Supplementary data:

Influencing Factors and Nutrient Release from Sediments in the Water Level Fluctuation Zone of Biliuhe Reservoir, a Drinking Water Reservoir

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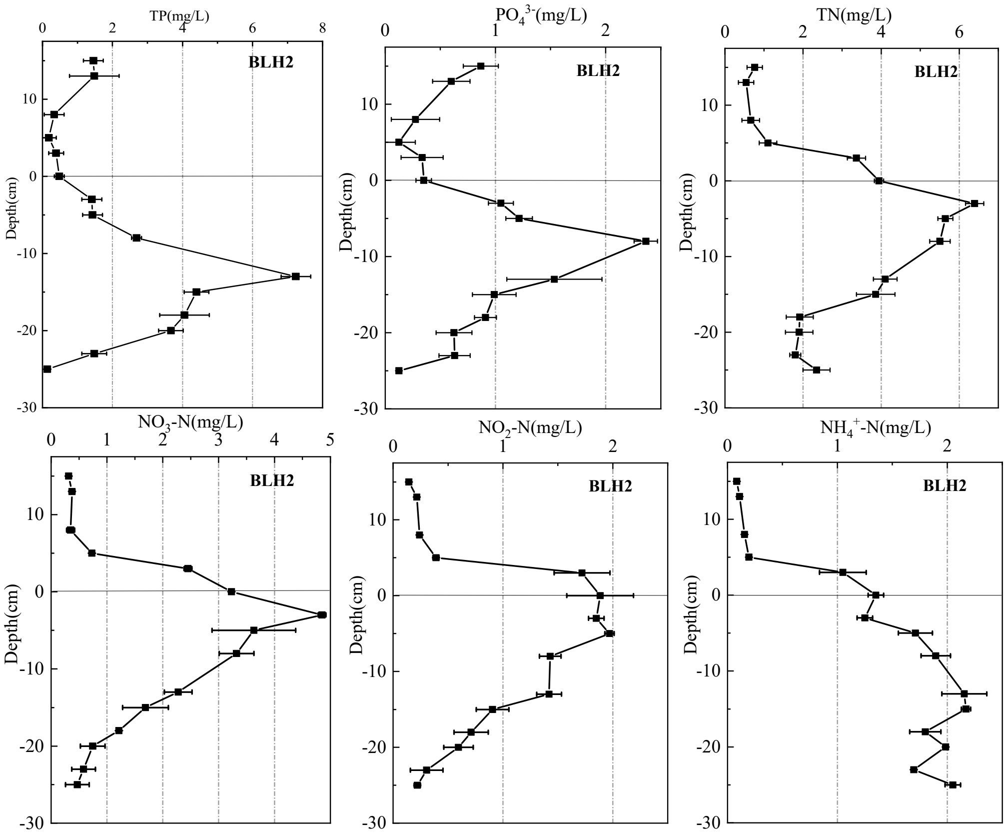

Figure. S1. Nutrient concentrations in overlying water and the pore water at the sediment-water interface(SWI) of BLH2

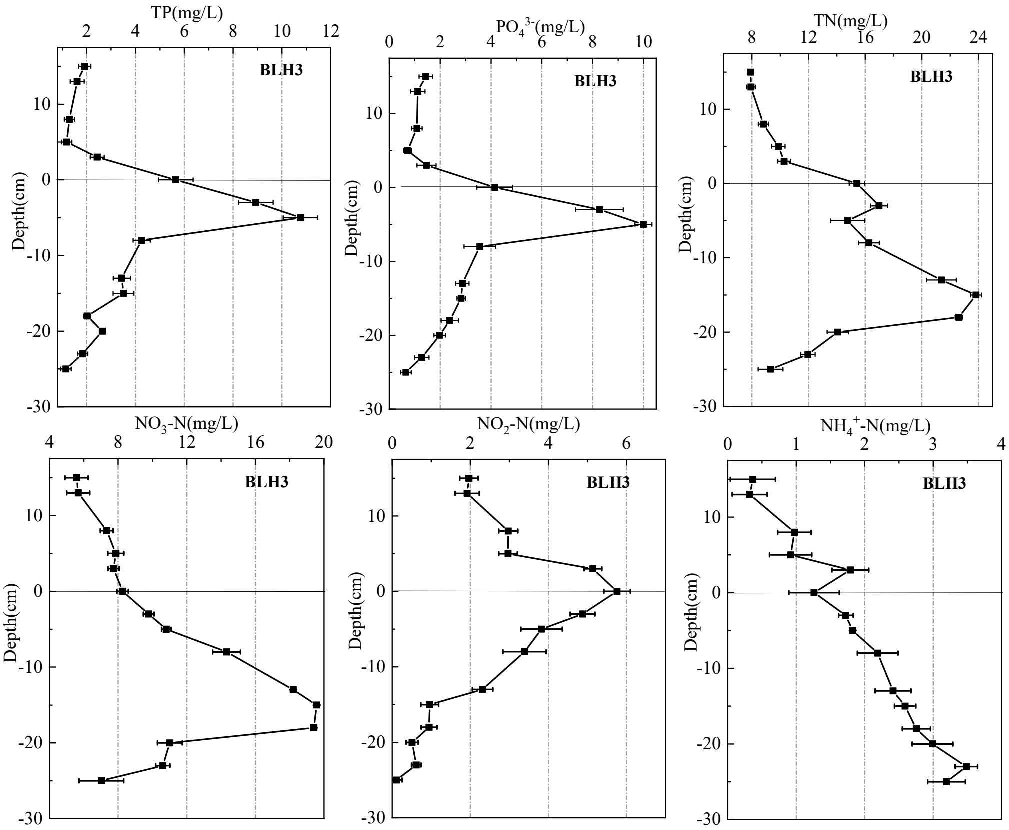

Figure. S2. Nutrient concentrations in overlying water and the pore water at the sediment-water interface(SWI) of BLH3

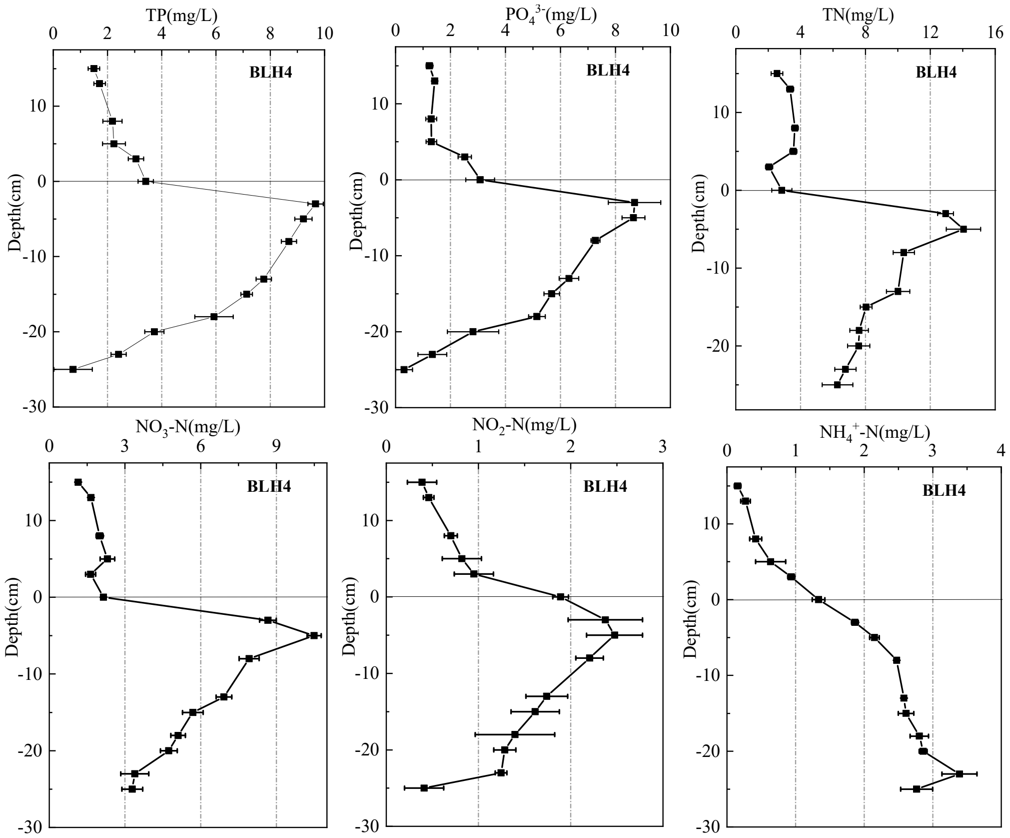

Figure. S3. Nutrient concentrations in overlying water and the pore water at the sediment-water interface(SWI) of BLH4

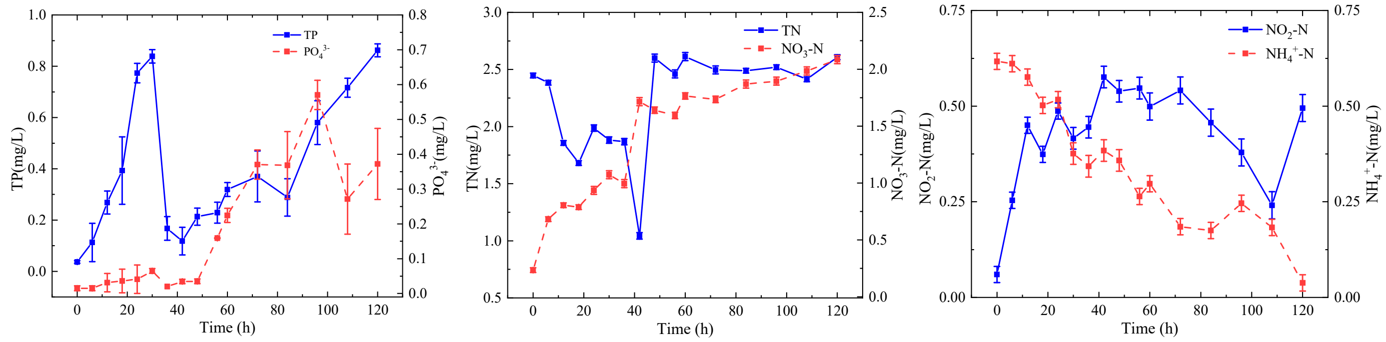

Figure. S4. The temporal variation characteristics of N and P in the overlying water during sediment incubation process of BLH2.

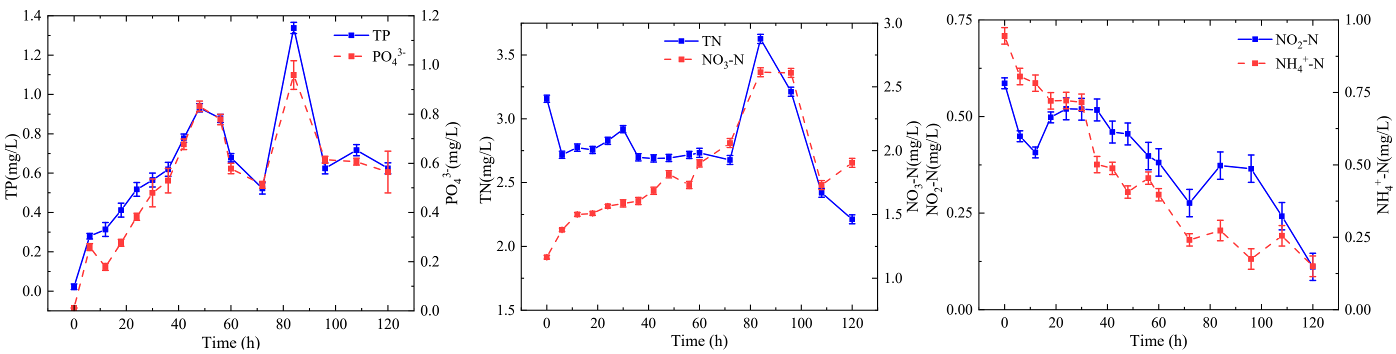

Figure. S5. The temporal variation characteristics of N and P in the overlying water during sediment incubation process of BLH3.

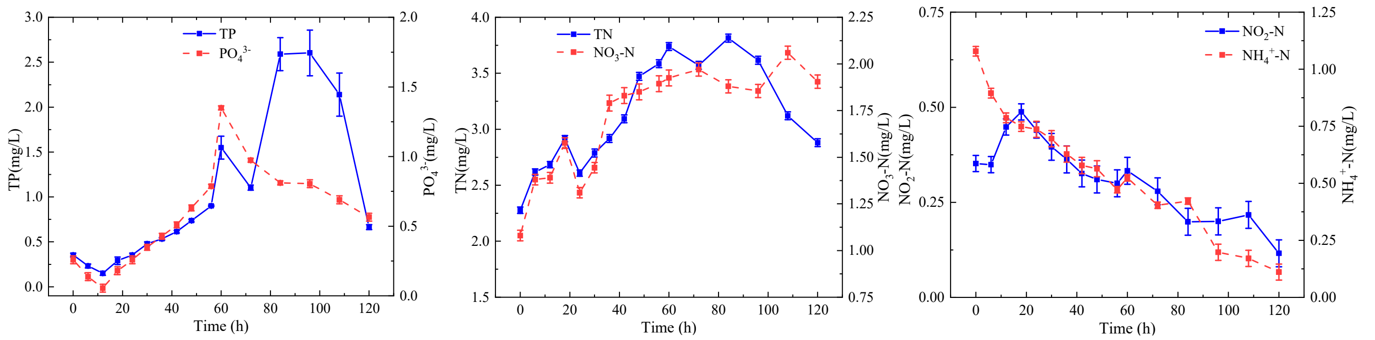

Figure. S6. The temporal variation characteristics of N and P in the overlying water during sediment incubation process of BLH4.

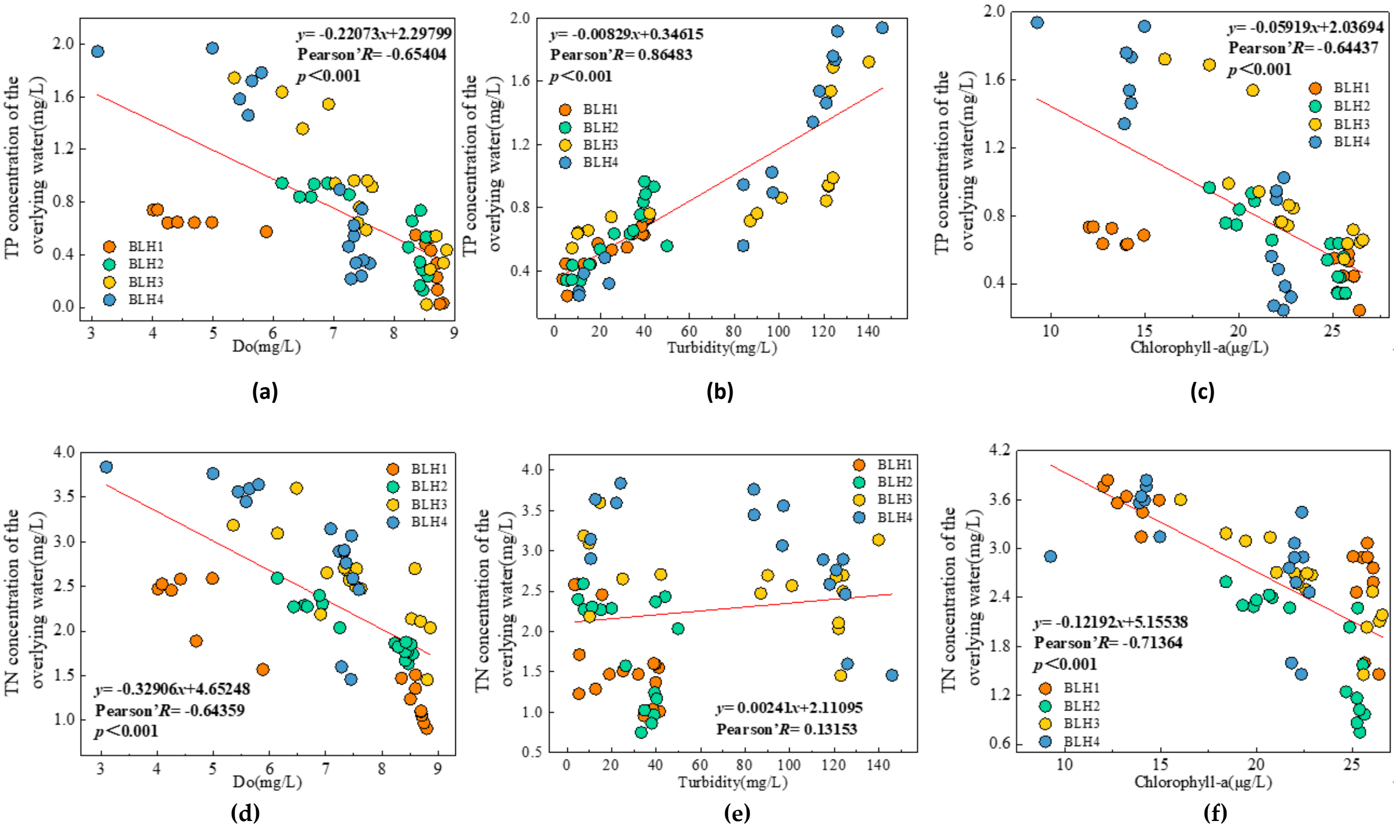

Figure S7. The correlation between water environmental factors and the release of N and P in sediments.

Table S1. The porosity and grain size fractions of sediment core in Biliuhe Reservoir

Sampling sites	The porosity(%)	Grain size fractions(%)	
BLH1	18.26	Clay (<2um)	3.6
		Silt (2 - 50um)	36.57
		Very fine sand (50-100um)	19.35
		Fine sand (100-250um)	21.94
		Medium sand (250-500um)	4.21
		Coarse sand (500-1000um)	1.43
		Very coarse sand (1000-2000um)	8.58
BLH2	32.45	Clay (<2um)	9
		Silt (2 - 50um)	52.12
		Very fine sand (50-100um)	14.79
		Fine sand (100-250um)	8.1
		Medium sand (250-500um)	0.03
		Coarse sand (500-1000um)	4.08
		Very coarse sand (1000-2000um)	8.76
BLH3	29.16	Clay (<2um)	6.22
		Silt (2 - 50um)	42.03
		Very fine sand (50-100um)	18.12
		Fine sand (100-250um)	22.92
		Medium sand (250-500um)	8.94
		Coarse sand (500-1000um)	1.77
		Very coarse sand (1000-2000um)	6.22
BLH4	50.52	Clay (<2um)	7.11
		Silt (2 - 50um)	60.76
		Very fine sand (50-100um)	22.39
		Fine sand (100-250um)	9.57
		Medium sand (250-500um)	0.17
		Coarse sand (500-1000um)	0
		Very coarse sand (1000-2000um)	0

Table S2. Component score coefficient matrix of factors affecting nutrient salt release rates of sediment-water interface.

Sediment Factor	Component	
	1	2
DO	0.972	0.073
Turbidity	0.965	0.160
Chlorophyll-a	0.942	0.041
NO_3-N	-0.936	0.208
TP	-0.916	0.130
TN	-0.884	0.164
PO_4^{3-}	-0.873	0.282
Ec	-0.807	-0.487
NO_2-N	-0.789	0.274
pH	0.732	-0.383
WT	0.716	0.575

Table S3. Nutrient fluxes in previously published studies across the sediment-water interface around the world.

Source	**Location**	**Season**	NH_4^+-N /mg·(m²·d)⁻¹	PO_4^{3-} /mg·(m²·d)⁻¹	Method
this study	Biliuhe Reservoir, China	Summer	1.02±0.08	3.38±2.49	Sediment core incubation
Wang et al. 2013 [1]	Lake Nansihu, China	Summer	3.1–10.3	0.3–2.7	Sediment core incubation
Petranich et al. 2018 [2]	Marano and Grado Lagoon, Italy	Summer	24.3	2.28	In-situ benthic chambers
		Autumn	10.98	0.285	
		Winter	3.96	-0.19	
Denis and Grenz 2003 [3]	Gulf of Lions, NW Mediterranean	Spring	−0.4–3.67	−0.64–2.76	Sediment core incubation
Beutel et al. 2008 [4]	Deer Lake, Canada	Summer	39.0~62.0	1.0~1.8	Sediment core incubation

* 1. Wang, Z.Q.; Li, B.; Liang, R.J.; Wang, L.Z. Comparative study on endogenous release of nitrogen and phosphorus in Nansi Lake, China. *Acta Sci. Circumstantiae* **2013**, *33*, 487–493. (In Chinese)

2. Petranich, E.; Covelli, S.; Acquavita, A.; De Vittor, C.; Faganeli, J.; Contin, M. Benthic nutrient cycling at the sediment-water interface in a lagoon fish farming system (northern Adriatic Sea, Italy). *Sci. Total Environ.* **2018**, *644*, 137–149.

3. Denis, L.; Grenz, C. Spatial variability in oxygen and nutrient fluxes at the sediment-water interface on the continental shelf in the Gulf of Lions (NW Mediterranean). *Oceanol. Acta* **2003**, *26*, 373–389.

4. Beutel, M. W.; Leonard, T. M.; Dent, S. R.; Moore, B. C. Effects of aerobic and anaerobic conditions on p, n, fe, mn, and hg accumulation in waters overlaying profundal sediments of an oligo-mesotrophic lake. *Water res*. **2008**, *42*, 1953–1962. https://doi.org/10.1016/j.watres.2007.11.027.

Table S4. Abbreviations and their specific meaning

Abbreviations	**Specific meaning**
WLFZ	water level fluctuation zone
N	Nitrogen
P	Phosphorus
SWI	Sediment water interface
TP	Total phosphorus
PO_4^{3-}	Orthophosphate
TPP	Total particulate phosphorus
TN	Total nitrogen
NH_4^+-N	Ammonia nitrogen
NO_3-N	Nitrate nitrogen
NO_2-N	Nitrite nitrogen
DIN	Dissolved inorganic nitrogen
OP	Organic phosphorus
IP	Inorganic phosphorus
NaOH-P	NaOH-extractable phosphorus
HCI-P	HCl-extractable phosphorus
PCA	Principal component analysis
WT	Water temperature
DO	Dissolved oxygen
EC	Electrical conductivity

Supplement of Experimental Scheme：

1.Selection of study location and sampling sites

In this study, the WLFZ of Biliuhe Reservoir was selected as the research area. Throughout the entire operational period of the reservoir, there is a 16.23% probability of submergence frequency at 66.45m. The sediment at this elevation is exposed for an extended duration. As the water level increases, previously exposed sediment nutrients will be released into the overlying water, leading to a deterioration in reservoir water quality.

In order to analyze the law of nutrient release in sediments of the WLFZ, the original columnar sediments and overlying water samples were collected in July 6, 2022. The distribution of sampling sites are shown in Figure 3. The latitude and longitude of sampling points are positioned by GPS. Four typical sampling sites(BLH1, BLH2, BLH3 and BLH4) were set up in the main tributaries from upstream to downstream (Figure 3). BLH1 is situated in the main stream of the reservoir where a water diversion project has been implemented to introduce Dahuofang Reservoir's water into Biliuhe Reservoir, leading to erosion of BLH1 sediment. Meanwhile, BLH2, BLH3 and BLH4 are located in the tributaries of the reservoir. Through field investigation, it is found that BLH2 is located in Geli river, which is located in the agricultural planting area. Both BLH3 and BLH4 are located in residential areas and agricultural planting areas. BLH4, a submerged dam project was established. It can be seen from Table S1 that the porosity of the sediment core of the Biliuhe Reservoir varies from 18.62 % to 50.52 %. From the upstream to the downstream of the reservoir, the porosity of the sediment core gradually increases.

2. Collection of columnar sediment samples and the overlying water

Columnar sediments were collected vertically with PVC tubes (diameter of 100mm) in BLH1, BLH2, BLH3 and BLH4. The sampling frequency is 5 times a month. The statement implies that a total of five sample collections were conducted in the month of July. Four sampling sites were collected in each sampling, and three parallel experiments were conducted for each sampling site to ensure experimental accuracy. Consequently, a total of 12 columnar sediment experiments were performed to minimize potential errors at each sampling. Finally, the average value of July sampling is taken as the final result. The vertical sampling depth was about 25cm. This depth has been chosen as it falls within the range of water level fluctuations observed in the Biliuhe Reservoir over a 20-year period and aligns with global change projections for the 21st century. After taking the columnar sediment sample with a PVC pipe at the site, we quickly used a stopper to block the columnar sediment at the other end of the pipe to prevent any potential leakage. Then, the columnar sediments were subsequently sectioned and divided into 5 cm intervals. Then the separated 5cm columnar sediment samples were quickly loaded into a clean polyethylene bag. On the same day, the sediment interstitial water was taken back to the laboratory and extracted by the centrifuge. The columnar samples are collected in a vertical position, without any shaking and with swift sampling, to eliminate the influence of other interlayers water. This approach effectively minimizes the impact caused by other interlayers water.

After sampling, the collected original column samples were sealed with rubber plugs to prevent the disturbance during transportation from affecting the experimental results. At the same time, the sediments were collected in situ by layers, and a sample was collected every 5cm depth and placed in a clean polyethylene bag for sealing and low temperature preservation. It was transported back to the laboratory and centrifuged by centrifuge to obtain the interstitial water required for the experiment. YSI EXO2 multiparameter probe (XYLEM, USA) was used to measure water environmental parameters: pH, water temperature(WT), dissolved oxygen(DO), electrical conductivity(EC), turbidity and chlorophyll-a on the vertical profile of each sampling point. At the same time, 10L in-situ bottom water samples were collected for static release incubation nitrogen and phosphorus experiments. And Niskin water sampler produced by HYDRO-BIOS, Germany was used to collect the overlying water. All water samples collected are transported to the refrigerator within the same day at 4℃ for testing.

3.Experimental apparatus and simulation scheme for indoor incubation experiments

To study the potential exchange of nutrients at the sediment-water interface, three replicates of sediment cores from each site were incubated. The collected sediment samples were transported back to the laboratory and the overlying water was drained by siphon method for release experiment. The filtered in-situ bottom water sample is slowly and undisturbedly injected into the in-situ sediment column in the WLFZ along the wall with a medical infusion tube. When the liquid level is 15cm away from the surface of the sediment (the volume of the water column is 1178ml), stop and mark the scale. All columnar samples were incubated at constant temperature according to the in-situ temperature of the reservoir, and the light and dark were set to 12h, respectively. The specific experimental device is shown in Figure. S8. Afterwards, at the specified time (0,6,12,18,24,30,36,42,48,54,60,72,84,96,108,120 h), a syringe with a volume of 50ml was used to connect the infusion hose to collect 50 ml of overlying water from 5 cm above the sediment-water surface. The water samples were collected in 50 ml polyethylene bottles. Store it in 4°C refrigerator in time. At the same time, the initial filtered water sample of the original sample point was immediately supplemented to the scale to maintain the water balance. All experiments were completed at 120h(5d). The reason for setting 120h is that the sediment will reach a state of adsorption or release equilibrium at about 120h.

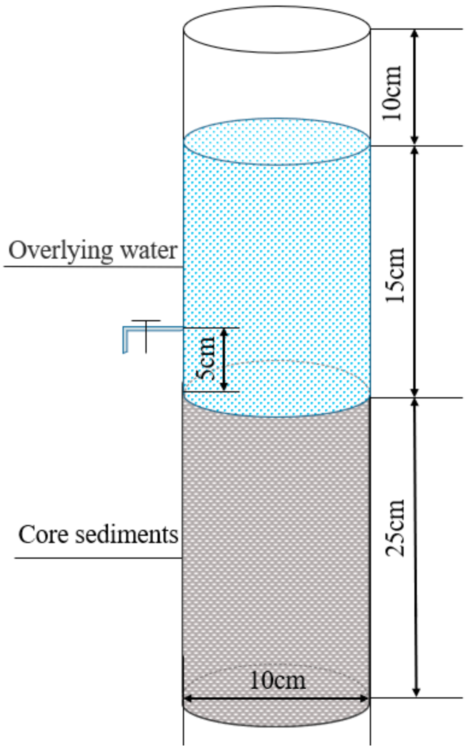

Figure. S8. Schematic diagram of experimental apparatus

4.The estimation of fluxes for the release of nitrogen and phosphorus

Since the inflow runoff will lead to changes in the physical and chemical properties of the sediment, the concentration difference between the overlying water and the interstitial water promotes the exchange of N and P. Therefore, the diffusion flux can be estimated by the measured concentration gradient between the sediment interstitial water and the overlying water. The positive value represents the release process, and the negative value represents the adsorption process. Theoretically, the molecular diffusion flux (*F*) is calculated according to Fick's first law, and its expression is:

$$F = \left[V\left(c_n - c_0\right) + \sum_{j=1}^{n} V_{j-1}\left(c_{j-1} - c_a\right) \right] / \left(S \times \mathrm{t}\right) \quad (1)$$

where *F* is the average exchange flux[mg·(m^2·d)$^{-1}$]; *V* is the volume of overlying water in the column(L); C_n, C_0 and C_{j-1} were the mass concentration of a substance(mg·L^{-1}) at the n th, 0 th (initial) and j-1 th sampling; C_a is the mass concentration of the substance in the added water sample(mg·L^{-1}); V_{j-1} is the *j-1* sampling volume (L); S is the contact area of water and sediment in columnar samples(m^2). *t* is the release time(d), and the calculated nutrient release rate is 5d average exchange flux. This formula is utilized for the investigation of total phosphorus (TP), orthophosphate(PO_4^{3-}), total nitrogen (TN), ammonia nitrogen(NH_4^+-N), nitrate nitrogen(NO_3-N) and nitrite nitrogen(NO_2-N) determination in the sediment release flux of Biliuhe Reservoir.