaseen, Z.M. 2020. A survey on river water quality modelling using artificial intelligence models: 2000-2020. Journal of Hydrology 585.

Vandecasteele, B., De Vos, B. and Tack, F.M.G. 2002. Identification of dredged sediment-derived soils in the alluvial plains of the Leie and the Upper and Sea Scheldt rivers (Belgium) based on physico-chemical soil properties. Journal of Environmental Monitoring 4(2), 306-312.

Wang, S., Wang, Y., Zhang, R., Wang, W., Xu, D., Guo, J., Li, P. and Yu, K. 2015. Historical levels of heavy metals reconstructed from sedimentary record in the Hejiang River, located in a typical mining region of Southern China. Science of the Total Environment 532, 645-654.

Xu, J.X. 2000. Grain-size characteristics of suspended sediment in the Yellow River, China. Catena 38(3), 243-263.

Yang, H.F., Yang, S.L., Xu, K.H., Milliman, J.D., Wang, H., Yang, Z., Chen, Z. and Zhang, C.Y. 2018. Human impacts on sediment in the Yangtze River: A review and new perspectives. Global and Planetary Change 162, 8-17.

Yang, S. and Liu, W. 2020. Application of image-pro plus in the shear strength and micro-structure of solidified soil mixed with fly ash. Multimedia Tools and Applications 79(15-16), 10065-10075.

Yu, X., Zhou, L., Jing, Y., Liu, D., Hu, M., Xiong, F. and Wang, Z. 2013. Application of image-pro plus in analysis of wheat starch granule microscopic image. Journal of Chinese Electronic Microscopy Society 32(4), 344-351.

Zhang, L., Yu, L. and Tang, Z. 2020. Thought of Pollution Control in Shenzhen River Basin Based on the Whole Factor ofPlant,Network,River and City. China Water & Wastewater 36(20), 81-85.

Zhang, X., Huang, T., Zhang, Y., Gao, H. and Jiang, M. 2015. Image-Pro Plus Analysis of Pore Structure of Concrete. Journal of Building Materials 18(1), 177-182.

Zhao, H., Guo, S., Xie, M. and Lei, T. 2010. Particle Sizes and Their Fractal Characteristics of Sediments from Wushui Watershed of Hunan Province. Journal of Soil and Water Conservation 24(3), 45-49.

Zhou, L., Liu, P., Gui, Z., Zhang, X., Liu, W., Cheng, L. and Xia, J. 2022. Diagnosing structural deficiencies of a hydrological model by time-varying parameters. Journal of Hydrology 605.

Figures

Figure 1

Study area map, (a) (b) Jiangsu Basin Map, (c) Point location diagram of the four study areas, (d) Land use map of the four study areas.

Figure 2

Particle measurement diagram, (a) Regional particle measurement diagram, (b) Schematic diagram of measurement parameters; A: particle projection area FD: particle fractal dimension RO: particle roundness GD: particle average particle size, (c) Sample of particle measurement results

Figure 3

Difference of suspended sediment particle shape distribution (a) Relationship diagram of GD, RO, FD, R and P values of point particles in three velocity zones; (b) K-S correlation test of GD, RO and FD particles in three velocity zones; (c) GD, RO, FD, R, Area and P values of point particles in the three flow velocity zones;

Figure 4

Distribution of elemental content of suspended sediment (a) to (c) average content of elemental mass fraction (W%) and elemental percentage (A%) in the three flow regions (d) basic elemental percentage at the point (e) characteristic elemental percentage at the point.

(a)	Pearson correlation test					
		V	FD	GD	RO	SSC
V	Pearson correlation	1	1.000**	.985	.941	.756
	Sig.		.008	.109	.220	.454
FD	Pearson correlation	1.000**	1	.983	.945	.764
	Sig.	.008		.117	.212	.446
GD	Pearson correlation	.985	.983	1	.869	.633
	Sig.	.109	.117		.330	.564
RO	Pearson correlation	.941	.945	.869	1	.933
	Sig.	.220	.212	.330		.234
SSC	Pearson correlation	.756	.764	.633	.933	1
	Sig.	.454	.446	.564	.234	

(b) Pearson correlation test

Figure 5

Analysis of differences in physicochemical properties of suspended sediment, (a) Correlation test between physical properties of particles and water environment quality, (b) Correlation test between physical properties of particles and elements.

Figure 6

Environmental impact of physicochemical properties of suspended clay particles (a) Comparison of the linear correlation between the enrichment factor (EF) of Ni by suspended clay and suspended clay particles (AE, SF, GD, 1/GD) in the three flow zones (b) Comparison of Ni sorption measured using AE, EF and GD at the measurement sites (c) Calculated equation of Ni enrichment capacity (AE) by suspended clay in the three flow zones.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- graphicalabstract.png