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# The treatment performance and nutrient removal of a garden land infiltration system receiving dairy farm wastewater

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ABSTRACT

Livestock wastewater is a major source of agricultural non-point pollution. Land treatment system is appropriate for livestock sewage treatment due to its low construction cost and high treatment performance. In this study, a garden land infiltration system (GLIS) was established to treat dairy farm wastewater. Our main concern was nutrient removal and plant uptake when the system is in operation. The removal rates in the outflow water of suspended solids (SS), $NH_4^+$—N, total N (TN), total P (TP), chemical oxygen demand (COD), and total organic carbon (TOC) were 86.1%, 78.0%, 78.2%, 94.6%, 76.8%, and 74.6%, respectively. Approximately 79.4–81.6 kg/ha of nitrogen and 9.1–13.1 kg/ha of phosphorus were removed from the system by ryegrass harvesting, which accounted for 14.5–14.9% and 17.0–24.6% of the TN and TP in the effluent, respectively. These results demonstrate that the system has the advantage of high performance efficiency and has the potential for greater nutrient removal by plant uptake. Therefore, a GLIS can be considered as a viable alternative for dairy farm wastewater treatment in rural areas.



## 1. Introduction

The livestock industry in China has developed rapidly in recent years along with rapid growth in the national economy and the increasing standard of living. An ecological mode of breeding, biogas, and irrigation is widely used (Yu et al., 2011). Approximately 26,600 poultry and livestock farm biogas projects had been built in China by the end of 2007 (Zhang et al., 2009). However, several established biogas digesters are not used due to problems with equipment, technology, and other relevant issues (Zhang and Lai, 2007). Biogas slurry is a high-quality organic liquid fertilizer when produced normally (Zhang, 2008). On the contrary, the digesters could become storage ponds for livestock wastewater if they are not in normal operation. Wastewater from the ponds could enter the environment through surface runoff or groundwater infiltration (Knight et al., 2000). As a result, the agricultural value of the wastewater would be lost, and the water body would become polluted.

Only a few wastewater treatment plants processing human waste can be found in the rural areas in China because they are expensive to build and operate (Massoud et al., 2009). Moreover, underground sewers are limited in rural areas (She and Luo, 2007). A nature-based method is environmental-friendly, cost-effective, and highly efficient (Kayser and Kunst, 2002). Thus, this method is favored by an increasing number of researchers (Craggs et al., 2004; Knight et al., 2000; Paranychianakis et al., 2006; Kayser and Kunst, 2002). Land treatment is a nature-based method and is the oldest practice for wastewater management and environmental pollution control (Tzanakakis et al., 2007a). Moreover, a land treatment system is an appropriate technology for small rural communities, clusters of homes, and small industrial units because of its low energy demands and low operation and maintenance costs (Paranychianakis et al., 2006). At present, many authors have studied the land application of livestock wastewater, mostly with pastureland (Phillips, 2002; Adeli et al., 2003; Cantrell et al., 2009). In addition, livestock wastewater, after primary treatment, was applied as a fertilizer for crop growth in some studies (Hoff et al., 1981; Woodard et al., 2002; Jacobs and Ward, 2007). However, the traditional land treatment system, often referred to as the slow-rate system, has some disadvantages. For example, the hydraulic loading rate is comparatively small (0.5–6 m/y) and the site area is often very large (23–280 ha) (US EPA, 2006). Therefore, several

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researchers have modified the system to adapt to local conditions and influent quality (Christen et al., 2010; Hatt et al., 2007; Wang et al., 2010).

Land resources are increasingly scarce in China, especially in the Yangtze River Delta where land possession per capita was only 18.2% of the national average according to statistical yearbooks (NSBC, 2010; SBJS, 2010; SBSH, 2010; SBZJ, 2010). Therefore, there is limited idle land for wastewater treatment. However, there are potentially 998,000 ha in garden land area in the Yangtze River Delta, including Shanghai, Jiangsu, and Zhejiang province in 2008 (NSBC, 2010). Accordingly, garden land was chosen for decentralized wastewater treatment in this region (Duan et al., 2014). To the best of our knowledge, no reports have previously studied dairy farm wastewater treatment in vineyards with laid-in subsurface drains.

Forage vegetation can substantially improve the potential of land treatment system for nutrient removal because, unlike grain production systems, nearly all aboveground biomass is removed during harvest (Paranychianakis et al., 2006; Woodard et al., 2002). For instance, 465, 528, and 585 kg N/ha per cycle were removed by a Bermuda grass–rye system for the low, medium, and high rates of dairy effluent, respectively, during a study of four 12-month cycles (Woodard et al., 2002). Ryegrass has often been advocated in land treatment systems because it is a common forage crop (Barton et al., 2005; Jayawardane et al., 2001).

In the present study, a garden land infiltration system (GLIS) was established in a vineyard. Dairy farm wastewater was applied to the experimental site six times after grape harvest. The system was evaluated for performance efficiency and plant uptake of nitrogen and phosphorus.

## 2. Methods

### 2.1. Vineyard site

The study was conducted in a vineyard in Houhong village, which is located in the northeast of Yixing City (31°28′N, 119°58′E), Jiangsu, China. The experimental site is in the subtropical region, with a mild and humid climate with an average annual precipitation of 1177 mm. The soil at the site was classified as a silty clay loam. The physical and chemical properties of the soil are shown in Table 1. The vineyard covered an area of nearly 6000 $m^2$ with six-year old Euramerican Summer Black grown on it. The planting distances of the vines were 1.00 and 2.5 m within and between double rows, respectively. There were four treatment plots (A, B, C, and D) and a control plot (CK), each with three replicates. The subsurface drainage system was installed in plots A and D in July. Ryegrass was intercropped in plots A and B on October 5, replanted on October 20, and was cut on November 28 and December 16. Plots C had no drainage and no ryegrass. The CK plot was irrigated with river water. Each plot covered 75 $m^2$, with an aspect ratio of 3:1. The experimental design was surrounded by additional plots to minimize edge effects.

### 2.2. Design and operating parameters

The wastewater pumped from an anaerobic lagoon was produced by a nearby dairy farm with approximately 400 cows. The structure of the distribution system is shown in Fig. 1. Double-row perforated-pipe irrigation was applied to distribute the wastewater. This distribution system was evenly placed on the ground. The capillary was made of polyethylene plastic pipes with 12-mm diameter. Holes with 50-cm hole spacing and 1.0-mm hole diameter perforated on the pipe through laser punching. The distance between the capillary and the plant was 62.5 cm. Hydraulic

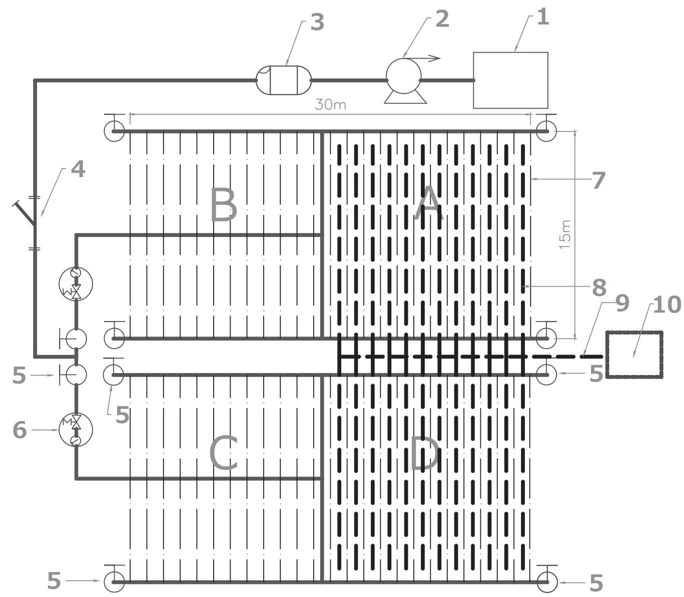


**Fig. 1.** Schematic diagram of distribution system and drainage system. 1—Anaerobic lagoon, 2—pump, 3—grit filter, 4—screen filter, 5—valve, 6—water meter and electromagnetic valve, 7—capillary, 8—drainage pipe, 9—collecting pipe, 10—well. (A) Intercropped with ryegrass with installed subsurface drainage; (B) intercropped ryegrass without installed subsurface drainage; (C) no ryegrass and no subsurface drainage; (D) no ryegrass with installed subsurface drainage.

performance tests of the pipe showed that the irrigation uniformity was 85.4% and 96.8% under pressures of 0.01 and 0.02 MPa, respectively.

The subsurface drainage pipe was made of HDPE double-wall corrugated pipe with a diameter of 10 cm. A layer of geomembrane was wrapped around the pipe to prevent plugging. The collecting pipes were vertical to the drainage pipes, and the gradient slope of collecting pipes was 1%. Drainage pipes were buried at 60 cm depth, with a pipe spacing of 2.5 m. The effluent was collected in the catchment through drainage and collecting pipes (Figs. 1 and 2).

The hydraulic loading rates for the entire treatment area were calculated based on the crop water requirement of the *Crop*

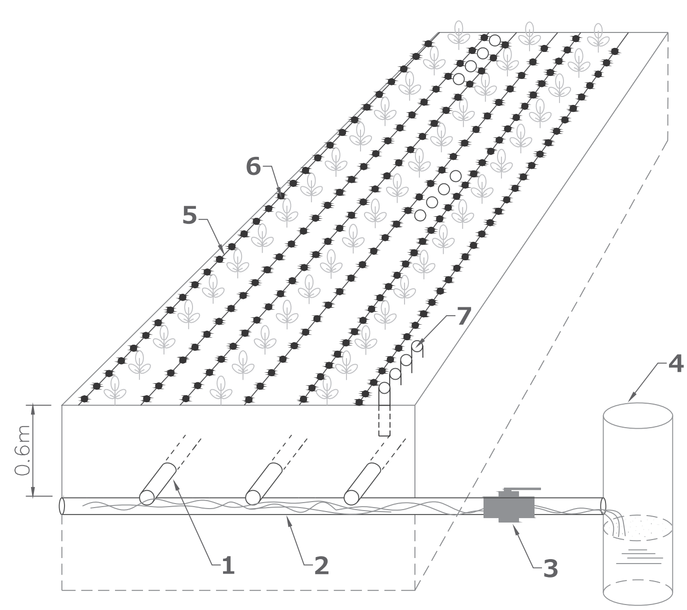


**Fig. 2.** Surface distribution system and underground drainage system. 1—Drainage pipe, 2—collecting pipe, 3—ball valve, 4—well, 5—capillary, 6—hole on the capillary, 7—soil percolation pipe.