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Rapid infiltration wastewater treatment for small communities in Beijing

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Abstract— This rapid infiltration (RI) system is proposed as the first one in China. The RI system treated 500 m^3/d of municipal and industrial wastewater. About 0.36 ha of field was used. It has been evaluated that the RI system has an excellent ability to treat the wastewater. The infiltration rate was 50.3 m/a.

Keywords: wastewater treatment; land treatment; RI system.

1 Introduction

The land treatment of municipal wastewater is being realized as a wastewater treatment alternative in China. The research work of rapid infiltration has been done in the TOP-state research program in the 7th Five-Year Plan of China (1985-1990). The high cost of treatment and shortage of financial backing for secondary treatment system require government to investigate the most feasible and economic treatment method. With the development of ecology, it is useful to consider the wastewater and pollutant as a resource which can be reused.

The rapid infiltration treatment system is located at Changping in the north suburb, 32 km from Beijing, that is the first pilot RI system in China. Changping County generated approximately 30000 m^3/d of wastewater, including industrial and municipal wastewater. Textile mill wastewater is about 7070 m^3/d. The wastewater is discharged untreated and water pollution is severe. The RI system treated 500 m^3/d of municipal and industrial wastewater. The system was built during May, 1988 and March, 1989 and operated from April, 1989 to July, 1990.

The treatment site is located on the alluvion of Wen Yu River on which the agricultural output is poor and the sand has been excavated for construction for many years.

2 Site investigations

To determine the long-term feasibility of rapid infiltration system at Changping site, a site study, including analysis of wastewater samples, water samples from on- and off-site wells, soil samples, was completed.

Extensive soil investigations indicated that the area is third geologic period. The soil textural class analysis is shown in Table 1. From the natural cross sections, test pit and test well, it is that the soil textural class changes a little for the whole area of site.

Table 1 Soil particle size analysis

Depth, cm	10 mm	1 mm	1-0.25 mm	0.25-0.05 mm	0.05-0.01 mm
0-30	–	5.13	15.65	9.57	40.2
30-60	–	0.7	45.9	12.8	24.2
60-100	–	0.94	58.6	24.3	12.2
100-200	–	4.35	72.9	23.3	4.2
200-300	14.1	10.1	47.4	16.2	4.2
300-400	8.89	38.8	45.0	6.55	0.2
400-500	4.46	25.3	35.5	24.3	2.2
500-600	–	1.1	2.68	1.98	34.2

Depth, cm	0.01-0.005mm	0.005-0.001mm	0.001mm	Soil textural class
0-30	12.2	10.3	6.2	Sandy loam
30-60	14.2	2.2	0.2	Sand
60-100	2.2	0.2	0.2	Sand
100-200	0.2	0.2	0.2	Sand
200-300	4.2	4.2	2.2	Sand
300-400	0.2	0.2	0.2	Sand
400-500	0.2	0.2	8.2	Sand
500-600	32.2	24.2	2.2	Clay

The chemical characters of the soil is shown in Table 2. The permeability of the soil below the sandy loam is 1.06 m/d.

Table 2 Chemical characters of the soil

Depth, cm	Organic mat, %	CEC, meq/100g soil	pH
0-20	0.71	1.85	7.5
20-50	0.18	1.62	8.34
50-100	0.18	2.68	8.16
100-200	0.18	1.48	8.50

Evaluation of the area hydrogeology indicated that groundwater moves in a northwestward direction in the depth of 13.5−14.5 m, to southeast in the depth below. The velocity of ground water is 0.44 ± 0.09 m/d, which is in agreement with the values for rash sand. Because of the low permeability of the clay, it is unlikely that applied wastewater would contaminate the ground water.

Based on the available site information, it was concluded that the site is suitable for rapid infiltration system.

3 System design

A great cost saving could be realized by applying primary effluent to RI system. Anaerobic acidized tank was used as pretreatment. The top layer of sandy loam was removed. Hydraulic rate of RI system is 50.3 m/a (α = 13%). System consisted of four basins (Fig. 1). The total site encompassed approximately 0.36 ha. The four basins were separated by a claydisk extending to claylayer from effluent storage lagoon. An underdrain system was installed to collect renovated water. This system consisted of one pair of 0.15 m perforated PVC pipe installed 3.8 m below the surface, one central manhole and pump system.

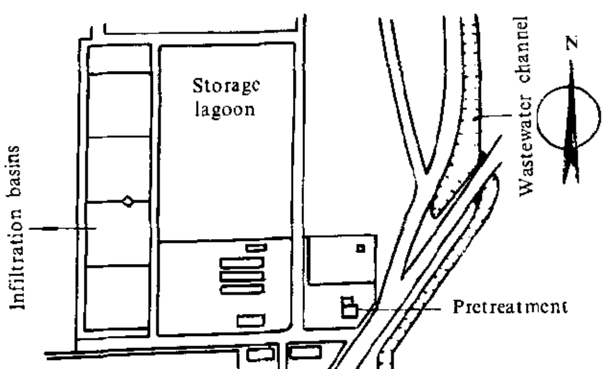

Fig.1 Plan of rapid infiltration system

Samples of the influent were collected at the wastewater channel and pretreatment effluent collection tank and renovated water samples were collected at the central manhole twice a week.

4 RI system performance

A operation schedule of flooding/drying 9/5 (d/d). 5/10 and 5/15 (for winter) was followed. The average infiltration rate is shown in Fig. 2. The average infiltration rate declined when the SS loading increased. An operation schedule of flloding for 9 days and drying for 5 days caused the infiltration rate decreased rapidly. When SS mass

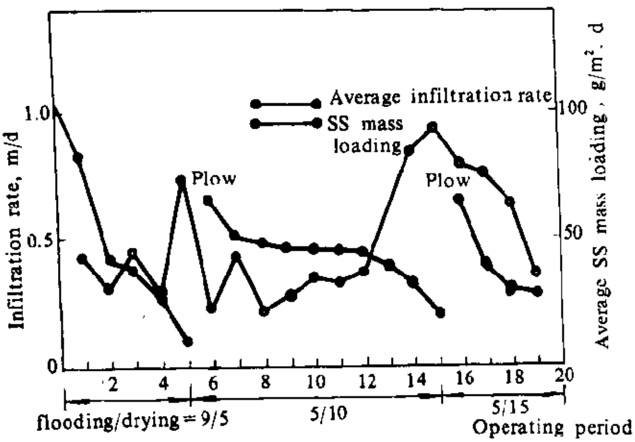

Fig.2 Relationship between average infiltration rate and SS mass loading

loading exceeds 70 g/m^2.d, the infiltration rate will be affected obviously. The operation schedule of flooding for 5 days and drying for 10 days was chosen to follow after about 70 days' operation. The result of operation shows that it is better than the schedule of 9/5 (flooding/drying). The longer dry-up maintained the infiltration rate slower, but the basins needed plow or clean-up once for running about 150 days.

5 Water quality

Quality of the renovated water is shown in Table 3. The samples collected were analyzed for nitrate, ammonium, organic forms of nitrogen, orthophosphate, total organic carbon, COD, BOD_5, SS, fecal coliform and volatile organic substances.

Table 3 Result of operation

	COD, mg/L	BOD_5, mg/L	SS, mg/l	NH_4-N, mg/L	NO_3-N, mg/L	Org-N, mg/L	T-P, mg/L	FecaL, No./100ml	TOC, mg/L
Influent	479.3	126.0	191.3	4.13	2.09	7.02	0.55	7.4×E4	78.6
Pretreatment effluent	404.1	112.7	116.1	4.43	1.35	5.86	0.48	3.0×E4	68.5
Effluent	38.8	5.9	<4.0	0.64	0.96	1.18	1.17	<38.8	13.8
Removal,%	91.9	95.3	98	85.6	54.1	83.2	69	100	82.4

All four basins demonstrated a good removal capacity of organic substances during the operation periods. The removal of COD concentration is shown in Fig.3. Examination of the COD removal indicates that the basins with the highest hydraulic and COD mass loadings tend to release the highest effluent COD concentrations and low temperature in winter causes the system to release higher COD effluent.

BOD_5 removal shows similar pattern. Average BOD_5 concentration of effluent is 5.9 ml/L. The hydraulic loading, mass loading and temperature are the main affecting factors. The relation between BOD_5 mass loading and removal is shown in Fig. 4. The RI system shows great capacity to remove organic pollutants by precipitation, infiltration, adsorption and bio-oxidation.

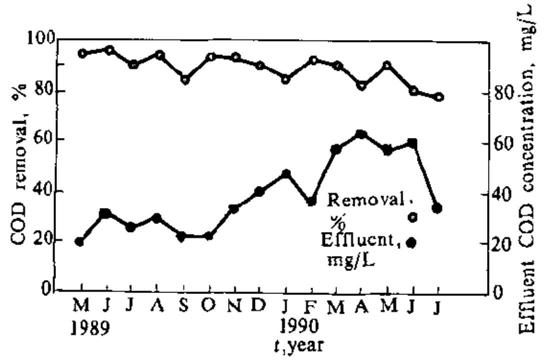

Fig.3 Effluent COD concentration and removal

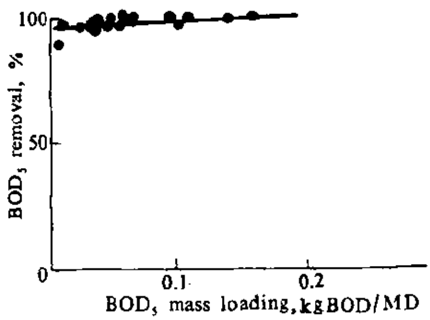

Fig.4 Relation between BOD_5 mass loading and BOD_5 removal

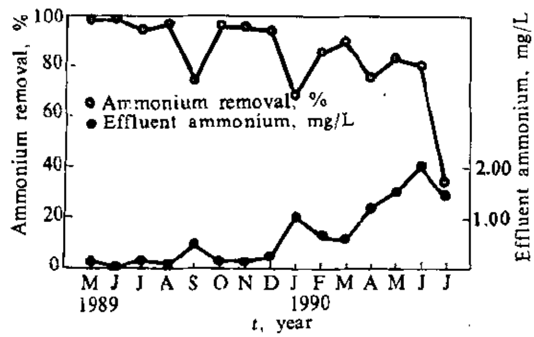

Fig.5 Effluent ammonium concentration and removal

Ammonium removal and effluent is shown in Fig.5. The result of ammonium removal is excellent. The average effluent of ammonium concentration is 0.64 mg/L, removal percentage is 85.6%. The temperature affects the removal of ammonium more than organic removal as shown in Fig. 6. The hydraulic loading is another factor, which is shown in Fig. 7. The RI system shows strong ability to endure the change of mass loading and hydraulic loading. The effluent of T-P concentration is 0.17 mg/L as shown in Fig. 8. The fecal coliforms concentration of effluent is equal to or smaller than 38.8 No./100 ml, as shown in Fig.9.

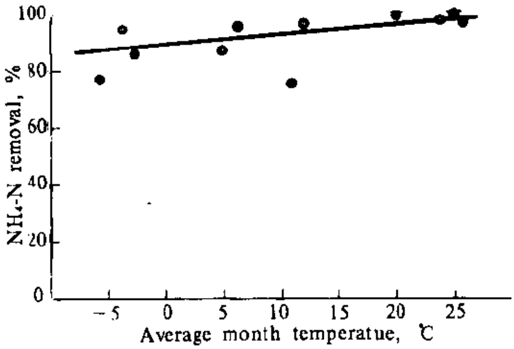

Fig.6 Effect of temperature on ammonium removal

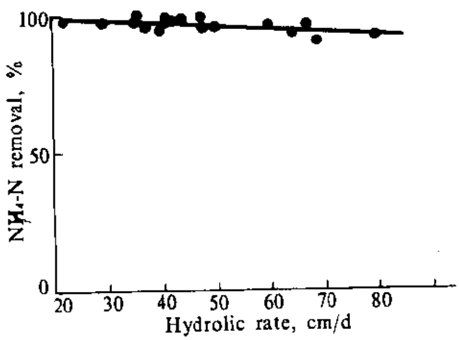

Fig. 7 Relation between hydraulic loading and ammonium removal

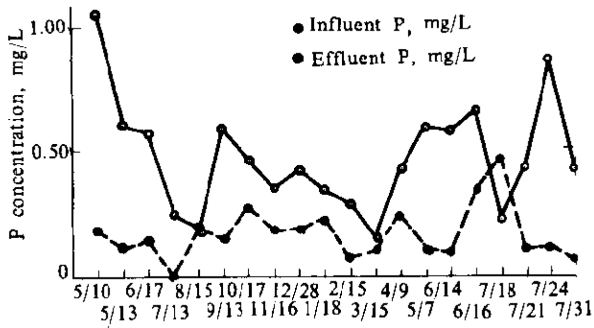

Fig.8 Influent and effluent P concentration

6 Nitrifier and denitrifier

Nitrification and denitrification is closely connected with quantity of biomass, pH value and temperature of the soil. The change of nitrifier and denitrifier with the change of flooding and drying was measured (Fig. 10). It is observed that, when ammonium was loaded in the basin, the growth of nitrifier showed a delay of growth. That is correspondent with flooding/drying date. During flooding period, the soil is lack of oxygen, the nitrifier can not grow well. The ammonium was adsorbed in the soil. But the denitrifier can grow rapidly and reach the high point That is because the denitrifier can use the nitrate produced in preceding period, and has a suitable circumstance of anaerobic condition or lack oxygen. With the end of flooding and beginning of drying(6th day). The soil restored the aerobic condition and contained a lot of ammonium adsorbed in flooding days. The nitrifier grows rapidly. The denitrifier decreases. The ammonium is oxidized into nitrate during drying period. When the next flooding begins denitrification and nitrification circulate again.

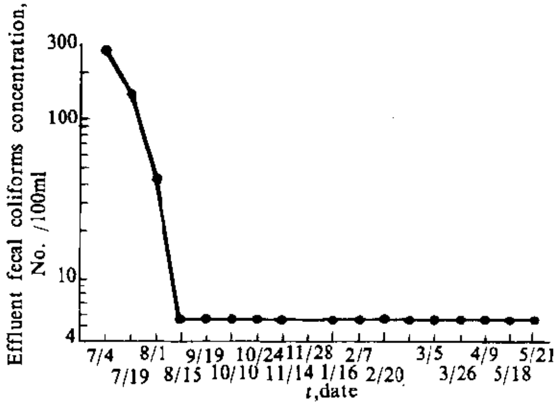

Fig.9 Fecal coliforms concentration of effluent

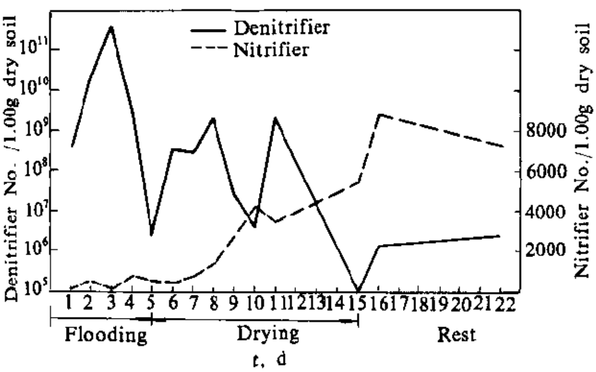

Fig.10 The change of nitrifier and denitrifier

There are a lot of nitrifier and denitrifier in the top of soil(0 – 03m depth). The quantity of bacteria decreases along the depth of soil, (Table 4). It shows that the top of soil adsorbs more subtances, the biomass grows actively, most of ammonium and nitrate are oxidized here.

Table 4 The quantity of nitrifier and denitrifier along depth of soil

Depth, cm	Nitrifier, No./g dry soil	Denitrifier, No./g dry soil	Moisture content, %
0–30	8550	1.5×10^{6}	6.38
150–200	5450	3.1×10^{5}	8.23
250–300	580	1.6×10^{5}	13.40

7 Volatile organic substance removal

Through extensive analysis of the wastewater, 1, 2-dichloroethane, 1, 2-dichloroethene, carbon tetrachloride and chloroform were chosen to measure the change of concentration before and after the treatment of RI system. According to the analysis of 130 samples, average concentration removal of 1,2-dichloroethane, 1, 2-dichloroethene, carbon tetrachloride and chloroform was 85.5%, 92.9%, 83.5% and 80.3%, respectively.

8 Ground water quality

As previously described, a dense clay lies about 4 m below the soil surface. The clay is between 1 to 2 m thick and has a very low permeability. The underdrain system collected most of the renovated water. As a result, vertical percolation is limited and very little of the applied wastewater was expected to reach the sand and gravel aquifer. To assure that the rapid infiltration system was not adversely affecting the groundwater in the sand and gravel aquifer, a series of monitoring wells on or off the site were chosen or installed (Fig.11). The Wells (Well 1−4) are about 12−15m deep and the Wells (Well 5−9) are about 45−50 m deep. Because the site and nearby area had been used for farming and wastewater irrigation for many years, it is possible th t the groundwater in the sand and gravel aquifer has been affected.

Table 5 Groundwater monitoring data, mg/L

Time(year)		COD	NO_3-N	TOC	TDS
Well 1	1989	3.1	1.49	4.6	762
	1990	16.7	2.83	6.7	805
Well 2	1989	4.6	6.84	5.2	626
	1990	10.6	5.06	2.9	845
Well 3	1989	3.05	9.34	4.0	776
	1990	12.1	5.3	2.2	874.5
Well 4	1990	9.8	5.0	3.5	794
Well 5	1989		11.13	1.15	743
	1990	4.1	7.37	1.37	697
Well 6	1989		25.47	1.78	717
	1990	8.7	13.25	1.7	794
Well 7	1989		12.94	2.01	493
	1990	2.2	25.73	1.0	711
Well 8	1990	3.3	21.03	1.0	812
Well 9	1990	2.9	15.68	2.8	806.5

Groundwater contours in the sand and gravel aquifer about 15m below the soil surface sloped generally to southeast. Monitoring Wells D-6 and D-7 were not likely to be affected by wastewater application. Monitoring Wells D-1, D-2, D-3, D-4, D-5, D-8 and D-9 sit on the downgradient and most likely to be affected.

Ground water analysis during the 2-year monitoring period verified the results of the hydrogeologic investigations and the assumption that the applied wastewater did not have a major impact on the water in the gravel aquifer as shown in Table 5. A slight increase in COD occurred although there was no apparent change in NO_3^--N and total dissolved solid (TDS). The data of controlling wells (Well 6 and well 7) show that the water in the gravel aquifer has a naturally high TDS and NO_3-N concentration. It may be caused by the wastewater channel, farming and the untreated wastewater irrigation for many years. The applied wastewater affects the aquifer in the depth of 15m below the soil surface obviously.

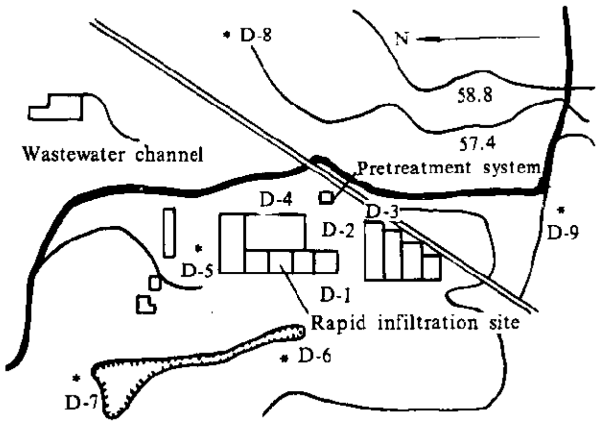

Fig. 11 Monitoring well locations
· —— Monitoring wells on wite (15m);
* —— Monitoring wells off site (40–50 m).

9 Summary

The rapid infiltration system treated 182500 m^3 of municipal and industrial wastewater each year. About 0.36 ha of field was used for RI system. After 15 months of operation, it is evaluated that the RI system has an excellent ability to treat the wastewater. The average removal of COD and BOD_5 concentration is 91.9% and 95.3% respectively. The removal of ammonium and T-N is 85.6% and 79.3%, respectively.

The operation schedule of flooding for 5 days and drying for 10 days was followed for primary effluent. The average BOD_5 mass loading is 626 kg/ha. The infiltration rate is 50.3 m/a.

The evaluation of the system indicated that based on hydrogeologic conditions, the applied wastewater should not contaminate groundwater. The data of groundwater monitoring indicated that no apparent adverse impact on the groundwater had occured.

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