TREATMENT AND UTILIZATION OF SEPTIC TANK EFFLUENT USING VERTICAL FLOW CONSTRUCTED WETLANDS AND HYDROPONIC CULTIVATION OF VEGETABLES

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1. Introduction

In traditional Chinese agriculture, human faeces and urine were used separately by householes to the soil as organic fertilizer in order to provide nutrients for crop growth and to reduce soil deterioration. This system could supply human being with organic foods such as cereals and vegetables. This recycling form was well known as organic agriculture. However, in urbanization areas, human faeces and urine of city dwellers could not be returned to the soil due to the larger amount of human excreta output and the pressure of communication and transportation between cities and rural areas. Although it should be the best organic fertilizer for agricultural use since it contains high nitrogen and phosphorus in human urine and excreta, it is becoming into very important pollution source of eutrophication in water body, and should be sent to the secondary biological treatment plant for reduction of nitrogen and phosphorus. This procedure not only needs capital investment, but also wastes energy and nutrient resources.

The objectives of this study were: (1) to use the combination system of septic tank and CWs for domestic wastewater treatment and to make the treated effluent for detoxification, disinfection, oxygenation, and sanitation; (2) to use nutrients in treated effluent from the combined treatment system for hydroponic cultivation of vegetable and to purify wastewater further by plant root system; (3) to plant ornamental plants and other commercial flowers in vertical-flow constructed wetlands surface for enhancing its economic benefit and esthetic value; (4) to build up a pilot- scale plant for decentralized ecological wastewater treatment and utilization in urbanized areas.

2. Materials and methods

2.1 Flow system.

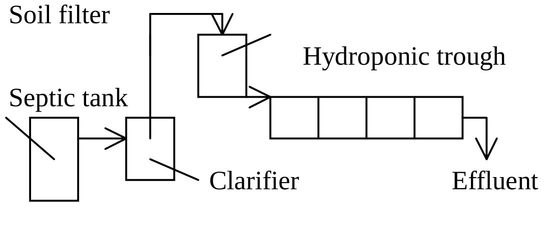

Fig. 1 Diagram of filter and hydroponic system

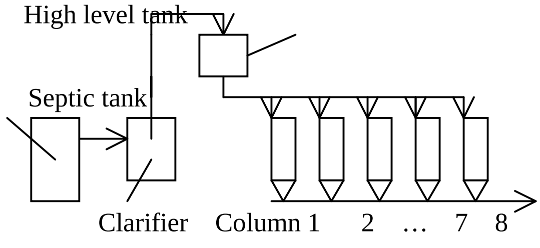

Fig. 2　Schematic of vertical flow system

2.2 System parameter.

Artificial soil filter, with 1m^2 of surface area and 1.3m high, was filled with 20cm gravel in the bottom and followed 90cm artificial soil. Hydroponic cultivation of vegetable, with 4m^2 of surface area and 0.4m high, divided to 4 parts, was designed for two serials. Each serial contains two parts. Serial 1 was water spinach (in Fall) and tomato (in Spring), serial 2 was romaine lettuce (in Fall) and cherry tomato (in Spring).

Vertical flow constructed wetlands, with two beds (each bed: 1.86mL×1.68mW×

1.2mD), were filled with 10cm high gravel in the bottom and followed with 100cm mixed substrate. Bed 1 was filled with artificial soil and planted with *Canna generalis*. Bed 2 was filled with the mixture of sand and topsoil and planted with ornamental plants like pink, lily, rose, and gladiolus etc.

2.3 Wastewater used in the experiment.
Wastewater used for experiment was pumped from septic tank effluent of W.C. in Building 5, South China Agricultural University. The monitoring results showed that this septic tank effluent concentration of organics is similar to municipal wastewater. COD ranged from 120 to 400mg/l and BOD_5 from 60 to 150mg/l. TN averaged from 10 to 50mg/l and TP from 1.5 to 12mg/l.

2.4 Operation and maintenance.
Artificial soil filter was operated from Sept. to June next year. It was continuously flooded 2 hours every 3 days followed by dry period for 70 hours. The treatment capacity and hydraulic loading rate were $0.6m^3$ and 20cm/d, respectively. The treated effluent was used to fill hydropnoic trough hydroponic cultivation of vegetables. The hydraulic retention time (HRT) was 5.4d.

3. Results and discussions

3.1 The removal effect of COD and BOD_5 by the artificial soil filter and hydroponic system

The effluent concentration of COD in septic tank, artificial soil filter and hydroponic basin was monitored during experimental period. The concentration of COD in septic tank effluent ranged from 120 to 180mg/l, and reduced to 60 to 80mg/l after artificial soil filter treatment. The average removal rate of COD in artificial soil filter was less than 60%. It is because of its long drying period, fast infiltration rate, low hydraulic loading rate and pollutant loading rate. Although the concentration of COD in the treated effluent after hydroponic cultivation of vegetable was less than 45mg/l and could meet the integrated wastewater discharge standard (IWDS) for secondary biological treatment plant, the removal rate of COD for the whole system was 71.4%. It was most likely due to the low temperature and slow growth of vegetable in the late autumn.

The effluent concentration of BOD_5 in septic tank, artificial soil filter and hydroponic basin was also monitored during the experiment period. Data showed that the concentration of BOD_5 in raw sewage was about 60mg/l, and averaged 10mg/l after being treated by artificial soil filter. It not only meets the integrated wastewater discharge standard for secondary biological treatment plant, but also is superior to the quality standards for irrigation water. The concentration of BOD_5 in the treated effluent dropped to 2mg/l after being treated by hydroponic cultivation of water spinach and romaine lettuce, and could reach the first level of the environmental quality standard (2mg/l) for surface water. The removal rate of BOD_5 by the system 1 was high up to 97.5%.

3.2 The removal effect of SS by the artificial soil filter and hydroponic system

The concentration of SS in the septic tank effluent was high, averaged 250mg/l. This high SS content effluent was directly pumped to the artificial filter without any primary treatment so that the SS concentration in the treated effluent was still higher than 60mg/l, and its removal rate averaged 73.6%. The reason is that the infiltrate rate of artificial soil filter was so fast that the SS concentration in the treated effluent was high, but the SS concentration in the final treated effluent was less than 10mg/l after being treated by hydroponic cultivation of water spinach and romaine lettuce. The water quality was superior to the IWDS for secondary biological treatment plant. The removal rate of SS by the system 1 was high up to 96.9%.

3.3 The removal effect of TN and TP by the artificial soil filter and hydroponic system

The effluent concentration of TN in the septic tank averaged only 10mg/l, but the TN concentration in the treated effluent varied slightly with a range of 3.73-6.04mg/l. Although the average removal rate of TN was only 49% by artificial soil filter, it could supply sufficient nitrogen for hydroponic cultivation of vegetables followed. Both ammonia nitrogen and nitrate nitrogen were absorbed and assimilated, and transmitted to organic nitrogen in plant body by vegetables culture. The concentration of TN in the treated effluent was lower than 1.5mg/l after being treated by hydroponic cultivation of water spinach and romaine lettuce, and could reach the fourth level of the environmental quality standard (2.0mg/l) for surface water. The removal rate of TN by the system 1 was 86.3%, and almost reached the tertiary treatment level.

The concentration of TP in septic tank effluent ranged from 1.5 to 2.0mg/l during experimental period. The average removal rate of TP by artificial soil filter was 78.7%, and the effluent concentration of TP ranged from 0.3 to 0.42 mg/l. It fitted to the IWDS (0.5mg/l) for secondary biological treatment plant. After taking up by hydroponic cultivation of vegetables, the concentration of TP in the final treated effluent was slightly high than 0.20mg/l, and almost reached the fourth level of the environmental quality standard (0.20mg/l) for surface water. The average removal efficiency of TP for septic tank effluent by the system 1 was 87.4%.

3.4 Effect on the quality of hydroponic vegetable cultivated by using treated effluent

Both hydroponic cultivation of romaine lettuce using nutrient solution in greenhouse and soil cultivation of romaine lettuce in field were also conducted as control when the experiment of hydroponic cultivation of romaine lettuce using treated effluent was studied. The quality analysis for romaine lettuce was measured. Coarse protein was accounted on percentage of dry matter. The results showed that the nitrate content in romaine lettuce hydroponicly cultivated by using treated effluent was the lowest, without adding any fertilizer. The content of vitamin C, coarse protein, and soluble sugar in romaine lettuce under three kinds of cultivation was no significant difference. For the output of vegetable, the nutrient solution hydroponic cultivation was higher than that of treated effluent hydroponic cultivation, and the latter was high than that of field soil cultivation.

3.5 The removal effect of total bacteria and coliform index by the VFCW treatment system

The vertical flow constructed wetland systems, which including two beds and eight columns, have being operated for nine months and three months, respectively. The total bacteria and coliform index in the treated effluent were measured recently. The result showed that the removal rates of total bacteria and coliform index for VFCW (bed) system of mixture, which used sand as main substrate, were 70% and 80%, respectively. And lower than that of mixture used cinder slag as main substrate. The removal rates of above two indexes by the mixture of cinder substrate were 80-90% and 85-96%, respectively. Especially in low hydraulic loading rate, the removal rates of above two indexes by the mixture of cinder substrate were 93.6% and 99.9%, respectively. The effluent quality was well fitted to environmental quality standard for surface water.

3.6 The removal effect for septic tank effluent by the VFCW treatment system

Bed 1 and bed 2 of VFCW system have been operated for 200 days till now. The treatment capacities of bed 1 and bed 2 were recorded by water meter, and showed that the total treatment capacities were 134.8m^3 and 124.8m^3, respectively. So the hydraulic loading rates of bed 1 and bed 2 were 21.6cm/d and 20.0cm/d, respectively. And the effluent quality from bed 1 and bed 2 was monitored. The results showed that the removal rates of BOD_5 and NH_4^+-N were going up with prolonged operation time. But this phenomenon was not showed for COD and TP. The removal rates of COD and TP most likely have relationship with inflow concentration of COD and TP. The higher inflow concentration of COD was treated, the higher removal rate of COD could get. Nevertheless, the higher inflow concentration of TP was treated, the lower removal rate of TP gained. In addition, compared bed 1 with bed 2 for removal rates, the removal rates of COD， NH_4^+-N, and TP for Bed 1 were better than that of Bed 2. This may attribute to the turf added in bed 1. However, the removal rate of BOD_5 for bed 2 was better than that of bed 1. This means that the removal rate of BOD_5 has no relationship with turf added.