Journal of Environmental Sciences Vol. 17, No. 1, pp. 59—61, 2005

ISSN 1001—0742
CN11—2629/X

Article ID: 1001-0742(2005)01-0059-03 **CLC number**: X171; X703 **Document code**: A

Synchronous municipal sewerage-sludge stabilization

Godefroid Bukuru, Yang Jian

(School of Environment Science and Engineering, Tongji University, Shanghai 200092, China. E-mail: gbukuru@caramail.com)

Abstract: A study on a pilot plant accomplishing synchronous municipal sewerage-sludge stabilization was conducted at a municipal sewerage treatment plant. Stabilization of sewerage and sludge is achieved in three-step process: anaerobic reactor, roughing filter and a microbial-earthworm-ecofilter. The integrated ecofilter utilizes an artificial ecosystem to degrade and stabilize the sewerage and sludge. When the hydraulic retention time(HRT) of the anaerobic reactor is 6 h, the hydraulic load(HL) of the bio-filter is 16 $m^3/(m^2 \cdot d)$, the HL of the eco-filter is 5 $m^3/(m^2 \cdot d)$, the recycle ratio of nitrified liquor is 1.5, the removal efficiency is 83%—89% for COD_{Cr}, 94%—96% for BOD_5, 96%—98% for SS, and 76%—95% for NH_3-N. The whole system realizes the zero emission of sludge, and has the characteristics of saving energy consumption and operational costs.

Keywords: municipal sewerage; sludge, microorganisms; earthworms; synchronous treatment

Introduction

The main purpose of wastewater treatment is to remove solids and BOD from the wastewater before the liquid effluent is released to a convenient, nearby body of water. What remains to be disposed of is a mixture of solids and water, called sludge. The collection, processing, and disposal of sludge can be the most costly and complex aspect of wastewater treatment. Many developing countries can not afford the cost of the sludge wasting line.

Therefore the aim of the research was to develop a system that can simultaneously achieve wastewater and sludge stabilization using innovative and clean technology that involves minimum capital expenditure.

Criteria to achieve organics stabilization and less sludge production are well known for the anaerobic system. And trickling filters are not normally constructed to achieve denitrification.

The adopted system combines the advantages of the anaerobic reactor-trickling filter system and incorporates an earthworm-eco-filter in order: (1) to improve and support the purification capacity of the anaerobic reactor-trickling filter system, (2) to stabilize and transform the sludge into useful resource with less operational cost, energy supply, and minimum maintenance expenditure and cleaning work compared to the traditional sludge wasting line.

1 Test procedures

1.1 Pilot plant and media

The pilot plant(Fig.1) is located at Shanghai Quyang Wastewater Treatment Plant. The primary effluent and return nitrified liquor are mixed in the influent wastewater tank. The influent wastewater flows up from the bottom of the anaerobic reactor first through the sludge blanket then through fibrous packing placed above the sludge blanket. The effluent collected at the top of the anaerobic reactor is directed to the roughing filter. The bed of the roughing filter is made of fibrous packing in the upper portion of the filter and granular-medium(CERAMSITE) in the lower portion, and is arranged in order to ensure good ventilation.

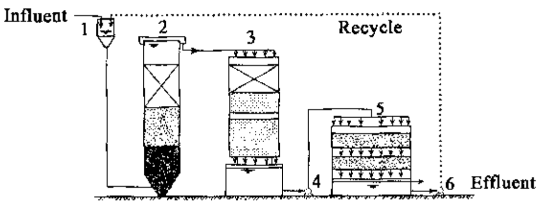

Fig.1 Schematic of the experimental system
1. influent tank; 2. anaerobic reactor; 3. roughing filter; 4. rising pump; 5. eco-filter; 6. return nitrified liquor pump

The effluent collected at the bottom of the roughing filter is pumped to the eco-filter. The bed of the eco-filter is composed of granular material (grit from plants) and earthworms. The anaerobic reactor is 0.6 m in diameter, 6.0 m in height. The roughing filter is 0.7 m long, 0.7 m wide, 4.5 m high. The earthworm bed is 1.0 m long, 1.0 m wide and 1.6 m high.

1.2 Experimental conditions and analytical procedures

The experiments were conducted using the primary effluent(P.E) from the full-scale facility with an average COD of 447 mg/L, NH_3-N of 35 mg/L, and SS 168 mg/L. The hydraulic retention time(HRT) varied from 3 to 7 h for the anaerobic reactor, the hydraulic loading(HL) varied from 10 to 25 $m^3/(m^2 \cdot d)$ for the roughing filter, and the hydraulic loading(HL) varied from 5.0 to 8.0 $m^3/(m^2 \cdot d)$ for the eco-filter. The system (anaerobic reactor) was inoculated with settled sludge from Quyang Wastewater Treatment Plant. A steady-state condition was assumed to have been attained(after three weeks of acclimation) when variations in the effluent COD and NH_3-N were less than 20 and 5 mg/L, respectively, over three consecutive days. The pilot plant was operated for more than one year. A complete check of the pilot plant was made everyday. During this survey the equipment (pumps) was inspected to ensure mechanical integrity. Flow rates were measured and adjustments to flow were made when necessary. At the same time, flow distribution system was cleaned. The analytical procedures, including COD, BOD_5, NH_3-N, SS, etc., were as outlined in the Standard Methods for the Examination of Water and Wastewater.

2 Results and analysis

2.1 Sewerage treatment efficiency

Removal efficiency of the process operating under a HRT of 6 h for the anaerobic reactor, a HL of 16 $m^3/(m^2 \cdot d)$ for the roughing filter, a HL of 5.0 $m^3/(m^2 \cdot d)$ for the eco-filter, and a recycle ratio of 1.5 is shown in Table 1 and Table 2.

Table 1 Removal efficiency of organic

No.	Temperature, ℃	COD_{Cr}, mg/L Inf.	Eff.	Rem. %	BOD_5, mg/L Inf.	Eff.	Rem. %	SS, mg/L Inf.	Eff.	Rem. %
1	9	526	58.0	89.0	218	7.9	96.4	226	4.2	98.1
2	11	423	55.3	86.9	176	8.1	95.4	175	2.9	98.3
3	14	419	52.9	87.4	159	9.3	94.2	202	3.3	98.4
4	15	486	49.8	89.8	167	8.5	94.9	156	4.4	97.2
5	18	454	52.0	88.5	182	7.6	95.8	158	2.1	97.3
6	20	472	55.4	88.3	173	6.7	96.1	163	2.5	98.5
7	23	413	48.2	88.3	158	6.8	95.7	139	2.3	98.3
8	26	372	45.6	87.7	145	7.5	94.8	142	2.8	98.0
9	30	388	52.9	86.4	139	6.6	95.3	164	3.3	98.0
10	31	365	50.5	86.2	148	7.2	95.1	154	2.8	98.2
	Average	432	52.1	87.9	166	7.6	95.4	168	3.1	98
	STDEV	52.1	3.7	1.15	22.9	0.9	0.7	27	0.8	0.4

Table 2 Removal efficiency of NH_3-N and TN

No.	Temperature, ℃	TN, mg/L Inf.	Eff.	Rem. %	NH_3-N, mg/L Inf.	Eff.	Rem. %
1	9	41.2	17.3	58.0	32.4	7.5	76.9
2	11	40.6	15.7	61.3	31.5	6.4	79.7
3	14	42.7	16.2	62.1	34.3	5.9	82.8
4	15	47.1	16.4	65.2	37.7	4.8	87.3
5	18	48.4	15.6	67.8	38.5	3.5	90.9
6	20	51.6	14.1	72.7	38.6	1.8	95.3
7	23	44.9	10.6	76.4	34.6	1.6	95.4
8	26	41.5	12.8	69.2	30.3	1.3	95.7
9	30	35.2	13.6	61.4	25.4	1.5	94.1
10	31	32.9	11.8	64.1	26.4	1.4	94.7
	Average	42.6	14.4	65.8	32.9	3.6	89.3
	STDEV	5.7	2.2	5.7	4.7	2.4	7.1

It can be seen from Table 1 and Table 2 that the process achieves not only remarkable removal ratio for BOD_5 and SS, but also high removal ratio for NH_3-N and TN. The concentration of the effluent TN is steadily 10—18 mg/L, with a removal ratio of 58%—76%. The concentration of the effluent NH_3-N is steadily 1.3—7.5 mg/L and its removal ratio is 76%—95%. But compared with the removal ratio of the organics, the removal ratio of NH_3-N and TN is influenced by the temperature(Fig.2), but still can reach the first class standard of GB 18918—2002.

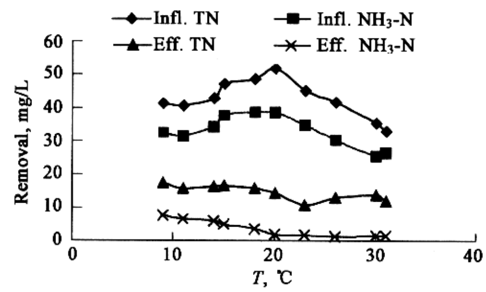

Fig.2 Influence of the temperature on NH_3-N and TN removal

2.2 Sludge stabilization

Experimental observations indicated that the microorganism-earthworm integrated biological treatment process do not need residual sludge drainage and can steadily operate on the long term. In fact, the process has two important characteristics. First the anaerobic reactor can digest and reduce the organic suspended solid in the sludge blanket and as the fibrous media above the sludge blanket provide solids capture, it can realize the "zero emission" of primary settling tank. Secondly effluent from the roughing filter contains sloughed sludge, which (along with the organics) is reduced and stabilized in the succeeding earthworm reactor(eco-filter). The earthworm is, in fact, a kind of sludge digester: the sludge is softened by the grume excreted in the "mouth" of the earthworm before it goes to esophagus where it is neutralized by calcium excreted by the inner sides of the esophagus. Then it comes into intestines where it is absorbed and decomposed by enzymes. Finally, the stabilized sludge is discharged in the eco-filter as excrements(Fig.3).

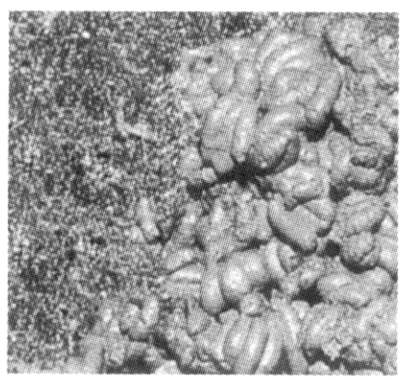

Fig.3 Excrement of earthworm

2.3 Environmental impacts

In the earthworm reactor the earthworm feces can be decomposed and utilized by other microorganisms. Thus an ecosystem composed of earthworms-microorganisms is established in the bio-filter providing reduction of pollutants and pathogens in the wastewater. The action of the ecosystem in the bio-filter is: (1) absorption and decomposition of the sludge; (2) to facilitate nitrification-denitrification process within bio-films; (3) to clean and prevent the filter bed from plugging(Elliot, 1991).

An outcome of the eco-conversion of sludge is the multiplication of earthworms in the eco-filter (Fig. 4). However, according to observations, the quantity of the earthworm in the filter is mainly restrained by the food. When the influent sludge is constant, the observed multiplication of the earthworm is little, and is kept at about 8 thousand per square meter. On the other hand, earthworms can be used as poultry forage. The earthworm feces are rich in nutrient element such as nitrogen, phosphorus and potassium(Table 3), and can be used as a kind of additive or fertilizer for soil improvement (White, 1997; Bouche, 1998). The organic component of the earthworm feces is stable and the emission of odors during cleaning is insignificant.

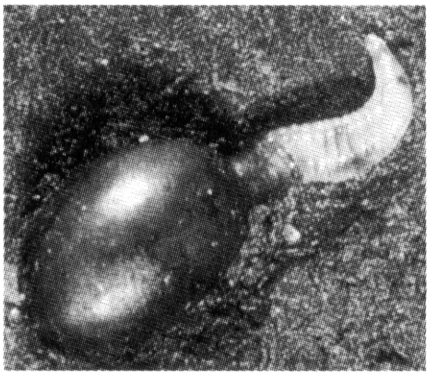

Fig.3 Hatch of earthworm

Table 3 Nutrient elements contained in the earthworm feces

Item	Nitrogen, %	Phosphorus, %	Potassium, %
Earthworm feces from eco-filter	1.16	1.22	1.00
Earthworm feces from breed	1.12	1.21	1.34

Compared with common treatment processes, the process has the advantage of minimizing the quantity of secondary pollutant, and has the remarkable characteristic of a clean technology.

3 Conclusions

The experimental results of the microorganism-earthworm integrated biological treatment process showed that when the HRT of the anaerobic reactor is 6.0 h, the HL of the roughing filter is 16 $m^3/(m^2 \cdot d)$ and the HL of the earthworm reactor is 5.0 $m^3/(m^2 \cdot d)$ and the recycle ratio of the nitrified liquor is 1.5, the removal ratio of COD_{Cr} is 83%—89%, the removal ratio of BOD_5 is 94%—96%, the removal ratio of SS is 96%—98% and the removal ratio of NH_3-N is 76%—95%. The whole system realizes the Zero Emission of the primary settling sludge.

It is obvious that the process can save operational cost because of the synchronous treatment of the sewerage and sludge. The process can also reduce the energy consumption as it uses energy only for pumps.

The process has the advantage of transforming the waste sludge into useful resource for agricultural use. The quantity of secondary pollutant is much less than that of other traditional biological treatment processes.

References:

Bouche M B, Qiu J P, 1998. Contributions des lombriciens aux etudes environnementales concretes[J]. Doc Pedozool Integrol, 3(8): 225—252.

Elliot P W, Knight D, Anderson J M, 1991. Variables controlling de-nitrification from earthworm cast and soil in permanent pastures[J]. Biol Fertil Soils, 11: 24—29.

White S, 1997. A vermi-adventure in India[J]. Worm Digest, 15: 1; 27; 30.

(Received for review March 31, 2004. Accepted May 13, 2004)

Introduction to author's research group

(1) Earthworm-microbial ecofilter system (EMES) for domestic wastewater treatment

Earthworm-microbial eco-filter system (EMES) being a combinative ecosystem of earthworms and microbial community is an innovative and cleaner domestic wastewater process, of which the mechanism is a synergetic effect of microorganisms and earthworm species to reduce pollutants and pathogens in sewage or wastewater. The ecosystem composed of earthworm-microorganism is established in the bio-filter that can more effectively work on sewage treatment than conventional trickling filter. The removal efficiency of EMES observed in this study is 91%—96% for the biological oxygen demand, 83%—88% for the chemical oxygen demand, 85%—92% for suspended solids, 35%—65% for ammonia and phosphorus. By contrast to trickling filter the primary and secondary clarifiers can be saved in EMES.

(2) The life-cycle assessment of energy consumption for three activated sludge processes

(3) The multilevel high concentration active sludge process for domestic wastewater treatment

(4) Experimental study on treatment of anthraquinone dye wastewater by hydrolytic-anaerobic aerobic process