RESEARCH ON POLLUTION CHARACTERISTICS OF RURAL RUNOFF
/
农村地表径流污染特征研究

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Abstract: *This paper studied the non-point source pollution type of Meijiadu Village, Gaocheng Town, Yixing City, Taihu Basin, analyzed the process of rainfall-runoff producing- pollution producing of two main runoff pollution sources in the rural area, calculated the mean concentrations of the different rainfall events. Based on local living conditions and poultry farming methods, the runoff pollution characteristics and the influencing factors were analyzed. Besides, a biological detention pond technology suitable for treating runoff pollution under rural conditions was proposed. The results show: The event mean concentrations of these two polluted areas differed significantly; within the same rainfall, the runoff peak occurred 0.6-1.1 h later than rainfall intensity did, and the concentration was also changed along with the runoff process. However, at different rainfall intensities, the loss law of the pollutants was similar. The concentration of runoff pollution reached the peak within the first 10 min, but the water quality became stable after the stabilization of the runoff. Therefore, the concentration of runoff pollution was affected by rainfall intensity, rainfall duration, poultry scale, human activities, surrounding soil properties and many other factors.*

Keywords: *rural runoff; free-ranging poultry; outdoor septic tank*

摘要: *本文调查了太湖流域宜兴市高塍镇梅家渎的非点源污染类型，分析了农村两大径流污染源的降雨-产流-产污过程，计算了不同场次降雨的平均浓度，结合当地生活状况及家禽养殖方式分析了径流污染特征及影响因素并提出了适用于农村条件处理径流污染的生物滞留池技术。结果表明：对于这两大污染区EMCs差异较大；对同一场次降雨，径流量高峰晚于降雨强度0.6-1.1h，浓度也随着径流过程不断变化，对于不同降雨强度，污染物流失规律相似，在前10min内径流污染浓度最大，径流稳定后水质趋于稳定，径流污染浓度受降雨强度、降雨历时、家禽养殖规模、人类活动和周边土壤属性等诸多因素的影响。*

关键词: *农村径流；散养家禽；露天化粪池*

INTRODUCTION

Water environmental problems of Lake Taihu are mainly endangered by runoff pollution coming from agricultural production, living of residents and poultry farming, etc. [1]. The clumsy life patterns and inadequate understanding of water-use have increasingly overburdened the aquatic system. The obsolete construction of relevant environmental facilities has rapidly degraded the aquatic system in rural areas. Besides, the aquatic system in small towns is prone to eutrophication that is characterized by the increment of organisms, nitrogen and phosphorus [2]. Particularly, runoff pollution is the main factor of rural non-point source pollution [21]. Rainfall runoff pollution refers to the water environment pollution in surface and underground water, which is caused by the diffusible entrance of pollutants in the atmosphere, ground and the soil under the leaching and scouring effect of rainfall runoff. In particular, the chemical fertilizers and pesticides used in agricultural production contribute the most to such pollution [3]. Currently, the urban runoff water quality [4; 5] and rural farmland surface runoff [6] have been studied extensively, while the runoffs of typical residential villages have seldom been referred.

In this study, typical runoff pollution sources in the study area were interviewed and investigated. The runoffs of poultry farming area and outdoor septic tank were determined as two major point source (PS) pollutions of typical rural pollutions. Their pollutants entered the river along with the rainfall runoff and polluted the rural water seriously. Meanwhile, a method for synchronization detection of rainfall- runoff producing- pollution producing was employed to clarify the runoff pollution characteristics and laws. Besides, a biological and ecological treatment

引言

太湖水环境问题日益严峻[1]，其中来自于农业生产、居民生活的及家禽养殖等的径流污染是这一现状形成的重要诱因。由于农村粗放的生活方式及用水知识薄弱，水环境负荷日益加重，而相应的环境设施建设滞后，从而引发农村水环境的急剧恶化，以有机物、氮和磷富积为特征的小城镇水环境富营养化呈蔓延趋势[2]。其中径流污染是农村非点源污染的一大因素[21]。降雨径流污染指在降雨径流的淋溶和冲刷作用下，大气、地面和土壤中污染物扩散性的进入地表水和地下而造成的水环境污染，农业生产活动中使用的化肥、农药是最主要的污染源[3]。目前的研究主要集中在城区内的径流水质[4-5]和农村农田地表径流研究[6]，对于典型村庄居民区径流研究较少。

本文对所研究的区域内的典型径流污染源进行了走访调查，确定了家禽养殖区及露天化粪池区径流是典型农村污染严重两大点源污染。在降雨时随径流进入河流，严重污染农村水环境质量。本文采用同步检测降雨-产流-产污的方式， 重点研究了径流两大污染区的径流污

technology- biological detention pond technology- suitable for treating runoff pollutions under rural living conditions was proposed [7; 8].

染特征及规律，并提出适合农村生活条件下处理径流污染的生物生态处理技术-生物滞留池技术 7-8]。

MATERIALS AND METHODS

Area overview and study object

Meijiadu Village, Yixing City is located in the west of Gaocheng Town of the 5 square kilometers area and 580 households in total. There are about 244 scattered small-scale poultry farming households that mainly breed chickens and ducks using free-ranging raising pattern, so the poultry manure cannot be easily collected. The barns are mainly classified into open shed type, simple brick-concrete style and simple wooden assembling type. All of them do not have cushion bedding or manure collection facilities. Hence, the poultry manure pollutants flow to the river directly along with the runoff, thus becoming one of the important pollution sources in rural rivers. In addition, 80% of local farmers have septic tanks, of which 20% are open ones. The manure in open septic tanks flows into ditches and ponds along with the rainfall runoff and eventually into the rivers, thus polluting the water environmental quality seriously and damaging the living environment of villagers.

Based on the local runoff pollution characteristics, poultry farming area and open septic tank as the typical runoff pollution were selected to do the runoff pollution detection, and TN, TP, COD and NH_4^+-N are the major indicators.

材料与方法

地区概况及检测对象

宜兴市梅家渎村位于高塍镇镇西，总面积5平方公里，共580户。当地零散的家禽养殖户约244户，采用分散养殖模式，以鸡鸭为主，规模较小，家禽粪便不易集中收集，棚舍构造主要有开敞型网棚式、简易砖混结构式和简易木板拼搭式三类。此三类家禽棚舍均无垫层铺垫或粪便收集设施，家禽粪便污染随地表径流直接入河，成为农村河流重要污染源之一。另外，当地80%农户设有化粪池，其中20%为露天化粪池。露天化粪池粪便在降雨时随着径流流入沟渠塘，最终流入河流。严重污染水环境质量且破坏了村民的生活环境。

根据当地径流污染特征，选取了较典型径流污染的家禽养殖区和露天化粪池旁进行径流污染检测，主要指标是TN、TP、COD、NH4+-N。

Sample collection and analysis

Within the catchment area of the study area, there are two sampling sites. Since the areas were not frequently cleaned, the surroundings of the open shed type hennery and the septic tank were cleaned to remove the large floating debris and fodders in the early period of rainfall to minimize the effects of the outside factors. During rainfall, synchronous sampling was collected in two sampling sites. To ensure complete detection of rainfall- runoff producing-pollution producing process, the samples were collected at 0-5 min, 5-10 min, 10-15 min, 15-30 min, 30-45 min and 45-60 min respectively within 60 min from runoff formation to stabilization. Since sampling sites had high particle contents at the bottom, the surface runoff samples were obtained by a glass syringe, and then injected into 500 ml polyethylene bottles. Each sample was filled fully in the bottle without air so as not to affect the monitoring. Meanwhile, a measuring cylinder was also placed in the area during sampling, within which the runoff volume was recorded hourly. After sampling, water samples were sent back to the laboratory for analyses. Monitoring indicators included TN, TP, COD, and NH_4^+-N.

The fourth edition of the National Standard Sample Monitoring Method was employed for sample analyses [9]. The pollution degree was determined by comparing the concentrations of various pollutants and the ninth category of water standards in GB-3838-2002 *Quality Standard of Surface Water Environment*.

样品收集与分析

研究区域汇流面积覆盖两个采样点，由于区域内日常打扫次数较少，为减少影响径流特征的外界因素，在降雨前期对开敞型网棚式鸡舍周围进行清扫，以去除较大漂浮物及饲料影响；化粪池旁也进行了清扫。降雨过程中对两个采样点进行同步采样。 为保证能够完整的检测降雨-产流-产污过程， 在径流形成到径流稳定的60分钟内， 按照0-5分钟，5-10分钟，10-15分钟，15-30分钟，30-45分钟，45-60分钟共6个时间段内取样。 由于取样点底部颗粒物含量高，取样时使用玻璃注射器吸取表层径流样，注入到500ml聚乙烯瓶，每样装满不留空气，以免影响监测。采样同时在区域内放置量筒，每小时记一次量筒内径流体积。采样结束后，将水样送回实验室待分析。监测指标包括TN、TP、COD、NH4+-N。

样品分析均采用国家标准第四版样品监测方法[9]。各种污染物浓度与GB-3838-2002 《地表水环境质量标准》中⑼类水标准对比可知其污染程度。

Table 1 ***表1***

Water Quality Testing Methods

Water quality index	***Analysis method***
COD	Potassium dichromate
TP	Potassium persulfate digestion - spectrophotometry
TN	Alkaline potassium persulfate digestion - UV spectrophotometry
NH_4^+-N	Nessler reagent spectrophotometry

Rainfall characteristics

There were four rainfalls occurred during this study, mostly in the evening, and lasted 6-14 hours. The rainfall capacity changed significantly from 5.6 mm to 27.3 mm at the 12th hour. In the selected area, the runoff formation time was postponed by 40-210 min owing to rainfall collection area and rainfall intensity. The characteristic data of the four rainfalls are shown in Table 2.

降雨特征

试验期间共四场降雨，降雨多发生在晚上，历时在6-14小时，降雨量变化明显，从12小时降雨量5.6毫米到27.3毫米。在所选的区域内，受降雨收集面积及降雨强度影响，径流形成时间延后40-210分钟不等。 四次降雨特征列表2如下。

Table 2 / *表2*

Characteristic data of four rainfalls

Rainfall session	*Rainfall time*	*Runoff formation time*	*End time*	*Accumulated rainfall (unit /:mm)*
2013-03-01(3301)	01:30	02:10	07:05	5.6
2013-03-22(3322)	01:40	03:00	07:15	27.3
2013-03-23(3323)	16:45	20:15	23:20	8.2
2013-04-06(3406)	13:10	15:20	05:50	17.6

Calculation of quantitative index

Since the pollutant concentration changes in a rainfall, when study runoff water quality, the event mean concentration (EMCs) from rainfall runoff [10] is mostly utilized to calculate the pollution degree of a rainfall and to compare horizontally. EMCs, as the ratio of total pollutants amount to that of runoff, can be calculated as equation (1).

定量指标的计算.

由于一场降雨中污染物的浓度是变化的，在研究径流水质时，多采用降雨平均浓度[10]（EMCs）计算一场降雨的污染程度并能进行横向比较。EMCs为污染物总量与径流量的比值，可按公式（1）计算。

$$\mathrm{PEMCs} = \frac{\mathrm{M}}{\mathrm{V}} = \frac{\int_0^T \rho(t)q(t)dt}{\int_0^T q(t)dt} = \frac{\sum_0^T \rho(t)q(t)}{\sum_0^T q(t)} \qquad (1)$$

Where PEMCs is the rainfall mean concentration (mg/L), M is the total pollutants amount produced in the rainfall events (mg), V is the rainfall runoff amount (L), $\rho(t)$ is the pollutants mass concentration changed over time (mg/L), $q(t)$ is the flow changed over time (m^3/h), and *t* is the runoff duration (h).

As shown in Table 3, the mean concentration of 3323 is higher than that of 3406, while the value of 3301 exceeds that of 3323. Therefore, EMC was related to the rainfall capacity and the number of sunny days in early period, because the accumulated fallout and stacked poultry excrement were located on the surface in the long-sunny-day areas. In the meantime, the poultry wastewater accumulated on the soil surface of rural area over time. Intense rainfall affected the organic pollutants in soil and the surface particles, leading to more severe pollution of water quality in the initial runoff period. As suggested by the COD values, the two studied regions were subject to severe organic pollution.

式中，PEMCs为降雨平均浓度(mg/L)；M为降雨事件中产生污染物的总量(mg)；V是降雨径流量(L)； $\rho(t)$ 为随时间变化的污染物的质量浓度(mg/L)； $q(t)$ 是随时间变化的流量(m^3/h)；*t*为径流持续时间(h)。

由表3知，场次3323平均浓度比场次3406平均浓度大；场次3301比场次3323平均浓度大。可知事件平均浓度与降雨量和前期晴天数有关。这主要是由于前期晴天数长的地区积累的散落物及堆积的家禽排泄物在区域表层，且家禽污废水在农村区域土壤表层随时间积累。降雨强度大时会冲击土壤中吸收的有机污染物和表层颗粒导致径流初期污染水质污染较高。由COD值可知两个调查区内有机污染负荷严重。

Table 3 / *表3*

Event mean concentrations (EMCs) of different sampling sites (EMCs)

Rainfall session	*Rainfall time*	*Poultry farming area (mg/L)*				*Surroundings of septic tanks (mg/L)*				*Number of sunny days*
		TN	TP	COD	NH_4^+-N	TN	TP	COD	NH_4^+-N	
1(3301)	2013-03-01	7.8	4.3	267	3.2	8.4	3.1	260	2.9	30
2(3322)	2013-03-22	12.5	5.4	240	4.6	11.6	4.3	271	3.2	21
3(3323)	2013-03-23	9.4	4.9	120	3.1	9.1	3.2	120	2.7	1
4(3406)	2013-04-06	10.3	5.0	220	3.2	10	3.5	255	3.1	14

RESULTS AND DISCUSSIONS

Water quality changes of rainfall

1) Rainfall - runoff changes

结果与分析

降雨水质变化

1) 降雨量-径流量变化

选取了2013-03-22中到大雨降雨事件、2013-04-06中

Heavy rainfall event on March 22, 2013 and moderate rainfall event on April 06, 2013 were selected to analyze the rainfall change trend. The runoff volume in the rainfall was calculated according to the hourly flow of rainfall into the cylinder. As presented in Figure 1 and Figure 2, the runoff lagged 0.6-1.1 hours behind rainfall. When the rainfall capacity exceeded 1 mm, runoff formed in the investigated area, with its volume increasing first and then decreasing. Rainfall capacity and runoff volume changed in the same way.

雨事件进行降雨变化趋势特征分析。降雨期间径流量由每小时流入量筒内的体积计算径流量。由图1和图2可以看出径流量滞后降雨0.6-1.1小时。 降雨量大于1mm时， 在调查区环境可形成径流，径流量先增大后减小，降雨量和径流量有着相同的规律

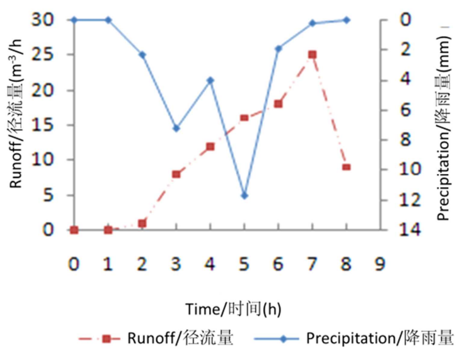

Fig. 1- Runoff duration curve on March 22, 2013

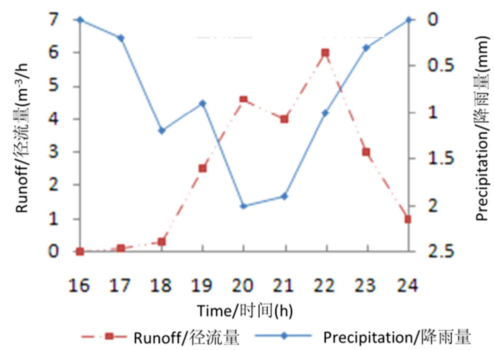

Fig. 2 - Runoff duration curve on April 6, 2013

After the formation of runoff, every runoff in poultry farming area and septic tank behind the house was sampled at different times to get 6 samples. These samples were examined in the laboratory to analyze the runoff water quality changes of TN, TP, COD, and NH_4^+-N.

2) Runoff water quality changes of septic tanks

Rural septic tanks are featured with low rate of harmless manure treatment and poor health status. The environment of most toilets is poor. Without harmless treatment, the environment is polluted directly by fecal residues that are accumulated for a long time and discharged arbitrarily. When raining, the pollutants flow into the surrounding rivers along with runoff, and pollute water quality severely [11]. Owing to the difficulty of sampling, the samples were actually collected 20 meters away from the outlet of runoff, and the test data are shown in Figure 3 - Figure 6.

在径流形成后，分时段每场径流在家禽养殖区和屋后化粪池区各取6个样，带回实验室分析TN、TP、COD、NH4+-N径流水质变化。

2) 化粪池径流水质变化

农村化粪池粪便无害化处理率低，卫生状况不容乐观，大部分厕所内环境条件差，粪渣长期堆积，任意排放，未经无害化处理会直接污染环境，在降雨天气时，随径流流进周边河道，水质污染严重[11]。由于采样不便，在径流出水20米外采样。检测数据如图3-图6所示。

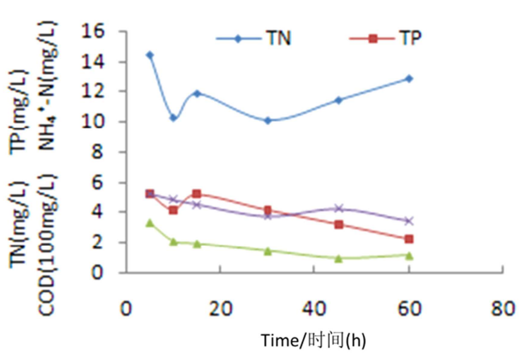

Fig. 3- Rainfall runoff water quality changes in septic tanks on March 22, 2013

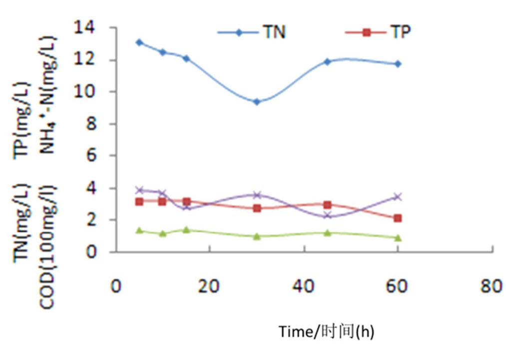

Fig. 4 - Rainfall runoff water quality changes in septic tanks on April 6, 2013

At two different rainfall intensities, each index decreased with extended time (Figure 3 and Figure 4). The water quality changed significantly during the first 20 min and then stabilized. The rainfall of 3322

由图3、图4比较两场不同降雨强度的水质变化，可见各个分析指标随时间整体下降。在最初的20min内水质变化

changed significantly within the first 20 min, indicating that the particles were obviously impacted by the rainfall. Probably, TN concentration decreased before rising while TP concentration dropped steadily owing to the dilution of runoff. COD content decreased over time in the heavy rainfall but fluctuated throughout little rainfall.

3) Runoff water quality changes in poultry farming area

The studied poultry farming area has bred 10 chickens and 4 ducks in the main form of open shed free-ranging, and ducks are placed in the pond next to the hennery. The runoff flowed through the hennery to the pond, so the runoff at the exit of pond was selected. The surface water was sampled due to considerable impurities at the bottom of the pond.

显著，随后趋于稳定。3322场次降雨在前20min内变化明显，说明降雨强度冲击颗粒作用明显。可能是径流稀释作用，TN浓度均经过先下降后又上升的过程，TP浓度稳步下降。COD含量在降雨强度大时随时间下降，降雨强度小时在降雨期间波动。

3) 家禽养殖区径流水质变化

调查的家禽养殖点内养殖鸡10只，鸭子4只，以开敞型网棚式散养为主，鸭在鸡舍旁的池塘。径流经过鸡舍流入池塘，径流选在池塘出口处。由于池塘底部杂质多，取样吸取表层水样进行检测。

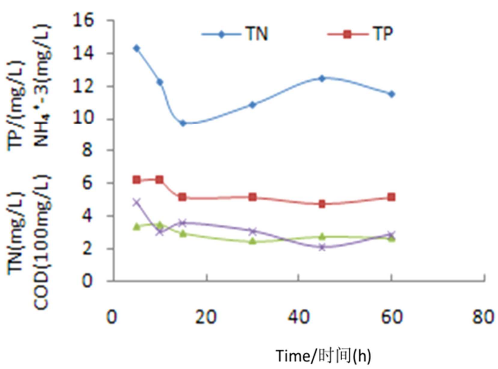

Fig. 5- Rainfall runoff water quality changes in poultry farming area on March 22, 2013

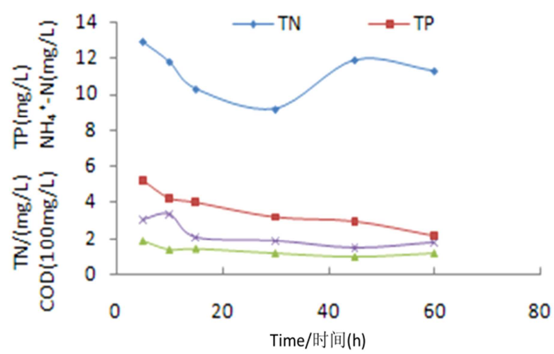

Fig. 6- Runoff water quality changes in poultry farming area on April 6, 2013

As exhibited in Figure 5 and 6, all pollution-related indices in poultry farming areas and septic tank areas decrease over rainfall time in the same way. The difference between various rainfalls affected TP more evidently. Phosphorus mostly adhered to small particles. Upon heavy rainfall, the surrounding soils were scoured and the TP contents changed. In the case of little rainfall, TP concentration in the poultry area was higher than that in the septic tank area, probably because the soils surrounding the poultry area were less firm.

TN concentrations in both detection areas changed in the same pattern of “V”-type, being consistent with the results reported by Su et al. [12]. The low ammonia proportion in the process may be attributed to the low contents of DO and oxygen as well as unobvious nitrification in wastewater. Based on the outcomes of the two rainfalls, the number of sunny days in early period and the rainfall intensity exerted significant effects on water quality, especially on TP and COD.

Effects of runoff water quality features

(1) Functional areas and rainfall intensity

The rainfall in 3322 was selected for analysis. This rainfall lasted for 12 hours with the capacity of 27.3 mm, accompanied by obvious runoff and serious particle scouring. The runoff water qualities in poultry farming area and open septic tank area were compared as the following figures.

由图5、图6可见，家禽养殖区与化粪池区各污染指标变化相似。污染物变化过程均随降雨时间呈减小趋势。不同场次差别对TP影响较大，主要是磷多附着在小颗粒上，降雨强度大时，冲刷周围土壤引起的TP含量变化。家禽区在小降雨强度时TP浓度比化粪池区TP浓度高，可能是因为家禽区周围土壤踩实程度比化粪池周围踩实程度小，颗粒冲刷效果明显。

两个检测区内的TN浓度均呈现“V”型变化，这与苏保林的[12]分析结果类似。过程氨氮比例低，可能是由于废水中DO含量低，氧含量少硝化作用不明显的原因。从两场降雨来看，前期晴天数对和降雨强度对水质作用明显，尤其是TP和COD。

径流水质特征影响分析

(1) 功能区、降雨强度

选用3322场降雨进行分析，该场雨12小时内降雨27.3mm，径流明显，颗粒冲刷严重，对比家禽养殖区和露天化粪池区径流水质比较如图：

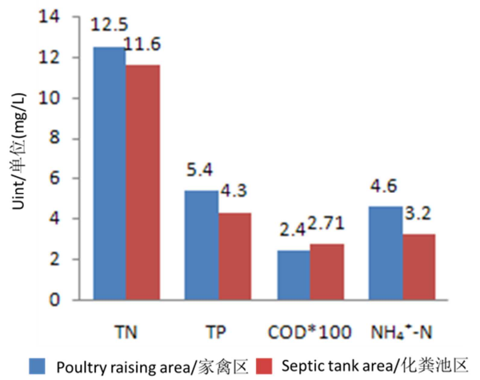

Fig. 7 - Water quality comparison of different functional areas

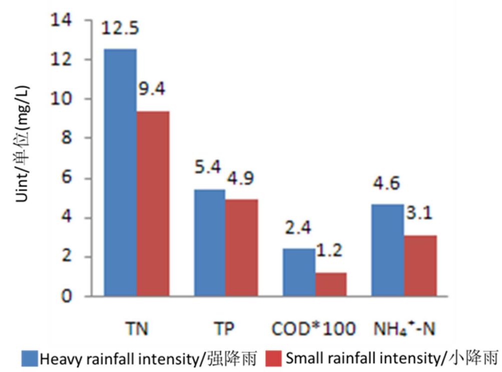

Fig. 8 - Water quality comparison of different rainfall intensities

Within the catchment area, runoff water quality in different functional areas was controlled by soil properties. Both catchment areas in poultry area and septic tank area were manure-containing rains, so the water qualities of two functional areas were similar. Figure 7 shows that TN, TP and NH_4^+-N concentrations in poultry farming area are all higher than those in septic tank area at the same rainfall intensity, while the COD concentration is lower. The results can mainly be ascribed to the higher organic contents of human feces compared to poultry feces. Phosphorus is produced as a non-point source pollutant by a very complex process, and it is subject to the combined effects of rainfall process (rainfall type, intensity and duration) and the underlying surface factors (topography, landform, chemical and physical conditions of the soil, and agricultural time measures, etc.) [13]. The phosphorus concentration in poultry area was higher because phosphorus compounds were generally adsorbed on particulate matters. However, the loose soils around the poultry area rendered them easily to be washed out by the runoff. As shown in Figure 8, in the same functional area, all pollution indices at heavy rainfall intensity are larger than those at small rainfall intensity, suggesting the impact of rainfall scouring is greater than that of dilution. The influence of rainfall duration remains unclear.

(2) Different times

As evidenced by the detected values, the difference between the pollutant concentrations in initial runoff and later runoff was not significant. The pollution value was high within the first 10 min, but total nitrogen increased slightly in the late period. Overall, each index only decreased a little over time. The highest concentrations all appeared before the runoff peaks.

不同功能区地表径流水质差别由汇水面积内土壤性质决定，家禽区和化粪池汇水面积内均是粪便类雨水，因此两功能区水质差别不大。由图7，同一降雨强度下家禽养殖区的TN、TP、NH4+-N浓度均比化粪池区浓度大， COD浓度小于化粪池区，主要是由于人类粪便比家禽有机含量高。磷元素作为非点源污染物，其产生的过程十分复杂，它受降雨过程（降雨类型、强度和持续时间）和下垫面因素（地形、地貌、土壤的化学和物理状况及农业时间措施等）的综合影响[13]。家禽区磷浓度高，是由于磷化合物一般都是吸附在颗粒物上，而家禽区周围土壤疏松，易被径流冲刷出。由图8知，对于同一功能区，强降雨强度下各污染指标均高于小降雨强度下的指标。说明降雨冲刷造成的影响比稀释作用大。降雨历时造成的影响还有待观测。

(2) 不同时段

由检测值可以看出，初期径流和后端径流中污染物的浓度差别不显著，前10min内污染值高，但总氮在后期又有所回升。整体各指标随时间变化较小，呈小幅下降趋势。浓度最高时刻均出现在径流峰值之前。

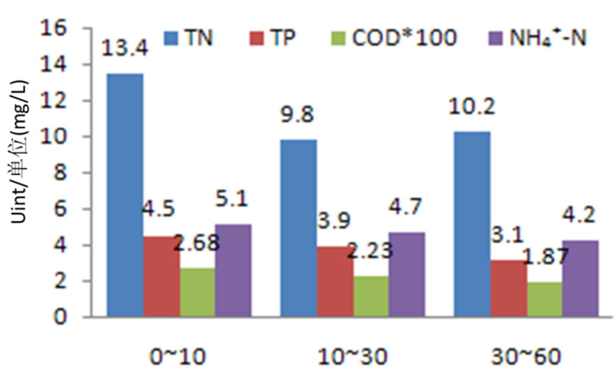

Fig. 9 - Water quality comparison of different times

Rural runoff treatment technology

The traditional rural rainwater drain method of overflowing anywhere has many drawbacks. Rainwater runoff management measure has been widely studied to meet multiple benefits of environment, ecology and economy, which is one of the problems that rural runoff encounters.

Rural surface source pollution has been well treated by constructed wetlands [14-15], with the removal rates of NH_4^+-N, TN and TP being higher than 80%. Slope buffer zone can also improve the river water quality in stagnant runoff pollution effectively [16]. Rainwater storage tanks, shallow trench and ponds of vegetation [17], and multiple BMPs ecological processing have been widely used to handle runoff pollution in rural areas, of which biological detention pond is a novel, eligible runoff treatment technology. It has been successfully applied to treat runoff pollutants [18-20]. According to rural land conditions and soil properties, runoff pollution can be feasibly treated by biological and ecological approach. Especially, combined ecological processing technology has been proposed for runoff pollution disposal in poultry farming sites and areas next to the improved septic tank. This technology costs a little for running, but it can significantly improve water quality by partial reuse of treated water and by supplementing the residual into the groundwater.

农村径流处理技术

传统的农村雨水排水方式是随地漫流，这种方式存在诸多弊端。探求如何满足环境、生态、经济等多重效益的雨水径流管理措施，是农村径流面临的问题之一。

人工湿地处理农村面源污染取得了很好的效果 [14-15]，对NH4+-N、TN、TP的去除率均在80%以上。坡度缓冲带在滞缓径流污染中也有效改善了河道水质[16]。雨水调蓄池、植被浅沟、塘等[17]多种BMPs生态处理技术已广泛用于处理农村径流污染，其中生物滞留池技术作为新兴的径流处理技术逐渐被应用于径流污染物[18-20]取得很好的效果。对于农村用地条件及土壤性质，采用生物生态方式处理径流污染是可行的。建议在家禽养殖点及改善的化粪池旁可采取组合生态处理技术处理径流污染，运行费用小且能明显改善水质，处理水部分回用，其余补充地下水。

CONCLUSIONS

(1) At different rainfall intensities, runoff formations were delayed by 40-210 min. Runoff formed in the survey area when precipitation exceeded 1 mm;

(2) The runoff and precipitation changed similarly: both increased first and then decreased;

(3) Water qualities in poultry farming site and septic tank area both changed in the TN's “V”-type pattern, with low ammonia proportions. TP and COD fluctuated less after the stabilization of runoff. At the same rainfall intensity, TP concentration in poultry area was higher than that in septic tank area;

(4) The pollution value was highest within the first 10 min before runoff formation and the water quality concentration decreased after stabilization. Both of their values were lower than the initial ones.

结论

（1）对于不同降雨强度，径流形成时间延后40-210min。降雨量大于1mm时在调查区内可形成径流；

（2）径流量和降雨量变化规律相似，均先增大后减小；

（3）家禽养殖点和化粪池区水质变化规律相同，TN均出现“V”型变化，氨氮浓度比例低。TP和COD变化趋势相同，径流稳定后波动较小。家禽区TP浓度在相同雨强时比化粪池区浓度高；

（4）在径流形成前10min内污染值最高，稳定后水质浓度下降，均低于初始值。

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