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# 水利学报

SHUILI XUEBAO

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## Study on ecological scheduling of multi-scale coupling of reservoir group

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**Abstract:** The connotation of the ecological scheduling of the reservoir group was defined in this paper with an aim of finding the solution of the ecological problems in the Irtysh River Basin in China. In order to protect the health of the river and the safety of the valley ecosystem, the ecological multi-scale coupling scheduling system of the reservoir group with long, medium and short terms were constructed. According to the principle and basis of ecological scheduling, the multi-objective ecological reservoir scheduling model with multi-scale coupling, the long-mid-term, the short-term and real-time-term ecological reservoir scheduling were constructed. Then, the solution technology of multi-objective non-linear reservoirs group scheduling for multi-timescale coupling and the infiltration irrigation system were proposed. The infiltration irrigation was defined, and the infiltration irrigation system was developed. With the application of the above system, model and method, the results show that the long-mid-term scheduling model met the water supplement and guaranteed rate requirements of the comprehensive utilization of water resources in the Irtysh River Basin, especially the destruction depth of the ecological water supply in the valley and forest and the maximum continuous year numbers of water shortage. Regarding to the real-time-term ecological reservoir scheduling model, the model calculation and the measured value of the reservoir artificial ecological flood process for the river valley grassland, wetland are similar, the relative error was 0.04%, indicating that the result is reasonable. The effect of the river valley grassland, wetland is monitored including the range, area and water depth by real-time. The artificial ecological flooding process of the reservoir basically satisfied the requirement of irrigation area and water depth. It is of important theoretical significance and application value for the research results in maintaining river health in Irtysh River Basin, protecting the ecological security, solving the international river water resources utilization, and developing the reservoir group ecological scheduling theory and methods, which could provide an experience for ecological scheduling in north China.

**Keywords:** the ecological operation of reservoir group; multiple utilization of water resources; ecological operation system; multi-scale coupling scheduling model; artificial flood process

**Study on theoretical analysis of water resources carrying capacity:  
Definition and scientific topics**

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**Abstract:** Water resources carrying capacity (WRCC) is a comprehensive index to evaluate the coordinated development of water resources, economic society and ecological environment, thus, it is significant to study WRCC to realize the harmony of water and human beings. Based on the research progress of WRCC, and take the main interference and influence of human activities on water system as a starting point, a new meaning of WRCC is defined from water quantity, water quality, water space and streamflow, and the evaluation index system of WRCC is constructed. The surface water resources availability and groundwater should be determined on the prerequisite of ensuring ecological water use; water quality should meet the water function regionalization target and the demand of the biodiversity to determine the concentration that ensure the normal growth of fish; it is necessary to take into account flood control, ecology, landscape and other requirements in the water space, and determine the appropriate water space area under different precipitation conditions; it should focus on the impact of connected water system on water ecosystem in streamflow, and the threshold of different water system connecting index should be obtained. It is considered that evolution mechanism of WRCC “quantity – quality – domain – flow”, the elastic threshold of “water resources–economic and social–ecological environment” systems, the balance point between socio–economic development and ecological environment protection, and regulation mechanism of WRCC are four key scientific topics in this research field.

**Keywords:** water resources carrying capacity; water space; streamflow; definition and connotation; scientific topics

## Study on the migration and transformation of nitrogen and phosphorus in sediment–interstitial water–overlying water in farmland drainage ditch

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**Abstract:** Study on the migration and transformation of nitrogen and phosphorus among the sediment–interstitial water–overlying water can contribute to grasp the interception mechanism of nitrogen and phosphorus in farmland drainage ditch. In this paper, the migration and transformation of nitrogen and phosphorus through the three were studied and the sediment morphology was tested by scanning electron microscope (SEM). The results show that: the nitrogen and phosphorus are adsorbed and stored in the sediment in the early stage of rice growth, and the nitrogen and phosphorus are released in the later ice growth; during the entire rice growth, the concentration of nitrogen and phosphorus in the interstitial water are about 3.1 and 6.5 times the overlying water, which the  $\text{NH}_4^+\text{-N}$  as the main nitrogen form of storage; in the process of rainfall, the ditch sediment as the source of nitrogen and phosphorus which provide the nitrogen and phosphorus in the interstitial water gradually migrate to the overlying water,  $\text{NH}_4^+\text{-N}$  gradually change to  $\text{NO}_3^-\text{-N}$ , and the granular TN and TP had a great influence on the loss of TN and TP in the overlying water; and the surface of sediment particles is rough and has a pore structure, that is conducive to the adsorption of nitrogen and phosphorus.

**Keywords:** ditch; sediment; interstitial water; overlying water; SEM; nitrogen and phosphorus

## Efficiency and microbial community analysis of domestic sewage treatment by biological aerated filter

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**Abstract:** Taking rural domestic sewage in Daxing district of Beijing as an object, this paper designed four reaction columns, and studied the effect of biological aerated filters (BAF) on the efficiency of rural domestic sewage treatment and microbial community under three different filling structures and two gas water ratio. The removal rate of BOD<sub>5</sub>, COD<sub>Cr</sub> and ammonia nitrogen in #1, #2 and #3 column which had different filling structures and same gas water ratio reached 84.51%–96.49%; #4 column and #2 column had the same filling structure, but the gas water ratio was small, and the treatment effect of BOD<sub>5</sub> and COD<sub>Cr</sub> was very poor; however, all the removal rate of TP are low, so phosphorus removal measures need to be strengthened. The difference of OTU in #1, #2 and #3 columns were very small, which indicating that the number of microbial species was basically the same; the specific OTU number of #2 column was much larger than that of #4 column, indicating that high gas water ratio was favorable to the increase of microbial species. There were 6 dominant bacteria groups in #1, #2 and #3 columns, the dominant species of each reaction column were basically the same at different heights, but the quantity was different. Only Proteobacteria may contain poly P bacteria in these 3 reaction columns, which was also one of the reasons for poor phosphorus removal.

**Keywords:** filling structure; gas water ratio; treatment efficiency; microorganism; community structure



## Evaluation of water environment improvement by interconnected river network in plain area

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**Abstract:** River water system is an important resource and environmental carrier of the city. The contradiction between urban development and water environment protection is becoming more and more prominent in recent years, especially in the plain river network area. Due to geographical constraints, the improvement of urban river water environment is challenging. The sustainable development of urban water system will be directly related to the healthy development of cities and the whole society. Therefore implement modern water system management theory and promote water environment improvement through the interconnected river system has become an important step of urban water management. In this paper, the urban area of Changshu city is selected as the research area. The water transfer experiment and the hydraulic model are applied as technical support to formulate river interconnected schemes for the sake of water environment enhancement. Based on the concept of structural connectivity and functional connectivity, the river network connectivity assessment method is proposed. In the water transfer experiment, flow exchange in major rivers is satisfied and water quality of indexes is increased 20%–30% in average. Yet the river connectivity in the central downtown is limited which leads to less flow access. The improvement of river channel connectivity and the reasonable dispatching of water conservancy project have important influence on the connectivity system. Taking the scenario simulations in the paper as an example, channel regulation projects increase river connectivity and give rise to water quality about 30%–50%. The change of connectivity index also prove that structural connectivity greatly enhances water transfer efficiency, and promotes better flow distribution and water environment. The establishing methodology of interconnected water system to improve water environment can provide theoretical basis for water system connectivity decision, and provide reference for urban water system connectivity in China.

**Keywords:** interconnected water system; Changshu city; water environment improvement; water transfer experiment

# The prototype test study of prestressed concrete cylinder pipe structure deformation law I.

## The internal pressure

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**Abstract:** PCCP is a composite structure composed of concrete core, steel cylinder, prestressed wire and mortar coating; the internal pressure is the key load during PCCP project running. To study the limit bearing capacity and failure mechanism of PCCP under the internal water pressure, a prototype hydrostatic pressure test was carried out on 2.6 m diameter embedded PCCP (ECP). The test used BOTDA and FBG optical fiber sensor technology for the first time both at home and abroad, and the optical fiber implanted steel cylinder surface in the PCCP manufacturing process, continuously tested the strain of PCCP each layer structure in the process of loading. Through in-depth analysis of test data, it is found that test PCCP stressed uniformly during internal pressure of 0 ~ 1.8 MPa, the deformation of each structure layer is coordinated and jointly sustained the internal pressure, mortar coating and concrete core start crack when the internal pressure is greater than 1.8 MPa, and both of cylinder and prestressed wire yield at the internal pressure of 1.8 MPa. The full-scale test not only obtained the loading response law of the PCCP layers structure under the internal water pressure, determined the cracking and yielding load of each layer structure, but also provided valuable experimental data for deeply basic theoretical research and engineering application of PCCP structure.

**Keywords:** prestressed concrete cylinder pipe; prototype test; BOTDA; FBG; bearing capacity

## Experimental study on concrete deterioration caused by *Limnoperna fortunei* fouling

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**Abstract:** The concrete performance changes caused by *L. fortunei* fouling has important reference significance on decision and selection of anti-fouling measures. To study the micro performance changes caused by *L. fortunei* fouling of the homemade specimens colonized by *L. fortunei* for one year and the cores from the zones colonized by *L. fortunei* for more than 20 years, indexes of water absorption, pore characteristics and distribution, surface morphology, element composition, and calcium minerals were compared by water absorption method, mercury intrusion method, environment scanning electron microscope method and thermogravimetry method. Quantitative analysis indicated that the pores of different sizes increased, resulting in bulk density decreased by 13.5% (colonized for one year) and 19.5% (colonized for more than 20 years) respectively, and water absorption increased by 82% (colonized for one year) and 101% (colonized for more than 20 years) respectively. Concentrations of aluminium, manganese and iron increased whereas calcium especially calcium carbonate concentration decreased by 41.7% (colonized for one year) and 82% (colonized for more than 20 years) respectively as a consequence of the mussel colonization. Therefore, the colonization of *L. fortunei* can cause micro-properties deterioration of concrete. The longer the colonization period, the worse the performance deterioration.

**Keywords:** *Limnoperna fortunei*; concrete deterioration; absorption; pore characteristic; surface morphology; calcium ingredient

## Study on swimming behavior of juvenile grass carp for the fish channel hydraulic design

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**Abstract:** The swimming capability and swimming behavior of the juvenile grass carp (BL=5.0–16.0cm) were tested using self-made test chamber at  $25\pm 0.5^{\circ}\text{C}$ . The results showed that the mean induction speed of the juvenile grass carp was 12.84 cm/s. The absolute burst swimming speed increases linearly with increasing body length, and in contrast, relative burst swimming speed decreases linearly with increasing body length. Burst swimming speed is about 1.05–1.28 times of critical swimming speed, and the longer the fish body, the greater the difference between critical speed and burst swimming speed. Effects of rapid changes in flow rate on swimming behavior of fish were analyzed. It is found that in the process of adapting to the change of flow rate, downstream, countercurrent static, counter dash and countercurrent retreat four kinds of swimming behavior interspersed with each other. The entire testing process can consist of four stages. Proposed when the fishway passes through the object are the grass carp, the maximum flow rate of the main flow of the pool should not exceed the maximum flow rate of the first stage (burst speed of juvenile grass carp 52%–60%), for high-speed areas such as vertical joints, orifices, the optimum flow rate should not be higher than the maximum velocity of the second stage (burst speed of juvenile grass carp 52%–60%), must not exceed the maximum velocity of the third stage (burst speed of 90%–96%). The research results complement the swimming capability gaps of the four major Chinese carps, and provide an important reference for the hydraulic design of the fish way.

**Keywords:** fishway; swimming capability; the induction speed; burst swimming speed; critical swimming speed

## Bed load graduation of sandy bed in alluvial river

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**Abstract:** Bed load graduation of sandy bed in alluvial river is a key in the calculations such as bed load transport rate, riverbed erosion and siltation. In this paper, pattern of critical condition of sediment transport in near-wall region of sandy bed was analyzed firstly, and according to the law of momentum balance, the critical settling-rising condition of bed material in sandy bed was obtained. Based on the vertical instantaneous turbulent velocity abiding by Gaussian distribution, a theoretical relation for calculating bed load graduation in sandy bed was addressed by solving the stochastic equation. The formulae were verified by measured data from the Yellow and Yangtze Rivers, and the results showed that the measured data agreed well with proposed formulae. This study has theoretical significance and practical value for determining bed load graduation of sandy bed in alluvial river.

**Keywords:** Graduation; Bed load; Turbulence; Momentum; Sandy bed

# Effects of drying and re-flooding on phosphorus adsorption characteristic of fine bed sediment

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**Abstract:** Water-level fluctuations cause drying and re-flooding of river bed sediment, which could change the adsorption characteristic of sediment. Fine bed sediment ( $< 31 \mu\text{m}$ ) was taken from Huaihe River, and the change of particle size after air-drying was measured. In order to study the effects of drying and re-flooding on phosphorus adsorption characteristic of fine bed sediment, the batch equilibrium experiments were conducted on wet and dried sediments under different oscillation intensity. The results show that the dried sediment has a lower adsorption capacity and a higher  $EPC_0$  than wet sediment, which makes the bed sediment tend to be phosphorus source to water. In drying process, fine particles aggregate into micro-aggregate, which cause the significant difference between wet and dried sediment. The micro-aggregate breakdown with increasing hydrodynamic intensity increased the phosphorus adsorption capacity of dried sediment. Therefore, water-level fluctuation is unneglectable for the evaluation on phosphorus adsorption characteristic of bed sediment.

**Key words:** drying and re-flooding; micro-aggregate; phosphorus adsorption; oscillation intensity

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## Moving correlation coefficient-based method for the detection of change-points in hydrological time series

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**Abstract:** Detection of change-point is a primary task for the analysis of nonstationary hydrological time series. Those methods used presently for the practice cannot directly reflect the essence of changes in a time series. To overcome the problem, in this paper we first derived the expression of correlation coefficient between the original series and the jump-component series, and then quantified the relationship between the correlation coefficient and the difference degree of mean value before and after the change-point. Based on it, we proposed a new method for the detection of change-point in a time series, called moving-correlation coefficient-based detection method. Results of statistical experiments indicate that the proposed method is easy to be conducted, and the correlation coefficient is easily calculated, too. When encountering the influence of series length, position of change-point, and difference of mean value, variation coefficient and skewness coefficient before and after change-point, the proposed method has similar performance as those of the Pettitt test and Brown-Forsythe test, both of which have been widely used for detecting change-point. But the former has more stable efficiency. The proposed method was then applied to detect the change-points in the runoff processes at multi-time scales at the Yunjinghong hydrological station in the lower reaches of the Lancang River basin. The results indicate that the construction and operation of the water conservancy projects have great influence on the streamflow regimes of the basin, causing more water in dry season and less in the wet season in a year, and the obvious variability and abrupt changes in the runoff process in around 2004.

**Keywords:** change-point detection; hydrological variability; correlation coefficient; Lancang River; runoff; multi-time scale

## Discussion about the two rainfall control approaches in Sponge City Construction

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**Abstract:** “China Sponge City Construction Guide” (2014) uses rainfall volume capture ratio as runoff volume capture ratio to determine the designed rainfall, which is debatable because they’re not equivalent. Rainfall need be converted to runoff before estimating runoff volume capture ratio. US EPA uses rainfall event capture ratio to determine the designed rainfall and it’s equivalent to runoff event capture ratio. This paper compared two different methodologies with rainfall volume capture ratio and rainfall event capture ratio, and discussed which one is best suitable for Sponge City based on its goals. It discussed the concepts of these two methodologies, then compared them using Beijing, Wuhan and Guangzhou as examples. The designed rainfalls based on these two methodologies have certain correlation, but they’re not same and their concepts are different. The designed rainfall based on volume capture ratio is always higher than the one based on event capture ratio. The study found the optimized ratios, or the break-even point of capture ratio, are very close based on both methodologies. In conclusion, the runoff volume capture ratio represents the capture ratio of long-term annual runoff, hence is suitable for runoff utilization. But the runoff event capture ratio represents the capture capability of each rainfall event, hence is suitable for runoff pollution control.

**Keywords:** low impact development; volume capture ratio of annual rainfall; event capture ratio of annual rainfall; utilization of rainfall; runoff pollution

## Analysis method for the slope stability of earth-rock fill dam considering the effect of concurrent earthquake and dam-break flood

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**Abstract:** Earthquake and flood are the major factors which affect the slope stability of earth-rock fill dam in cascade reservoirs, and the effect of dam-break flood from upstream is especially remarkable. Analysis method was put forward for the earth-rock fill dam slope stability considering the effect of concurrent earthquake and dam-break flood. The method is based on the Bishop method, considering the variation coefficient of dam material, and the effect of dam-break flood is modeled by the fluctuation of dam front water level. Taking “Busigou-Shuangjiangkou” two ascades as an example, the dam slope stability and the risk of the downstream cascade dam slope of “Shuangjiangkou” were analyzed. The results show that, under the extreme condition of dam-break flood from upstream and earthquake, the downstream dam slope failure probability is  $1.571 \times 10^{-6}$ , and the corresponding reliability index is 4.667. The stability meets the standard requirements for the second class destruction of the first-grade structure.

**Keywords:** cascade reservoirs; dam-break flood; earthquake; dam slope stability analysis; reliability index